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INNOVATIVE VIEWPOINTS

Seeing science: using graphics to communicate research

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Abstract. Proper science communication is quickly becoming a professional imperative in ecology, but many researchers are not practiced in diverse and effective communication strategies. Academic jargon and text-heavy content are often cited as barriers for laypeople trying to access and understand research results. Here, we have presented scientific visualizations (infographics, figures, and illustrations) as a useful tool to reduce the information transfer gaps between researchers and the public. The graphics we have proposed are images with minimal text that convey ecological research concepts, methods, processes, and results. They are more captivating than text alone and more efficient at disseminating information to a broad audience because they reduce cognitive load. We applied tools and best practices from the fields of marketing and design to explain graphic construction and demonstrated how to build a visualization that is both aesthetic and effective. The basic principles of design are paramount to image composition, and we reviewed experimental literature to support the notions that the proper use of color, proximity, and balance helps to illuminate the main message or story that we wanted to communicate. We presented examples from wildlife ecology research in Alaska to highlight how researchers can use graphics for their own communication efforts, and emphasized the power of visual narratives to explain complex techniques and ecosystem processes. The best practices we outlined here are meant to help researchers understand the composition of science visualizations, build productive collaborations with artists, and ultimately create appealing and informative images that communicate research.

Key words: graphic design; infographics; interdisciplinary; science communication; science outreach; scientific illustration.

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Introduction

The field of ecology has a problem that it shares with other scientific disciplines. Researchers who live and are responsible for the content of science stories are not always the most effective at telling them (Baron 2010). Effective science communication is an invaluable middle ground between the dissemination and uptake of knowledge. Without it, the chasm of disconnect between scientific advancements and public understanding and policy will not narrow. Farmers do not grow and harvest their crops only to let the value deteriorate in the silo or on the shelf. Likewise, it is not prudent for scientists to conduct research and publish results without finding ways to optimize sharing of new discoveries. Fresh knowledge, like food, needs proper and strategic distribution to ensure it gets into the hands of those who are hungry for it. The traditional process of waiting for the user to find information (i.e., the loading dock strategy [Cash et al. 2006]) involves publishing in a peer-reviewed journal and then waiting for the end user to find, interpret, and use it appropriately. This strategy is problematic, but resolvable.

As ecology has become increasingly public-facing, researchers have been tasked with acquiring the tools necessary to effectively communicate with diverse audiences and decision makers (Peters et al. 2014, Kuehne and Olden 2015). These tools need to convey messages in engaging and concise ways that optimize the speed and extent of absorption and retention. We provide an overview of one such tool—the scientific visualization—that may foster communication and enhance the impact of ecological research in scientific and public arenas.

What are these Scientific Visualizations and Why are they Useful?

Scientific visualizations merge information and graphics to produce appealing images of data that boost a person's ability to quickly consume and understand content (Smiciklas 2012). These kinds of graphics are more than just illustrations next to technical content. Taken at face value, they can be analogous to scientific figures, though they are capable of functioning as tools that are more dynamic and more effective than the standard visual aids that academia employs (e.g., technical graphs with exhaustive captions). A good visualization should function equally well embedded in a scientific article as it would on a poster at a public presentation. Visualizations should be able to stand alone and still get their point across while maintaining professional standards.

Scientific visualizations are a type of graphic that communicates a complete story through a suite of interconnected visual cues, text, and imagery ([Krum 2013]; they use contrast, movement, and symmetry to draw the eye through the key points of a larger narrative). One can think of these visualizations as a more understandable guide to results and concepts that complement and elucidate technical language. For viewers, visualizations reduce cognitive load (Dunlap and Lowenthal 2016) associated with comprehension. The efficiency of a well-structured visualization should not be understated: Our brains process visual stimuli without prompting (Houts et al. 2006), so pictures help the viewer process information more quickly than words. Some marketing sources even go so far as to claim that visual content is processed by the brain 60,000 times more quickly than text (Pant 2015). While the exact speed at which our brains evaluate pictures is debatable, images are about as preferable as they are salient. For example, students express high satisfaction with the use of graphics as learning tools (Vanichvasion 2013) suggesting an optimistic willingness for uptake.

Visualizations augment the absorption of science. Communicating with the diverse audiences through text alone is less efficient (Dunlap and Lowenthal 2016) and interpretable. A scientific visualization is more engaging and targets many literacy skill levels, helping to bridge gaps that exist between researchers and other stakeholder groups. This gap is well-exemplified in health education, where many materials used to educate the public have been written at a 10th-grade level. This reading level is not in agreement with the average adult in the United States, who may only read at the 8th-grade level (Houts et al. 2006). Pictures can be used to help mitigate these effects by increasing reader comprehension of medical information; the impact such images have on comprehension is more pronounced among patients with no high school education (Houts et al. 2006). In educational settings, students exposed to visualizations learned a third more information and that learning gain was five times more pronounced for delayed recall (i.e., when students had to recall information a long time after the fact) (Houts et al. 2006).

Visualizations are such an effective tool at bridging these kinds of gaps that they are actually used by educators to help students learn foreign languages. For students learning English, the use of supporting graphics improved grammar retention significantly compared with standard teaching methods (Rezaei and Sayadian 2015). The relevance of this should be clear to anyone who has ever heard a technical or jargon-heavy lecture outside of their disciplinary expertise. Academic language loaded with scientific terms can seem as enigmatic as a foreign language to the general public, but it is sometimes not enough to simplify our language, especially when we run up against precise terms that cannot be substituted. This is where science visualizations can help, by eliminating the focus on less comprehensible terms and focusing on what those terms show us. For example, a study focusing on communication about water-induced hazards (e.g., floods, droughts) found significantly higher agreement between experts and laypeople on the definitions of terminology when pictures were provided, as compared to text alone (Venhuizen et al. 2019).

Visualizations are playing an increasingly prominent role as influential "framing devices" that encourage certain attitudes, behavior, and policymaking (van Beek et al. 2020). The process known as visual framing is when certain components of a visualization may be dismissed or neglected, while other parts are emphasized that elicit certain emotional responses or evaluations. For example, a growing number of studies have addressed the effects of visual framing on interpretation of visualizations on complex issues such as climate change (Wardekker and Lorenz 2019). Studies like these highlight the power of visualizations and also serve as lesson for researchers and artists on the potential consequences of their framing choices during the production phase.

Making Scientific Visualizations

The process of creating a scientific visualization requires cooperation and collaboration, ideally between a team of specialists who fact check, identify important information, and understand how to design and where to communicate a message (Fischhoff 2013, Khoury et al. 2019). It is more common, however, that researchers are on their own, without a panel of experts, and must partner directly with a graphic designer or artist (Rodríguez Estrada and Davis 2015). Figure 1 demonstrates some fundamental steps for researchers trying to build an effective infographic. A good starting point—both for yourself and for the artist(s) you work with—is to identify your key message. What specific information are you trying to communicate? What do you want the recipient of your message to understand and walk away with after viewing your visualization? Clarifying your message will separate essential from extraneous. In a simplified model of the communication process, the source (researcher and artist) encodes (develops) a message and then sends it through a particular media channel (e.g., science journal) to the receiver (audience) for decoding (interpretation) (Jacobson 2009). It is difficult to optimize the message without concurrently accounting for the other elements in the communication process.

Considering your audience from the very beginning will help you shape a "user-centered" visualization that streamlines communication (Bowler et al. 2011, Rodríguez Estrada and Davis 2015). This is because user-centered design takes into account the various perspectives of the audience (e.g., cultural, cognitive, and social) and works to create something that feels more accessible or functional for the viewer, something which they could understand, use, and share (Bowler et al. 2011). An important part of implementing a user-centered design is active involvement of the end user in the visualization construction. Just as researchers often seek informal reviews of early drafts of their manuscripts by stakeholders before submission to a journal, getting feedback from the end users on early drafts of visualizations will help address the unique effects of user personal experience, backgrounds, and cognitions (Bowler et al. 2011, Rodríguez Estrada and Davis 2015). Researchers and designers should be prepared for a back-and-forth of multiple drafts in the early stages in order to strengthen the composition and communication of their final product.

Once you have your key message and audience established, you can begin to think about your infographic's layout. It is helpful to ask yourself where you want the viewer's attention to be drawn first: Many designers call this the "entry point" or "point of entry," and viewers are more likely to scan the information around the point of entry than other places (Djamasbi et al. 2011). Popular research on the visual hierarchy of web designs has claimed that titles and large text make better entry points than images. More recent research has demonstrated that spatial location (Still 2018) and contrast (Henderson 2003) were better predictors of attention on webpages. Eye-tracking semiotic studies on print layouts have shown that non-verbal elements (i.e., images or symbols) were consistently points of entry over verbal elements (i.e., text) (Damaskinidis et al. 2018). In light of this, it may be good to place your principal image and text in a prominent location on the page with good contrast so that it acts as a good entry point for your reader. The exact placement of this depends on the flow

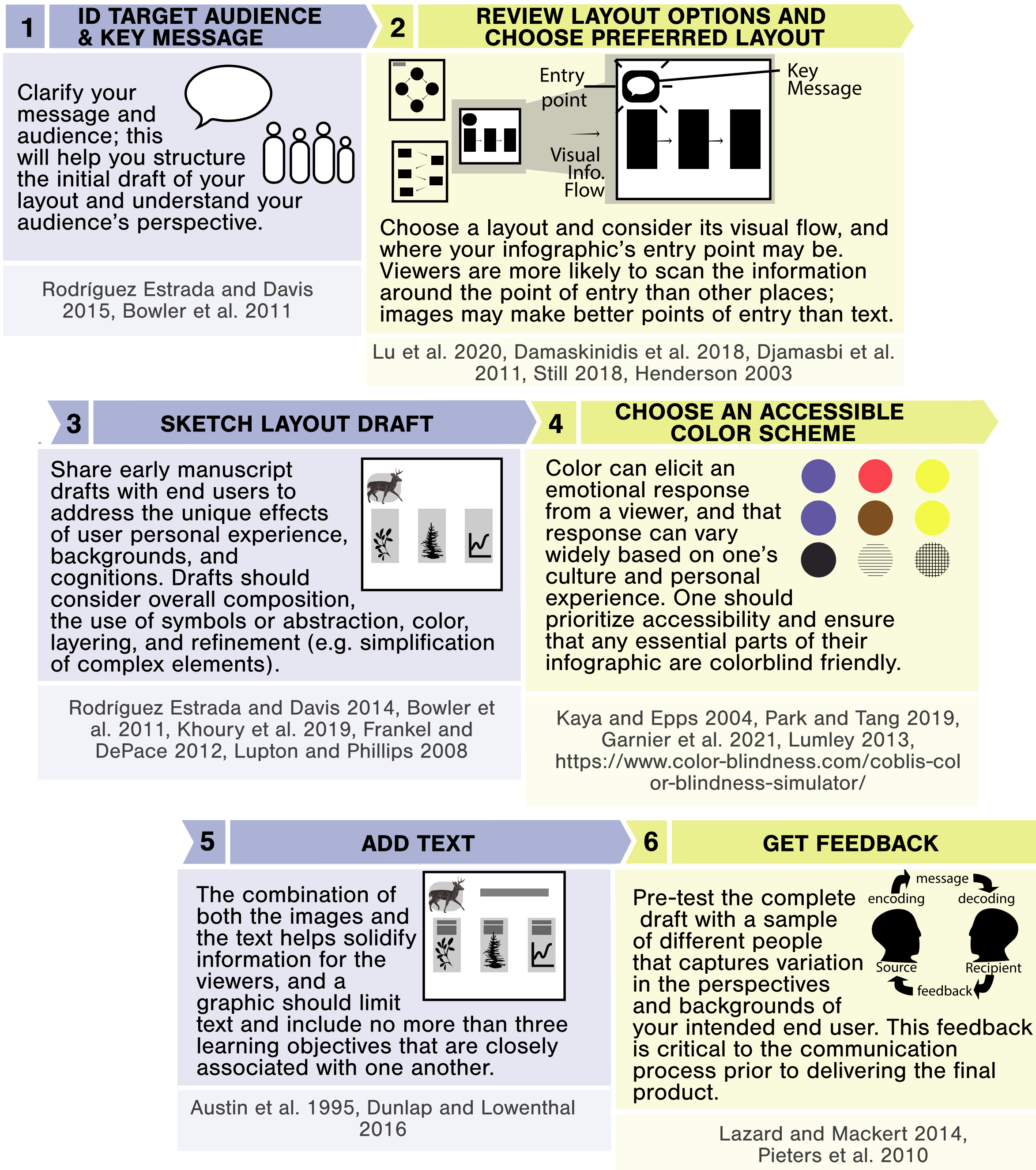

Fig. 1. A guide to some of the more fundamental steps to developing an effective infographic, including explanations for each step and the resources used to help develop our understanding of why these steps are important.

of your layout. Lu et al. (2020) have constructed a map of the visual information flows for 12 of the most common infographic layouts, and referencing these maps may help you identify the location of your entry point, and the information that follows.

There are many tools that designers use to build visualizations, and some of them can be as foundational as color. Color can elicit an emotional response from a viewer and that response can vary widely based on one's culture and personal experience (Kaya and Epps 2004). For this reason, color should be carefully considered in the composition. Park and Tang (2019) report that people have a preference for cool colors in graphics, but that their color preferences did not affect how persuasive or informative they found an image. Warm colors may be more activating than cool tones (Kaya and Epps 2004), and red can elicit negative reactions compared with blue (Bellizzi and Hite 1992). Colors like red that have strong associations (e.g., red often means "caution" or "stop") should be avoided unless you are choosing them specifically because of that association. Regardless of warm or cool, a cohesive color palette should be additive instead of distracting, and Arslan and Troy (2015) recommend avoiding excessive dark or neon colors.

Aesthetics aside, one should prioritize accessibility and ensure that any essential parts of their infographic are colorblind friendly. This means avoiding common red-green combinations in graphs, or simply differentiating groups or patterns by symbols instead of by color. In R (R Development Core Team 2013), there are a number of packages that can assist you in generating graphs that are accessible for the colorblind and the color deficiencies; "viridis" (Garnier et al. 2021) and "dichromat" (Lumley 2013) are examples of such packages. "Dichromat" (Lumley 2013) can also be used to simulate colorblindness in R, while Coblis (https://www.color-blindness.com/coblis-color-blindness-simulator/) is an online colorblindness simulator where you can upload images and see how different color deficiencies affect their legibility. Checking color accessibility of your infographic is an essential step before proceeding to publish it for your intended audiences.

After you establish an appropriate color scheme, you may begin adding further details to your infographic, artistic, or otherwise. Dunlap and Lowenthal (2016) make the argument that too many decorative details run the risk of distracting the viewer and drawing them away from the intended focus. It seems counterintuitive, then, that a more complex design can actually increase viewer attention and promote a positive perception (Lazard and Mackert 2014). We imagine a complex image as being cluttered or busy, but design complexity is a much different metric. It takes various aspects of an image's layout into account by measuring the complexity of many different principles of design. "Busyness" often refers to how much visual information is packed into a space, whereas design complexity evaluates how objects in an image are different from each other, the level of detail present, and how things are arranged, among others. More complex designs create intricate and interesting images that hold attention longer, make an image easier to comprehend, and improve the viewer's attitude toward the intended message (Pieters et al. 2010). For each principle of design complexity that you include, it increases attention by a factor of 1, which is predicted to increase overall attention by 30% (Pieters et al. 2010). In this way, complexity keeps the viewer focused and increases their chances of comprehension. Try to consider this as you move toward the final draft of your infographic, and give yourself or your designer extra time to work out the finer details.

While intricate details may add to the beauty of a visualization, the text we used benefits from a more spartan approach. This strategy is apparent among large corporations, such as Apple, that strive for simple and elegant product designs and slogans (Madni 2012). Visualizations are best limited to a single page that focuses on one idea or learning objective; all told, a graphic should include no more than three learning objectives that are closely associated with one another (Dunlap and Lowenthal 2016). Again, consider the key message you established at the beginning, and brief points or phrases that might move you most efficiently toward the goal of conveying that message to your viewer.

For certain messages that have a causative "this-then that" coherency to them, narratives can be a useful technique to bring viewers from their point of entry to a concluding point. A beginning, middle, and end is an intuitive way to move the viewer through explanations of longer processes or systems, with images acting as important cues to keep the viewer focused, and some elements of story structure and tension to keep their attention. Adding a storytelling component to scientific visualizations helps to increase information retention among children and adults alike (Payne et al. 2003, Pieters et al. 2010) and gives direction to the entry point of our image.

Pre-testing the visualization with a sample of people from your target audience is a critical step before finalizing your product. It is impossible to determine whether your message was received and interpreted as intended without completing the feedback stage of the communication process (Jacobson 2009). The characteristics of the pre-test group should capture variation in the range of perspectives, backgrounds, and abilities of your visualization end user (Bowler et al. 2011). Feedback tells you if the visualization worked and how it could be improved.

Below, we demonstrate some of the tools we have listed in practice, using scientific visualizations we have created to meet some of our own scientific communication needs.

Science visualization examples

We provide examples of scientific visualizations from wildlife ecology research in Alaska. These scientific visualizations convey information about research methodologies and complex interactions among wildlife, habitat, and people. They were created to explain our methods and findings to diverse audiences ranging from wildlife agencies with scientific backgrounds, as well as public stakeholders with little formal education or training in ecology. In our examples, we are assuming our audience has some pre-existing knowledge of the system, but other researchers should attempt to understand the demographics of their audience, and how the education, background, and political leaning can affect the receptiveness of their target group (Besley 2018), so they can adjust their key messages accordingly before beginning the design process.

Our aim is to use the following examples to highlight elements of a scientific visualization and guide the reader through its construction. We assume that the researcher has already identified the goal of the message and the audience. Figures 2 and 3 provide a progression of steps for assembling images and text; the goal of this infographic was to describe multiple techniques for monitoring caribou (*Rangifer tarandus*) populations. Figures 4–6 illustrate how hunting opportunities and Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) habitat quality changes following logging and forest management practices.

In Fig. 2, we used a "landscape layout," as identified in Lu et al. (2020). The information flow is left-to-right, and the three panels are balanced to create symmetry, and though there is no actual narrative, the presence of the panels compels the viewer to move across the page as if there were. The text and image boxes were placed at the same elevation in each panel, so that viewers can compare them easily. The inset image panels that show a zoomed in view of each sampling method should help the viewer identify the differences in these methods before they even read the accompanying text. Even so, it is the combination of both the images and the text that helps solidify information for the viewers (Austin et al. 1995). We tried to be brief with our use of text in order to avoid the pitfalls of written communication that we have already addressed, namely: literacy gaps between yourself and your audience, overwhelming technical terms, and decreased retention of your content. To increase the legibility of our writing, the text was placed in boxes that provided good background contrast.

The overall effect of this infographic should be that it is clean, balanced, and legible. Previous drafts of this infographic were more chaotic, as seen in Fig. 3. The lack of separate panels meant that the viewer had no clear focal point on the page, and the asymmetrical balance of the text interrupted what would normally be a left-to-right flow of information. In Fig. 3A, the arrows demonstrate how the inset image and text boxes have competing flows of visual information, a flaw would could distract and confuse the viewer. Figure 3B has a simpler flow, and one that is more in-line with Western layouts, where the written word flows left-to-right.

Another pressing issue with this earlier draft is that the color coding of the sampling methods is not accessible for the colorblind or color deficient (Fig. 3C), and the labeling key is almost too small to be legible. Running this image through an online colorblind simulation tool (we used "cosblind") allowed us to identify this issue, particularly with the use of the color red for the citizen science labels; for those red-green colorblind, or completely colorblind, the labels would be nearly invisible against the green background. In the

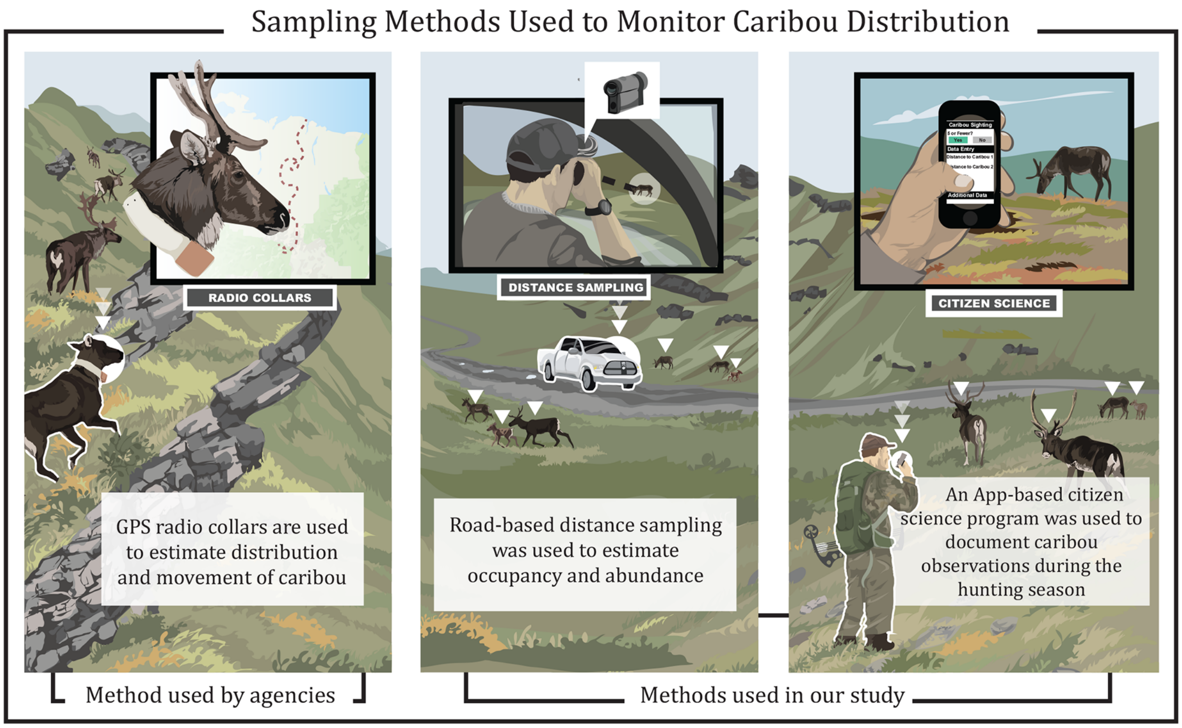

Fig. 2. An infographic meant to convey three different sampling methods used to monitor caribou distribution: radio collars, distance sampling, and citizen science. The text boxes in each panel provide short explanations of each method, and the tools used for each method are haloed in white. This infographic used a "landscape" layout that flows left-to-right.

revised version (Fig. 3B), we opted for contrast instead of color and used white to highlight the important elements.

Overall, reorganizing the elements of the layout was a quick way to make it more comprehensible. Ideally, these changes would be made in the early stages of an infographic's draft, before a majority of the finer details are committed to the page. However, it may be difficult to see larger structural flaws until a final draft is pre-tested with the intended audience(s). For this reason, digital programs that keep the elements of your infographic mobile (i.e., you can move a drawn object or a text box easily to a different spot in the composition) are highly recommended.

Our second infographic example is meant to describe how clear-cut logging—and subsequent forest regrowth—affects deer forage and hunting opportunities of Sitka black-tailed deer in southeast Alaska. Figure 4 shows a 3-step process in which we build our initial scene, then highlight our key features (deer, people, and habitat), and then add symbols and labels. The final panel (Fig. 4, step 3) is actually the first of 5 (Fig. 5A) and represents a chapter in a larger story about this ecosystem. The flow of a visualization often implicitly or explicitly illustrates a beginning, middle, and end (Fig. 5A). Like stories, structuring the graphic elements temporally and causally improves comprehension and recall (Hudson and Nelson 1983, Rand 1984). Our first panel from Fig. 5A will be altered in each subsequent panel to reflect the next steps in the process we are trying to illustrate: in this case, how deer forage and hunting changes as the forest transitions through successional stages.

Repetition is a fundamental design element that creates rhythm, similar to a musical hook in a song (Burns 1987). This sort of continuity makes the basic narrative clearer, because we want viewers to recognize the aspects that are shifting within the scene, rather than being distracted by a different setting. As the scene progresses in panel 2 (Fig. 5A), we see our key

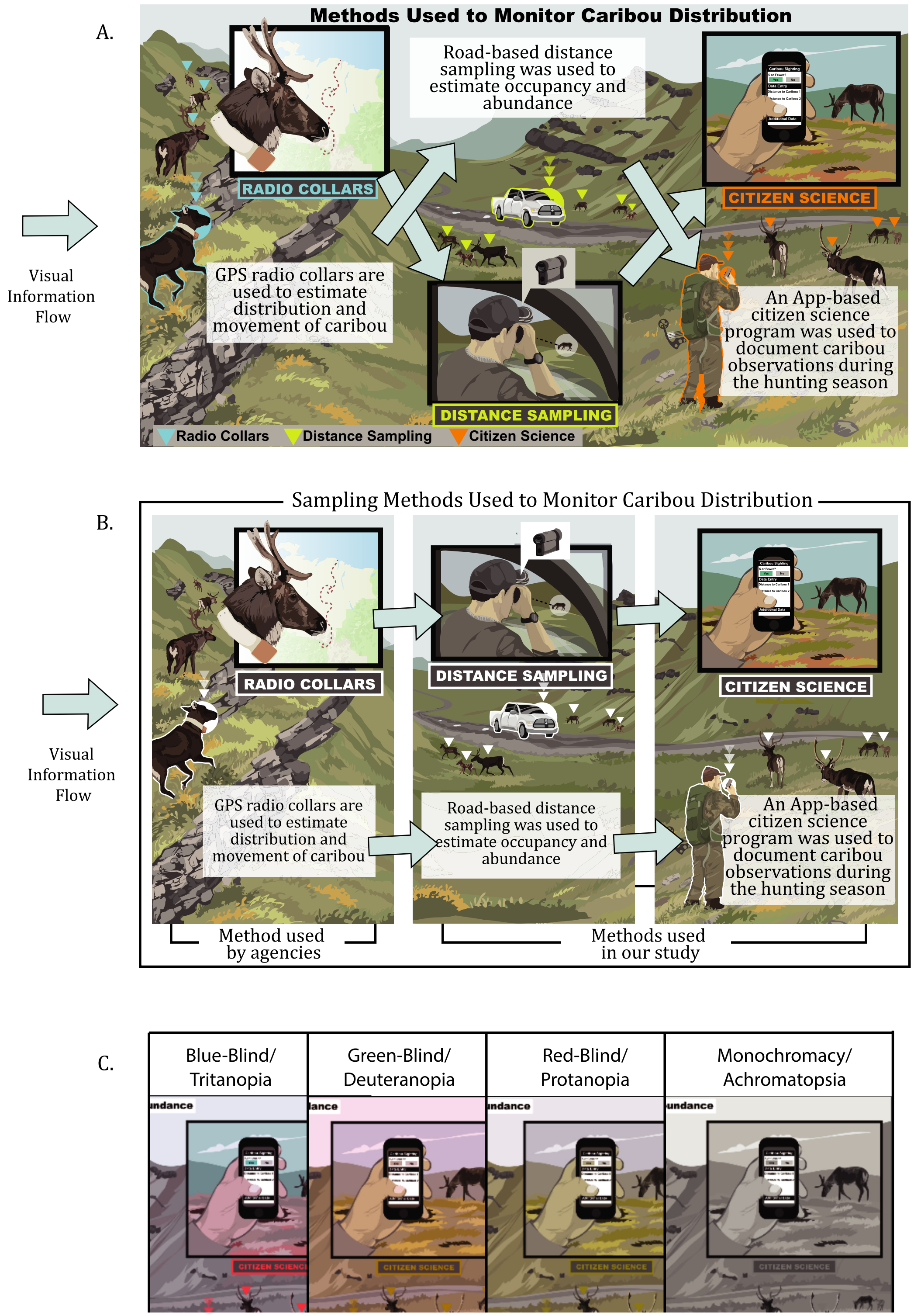

Fig. 3. (A) The visual information flow of an earlier draft of this infographic, with arrows indicating conflicting directions that the eyes are drawn. (B) The visual information flow of the final draft of this infographic,

(Fig. 3. *Continued*)
with arrows showing a linear left-to-right flow that's easier for the reader to follow. (C) A portion of the original draft—as seen through a color simulator—demonstrates how the colored symbols are hard to interpret for those who are colorblind. (Please note: text has been modified for legibility at the formatted size).

players—the deer and the hunter—are in the same place but harder to find, or absent altogether depending on the vegetation. Our narrative in the following panels is that, while clear-cuts support deer and deer hunting initially, the period of regrowth has a negative impact until the forest transitions to the old-growth stage again.

Presenting this process as a story, rather than a list of facts, has the power to transport the viewer into a story's world, experiencing "strong emotions and motivations" that may make them more open to attitude or belief changes, and more persuaded by facts presented within the narrative (Green and Brock 2000). While our graphics are by no means powerhouse plots filled with elegant metaphor, they still have elements of story structure. Our Sitka black-tailed deer story has the structure of a "Rescue" narrative, as outlined by Green et al. (2018). If we look again at Fig. 5A, you can see this narrative plotted against all four frames of our visualization (Fig. 5A, B). The deer and the hunters are characters in this story, and their fortunes are plotted against time. A classic rescue narrative boomerangs from prosperity to despair and then back to prosperity. In our case, the first panel shows prosperity, where there is ample forage for the deer, and the habitat characteristic foster hunting opportunities. The regrowth in panels 2 and 3 is periods of despair, with increasingly less forage for the deer to eat and fewer deer for the hunters to harvest. Panel 4 represents prosperity, when a forest has returned to old growth that can support consistent forage for deer and habitat characteristics better for hunting than the previous two stages. While Green et al. (2018) describe the upshot of the rescue curve as "a recovery aided by science," we believe this curve can also apply to natural recoveries in populations or habitat restorations.

Green et al. (2018) outline two additional narrative types, "mystery" and "discovery" (Fig. 5C). They present the narratives in examples where the researcher (or management agency) is the main character, so a narrative of discovery shows the ups and downs of research that a character goes through that can lead to a groundbreaking discovery. A narrative of mystery is not unlike discovery, but it begins at a point of despair that the character ultimately overcomes after a similar period of ups and downs that eventually lead to prosperity, and the resolution of the initial source of despair. These kinds of story plots can be applied to biological processes if we view an ecosystem or species as our main character. Discovering the cause of a species decline could be a "mystery" narrative, while finding a solution to human–wildlife conflict could be a "discovery" narrative.

A mystery narrative could be found in the struggle to recover bald eagle (*Haliaeetus leucocephalus*) populations in the Channel Islands of California even after the banning of DDT, a pesticide that causes thin eggshells and subsequent hatching failures (Sharpe and Garcelon 2005). It was discovered that the island eagles were to still being exposed to DDT through a large offshore dumpsites, and so researchers maintained the island's population by introducing fledglings into monitored nests until, several decades later, bald eagles begin successfully nesting on their own (Sharpe and Melling 2018), bringing their story to its closing prosperity.

Discovery narratives are somewhat easier to identify. In ecology, they are driven more by observation than active discovery, and the upward curve of prosperity leads to a better understanding of an organism or system. For example, researchers struggled to understand the nebulous movements of African elephants (*Loxodonta africana*) until they discovered that the animals were making infrasonic noise to communicate with one another (Poole et al. 1988). That discovery improved our understanding of how elephants communicate with each other over long distances in order to find family members (McComb et al. 2003) and reproductive partners

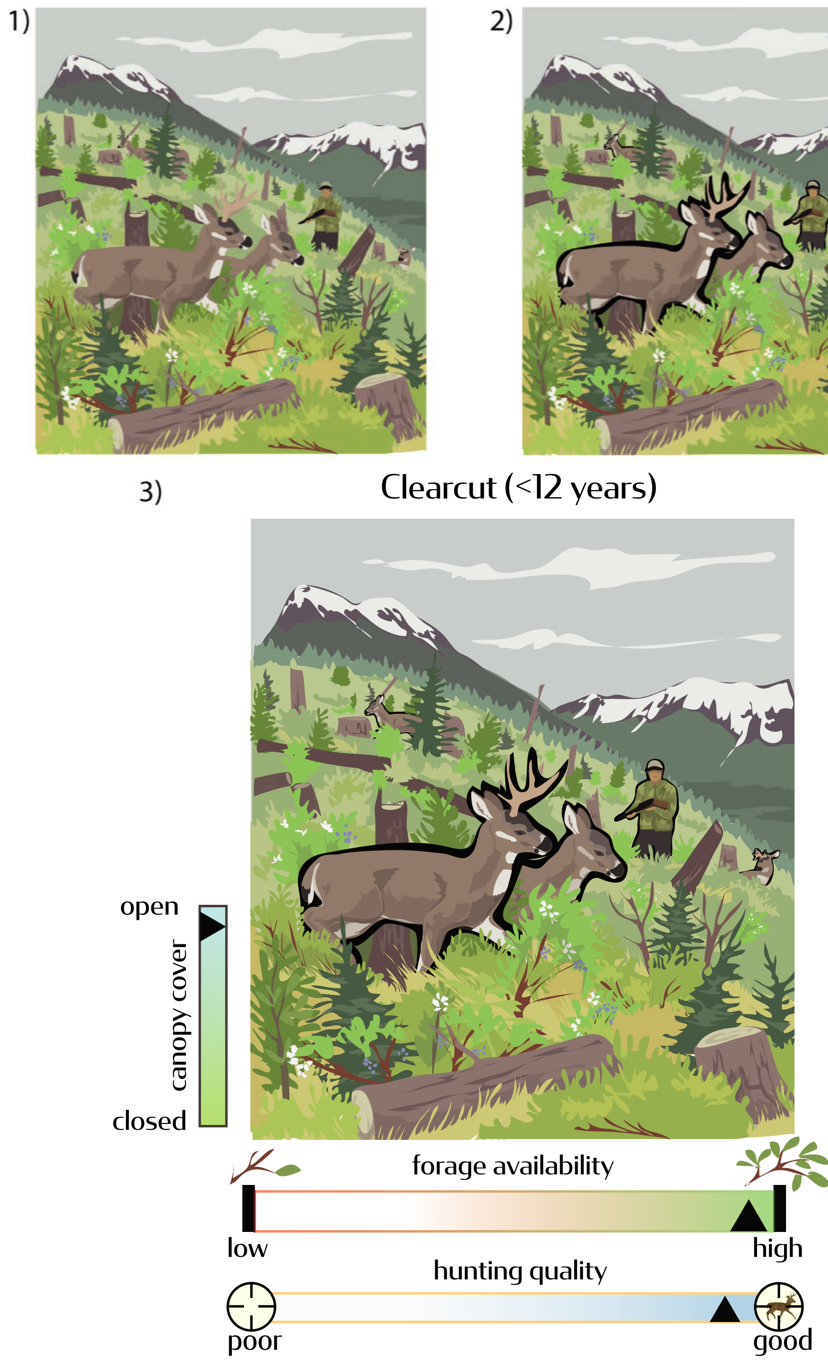

Fig. 4. A segment of a scientific visualization about the relationship between deer hunting opportunities and forestry practices. Step (1) builds the scene by illustrating the ecosystem and agents in the system, step (2) highlights with subtle contrast the key features that will be affected by change, and step (3) provides variables of interest by including scales of different factors (canopy cover, forage availability, hunting quality) at this stage of forest succession (12 yr post-clear-cut).

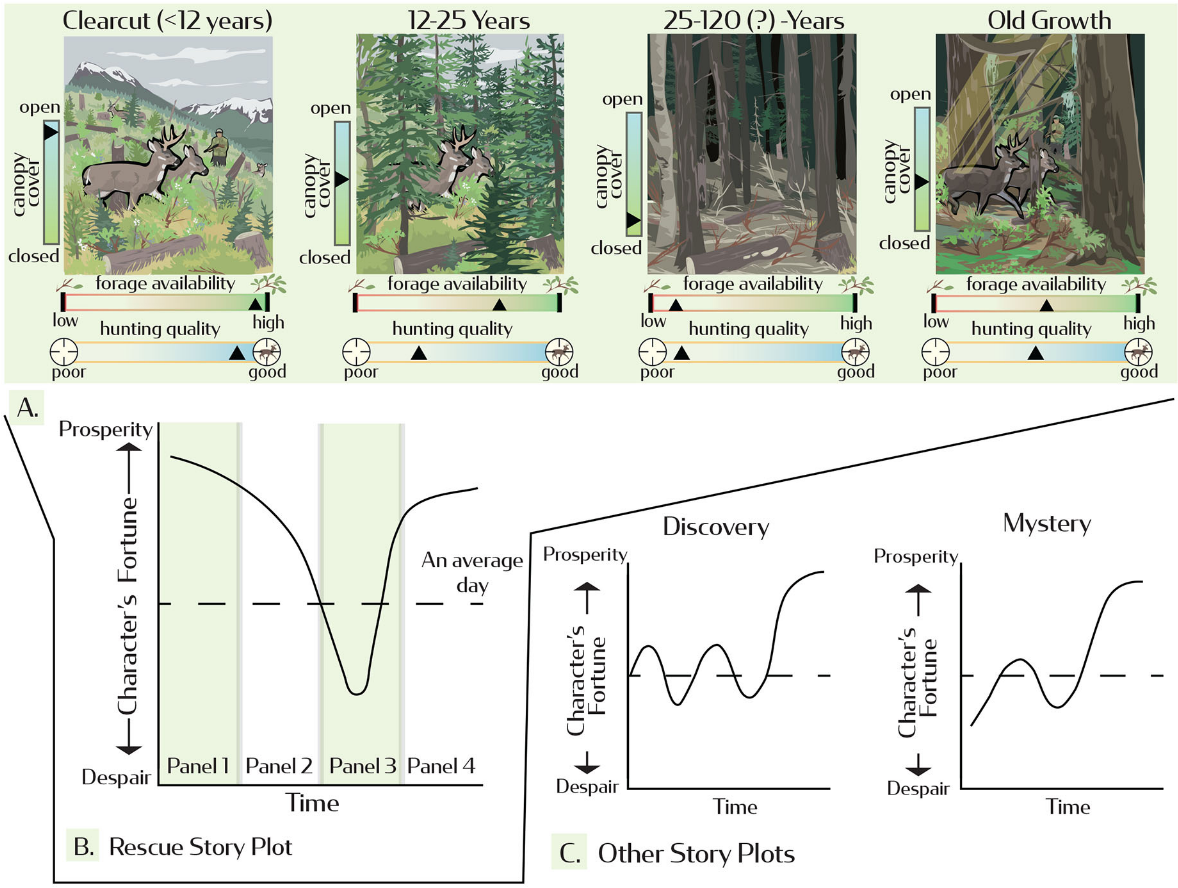

Fig. 5. (A) All four panels of our visualization on Sitka black-tailed deer, showing forage and hunting availability at different intervals after a clear-cut. Regrowth immediately following a clear-cut (<12 yr after) generates good forage for deer and boosts hunting opportunities, but subsequent time periods (at 12–25 and 25–120 yr) show decreasing forage quality and hunting opportunities, until the forest eventually recovers to an old-growth stand (final panel). (B) The rescue story plot from Green et al. (2018) matches the narrative of our four panels if we view the hunters and deer as our characters. The narrative starts with prosperity (good forage for deer and hunting opportunities for hunters) and then becomes a trough of despair (poor forage and few hunting opportunities) until the forest recovers to its natural old-growth state and the characters return to prosperity (good forage and hunting opportunities). (C) Other plots from Green et al. (2018) commonly used in science are "Discovery" (the ups and downs of the research process that ultimately leads to an important discovery) and "Mystery" (similar to Discovery, only we start a low point in the character's story and the ups and downs resolve the initial misfortune).

(Pieters et al. 2010), and even how they might find water at the end of the dry season by listening for thunderstorms (Garstang et al. 2014).

Once the narrative is established, the final step in illustrating our story is adding the small details that emphasize our message; we used symbols and visual scales to help walk the viewer through what's changing. The scales shown in Fig. 6 exist in each panel and add a simple point of reference for the viewer. The "forage availability" and "hunting quality" scales use icons to emphasize what either end of each scale represents. Icons are common in all aspects of our lives (graphics, computer programs, street signs) because they serve as efficient and appealing visual metaphors that make text unnecessary.

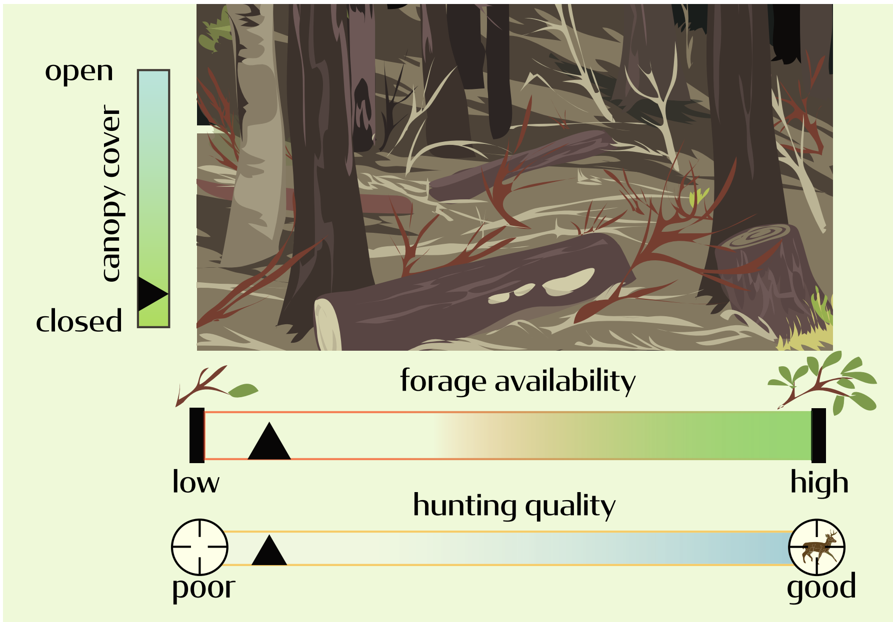

Fig. 6. A close-up of the lower scales with icons from panel 3 in the full visualization from Fig. 4, showing forage quality, hunting quality, and canopy cover with some associated symbols.

"Forage availability" is not a straightforward phrase to those outside of ecology. By having the low end represented by a branch with few leaves, and the high end represented by a branch with many leaves, viewers can come to understand that "high" forage means there's plenty of foliage, and "low forage" means there's very little. Even without knowing the definition of "forage", that is, plants available for the deer to eat, the viewer can grasp from the barren scene in panel 3 (Fig. 5A)—with no deer or forage—that there is a relationship between the two. Therefore, both ecological experts and laypeople are more likely to come to an agreement on the definition (Venhuizen et al. 2019).

Conclusion

Scientific visualizations are dynamic and powerful tools that can take many forms and be applied in a variety of contexts, and this is by no means a comprehensive guide to their design and the full breadth of their utility. More research and testing needs to be done to measure and evaluate their effectiveness in the natural sciences and for different audiences. Here, we have tried to summarize the value and considerations that may encourage the use of visualizations within the field of ecology. Good visualization offers clarity to stakeholders as well as peers; they are a vessel not only for technical information, but also for story. Understanding the principles of design that make a science visualization "good" is an important step for researchers to take even if they have no intention of creating the visualization themselves. This will help them identify what they want and be able to have a meaningful dialogue with the artists they work with. Scientific collaborations with artists and communication specialists may accelerate the integration of scientific visualizations and writing, build interdisciplinary capacity, and enhance the impact of a communication effort (Fischhoff 2013). Ultimately, scientific visualizations may catalyze science communication and close the loop among discovery, innovation, and application by diverse end users and decision makers.

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