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Center for Biodiversity and Conservation
Network of Conservation Educators and Practitioners

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Considerations for the Conservation Classroom



American Museum of Natural History

Center for Biodiversity and Conservation
Network of Conservation Educators and Practitioners

Lessons in Conservation is the official journal of the Network of Conservation Educators and Practitioners (NCEP)—a collaborative project of the Center for Biodiversity and Conservation (CBC) at the American Museum of Natural History—and is published as issues become available. Teaching and learning modules presented here in ***Lessons in Conservation*** are available in modifiable form for teachers on the NCEP website (ncep.amnh.org). All materials are distributed free of charge. Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the American Museum of Natural History or the funders of this project. All components of a module (e.g., Syntheses, Exercises, Case Studies) have been peer-reviewed and approved for publication by NCEP.

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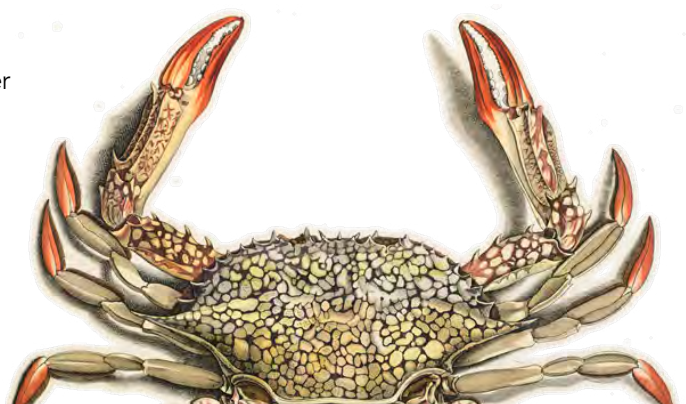
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Letter from the Editors

Dear Reader,

Welcome to Lessons in Conservation, the official journal of the Network of Conservation Educators and Practitioners (NCEP; ncep.amnh.org). We are pleased to present the fifteenth volume, "Considerations for the Conservation Classroom," which includes educational modules spanning different topics, ideas, methods, and challenges to incorporate into your classroom and teaching. The issue opens with a new "Conversation" format for our journal. For the inaugural piece, two educators reflect on and discuss their journeys from students to educators, learning and then teaching Systems Thinking within the context of conservation, the food system, and the wildlife trade.

We then turn to a short perspective and accompanying exercise about drawing as a systems-thinking learning technique using the example topic of One Health, a holistic framework on public health. Drawing is an extremely valuable learning and teaching tool—even if students (or instructors!) don't consider themselves, by any means, artistic. The issue continues with an invitation to incorporate poetry into the conservation classroom through a suite of activities. Poetry can enhance learning and sharpen our observation skills, while also helping us find solace and hope amongst the persistent, discouraging news of today's environmental and societal crises.

After that, we dive into a case study that shows how scientific inquiry can lead to tangible conservation management recommendations. Adapted from a three-part interactive online educational module created through the OCELOTS network (ocelots.nrem.iastate.edu/), this case study provides background on foundational concepts for studying sound and noise and then provides a tangible example for how acoustic monitoring can uncover the impact of ecotourism on bottlenose dolphins in Panama. This case study can be expanded to include activities for students to use acoustic software platforms, such as Raven Lite and Audacity through the interactive exercises on the Gala platform (learngala.com).

Finally, we close the issue with an exercise centered on video testimonials from a diversity of conservation professionals that strives to promote. An accompanying perspective piece frames how and why the authors developed and ran the exercise in their classrooms, including their different settings and approaches. In these times of uncertainty, these exercises can help guide us into deep and meaningful conversations with our students and fellow conservation educators and professionals.

We hope you enjoy this issue of Lessons in Conservation and encourage you to visit our website to start using the full collection of NCEP resources in your classroom!

Questions and feedback are welcome at ncep@amnh.org.



Suzanne K. Macey and Nadav Gazit



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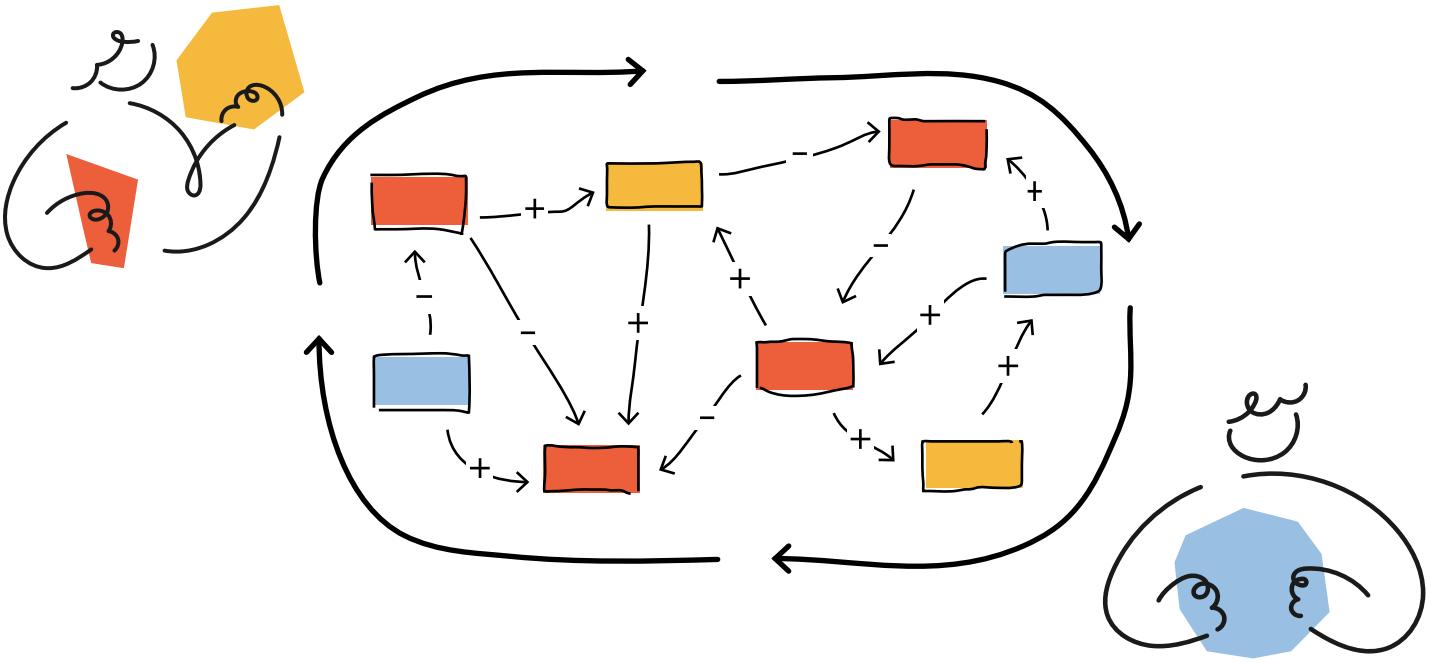
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Promoting Allyship in Conservation 84

Matthew L. Knope, Brendan Reid, Martha Groom, and Jessica Pratt

Full Circle on Thinking and Teaching in Systems

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Erin Betley *is a Biodiversity Specialist and Programs Coordinator at the Center for Biodiversity and Conservation at the American Museum of Natural History. She sees transdisciplinary and biocultural approaches that embrace different ways of knowing as key to understanding our world, and central to her research and teaching, including about food systems.*

Christian J. Rivera *is an Assistant Professor at the School for the Environment at the University of Massachusetts Boston. He uses social-ecological systems approaches to better understand and teach about human-wildlife interactions, biocultural diversity, and conservation in a rapidly changing and urbanizing world.*

Erin Betley: It's a pleasure to connect with you, Christian. I'm excited to talk with you about systems thinking and our experiences both inside and outside the classroom!

To set the stage for this conversation, we met at least a decade ago at Columbia University when you were a Master's student in an interdisciplinary course called Food, Ecology, and Globalization that my colleague and I, the late Eleanor Sterling, were teaching. At that time, you had already become connected with my colleagues at the Center for Biodiversity and Conservation (CBC) at the American Museum of Natural History. After that semester together, we became colleagues through the CBC's work related to biocultural approaches to biodiversity conservation, and recently you and I have collaborated on student mentorship opportunities at the CBC's Student Conference on Conservation Science.

It's so meaningful that it was a food course that brought you and me together, because, as we emphasized in the course, thinking about food and food systems in all their dimensions can help us build connections, make sense of the world, and make change. And, we had such fun in that class! Could you give a little bit of background on your involvement in the food course and how it evolved from there?

Christian J. Rivera: When I took the food course, it was the first time I was formally introduced to what we call the social-ecological systems framework. I always had an interest in social-ecological integration, but I didn't know this explicitly until then. But I guess that was the point of graduate training, and taking the food systems course was very helpful for me in figuring out my Master's project. I recall learning about the environmental and ecological dimensions of the food system and learning about how human culture fits into the food system.

And it wasn't just the content of what we were learning—but how we were learning it and the diversity of assessment tools. For example, one day we're doing a short quiz on our reading, the next day we're building a project where we have to lay out a menu or a meal. And then we're working with the Mental Modeler tool, which I have used in my research and recently in my teaching to model social-ecological systems in a way where students can also run different scenarios and assess outcomes[1]. The diversity of tools that you can bring into the process because of the goal of synthesizing and integrating across disciplines was fascinating.

At the same time, in that course, we were reading papers on systems thinking, human-nature feedbacks, and wicked problems. We were learning content related to food and environmental processes and social processes, while simultaneously familiarizing ourselves with the language of systems thinking, like boundaries, emergence, and so on.

And you do have to learn those concepts and their language and definitions, right? Especially if you're going to apply them in an academic context, as I was when doing my own independent research and independent readings with Eleanor Sterling and Mary Blair at the CBC. I also had my first introduction to Elinor Ostrom's way of thinking about systems, and thinking about social-ecological systems for sustainability in natural resource management. I just kept holding on to that framework during my initial training as a graduate student, because it gave me a starting point, and, in a way, a kind of freedom to train myself in conservation biology. It also taught me how to integrate approaches where I can explicitly engage people. At the same time, I was reinforcing my training in systems thinking through my independent research and through the biocultural research that I started to engage with at the CBC. So my experience in learning about systems and systems thinking reached far beyond the food course[1].

I would say that was the beginning of my formal training as a systems thinker. I think deep inside I always wanted that: a pathway to seeing environmental issues from a more holistic perspective. And it was wonderful.

Erin Betley: I'll share some insight into what Eleanor and I were experiencing as educators for that course: During the early years, we saw that students had difficulty connecting all the different content that was presented, from climate change to health to agricultural diversity. So, we redesigned it to take a systems-thinking approach and to teach what it means to think in systems alongside the rich content about food systems.

We investigated what kind of tools we could use and what kind of learning progressions might we anticipate, and asked: How could we build in some experimentation into the syllabus so that we could try to understand a little bit more about taking the systems-thinking approach, how effective it can be, and what kind of lessons we can learn?[2] That ultimately led to a collaboration with the

[1]Rivera et al., 2026
[2]Gray et al., 2019

Network of Conservation Educators and Practitioners (NCEP) and the publication of educational materials that we developed as part of the course. And that collection is living on through you, as one example, because of some recent work that you've done—which we'll get to soon!

What you shared makes me think about some of those wonderful moments during that course when things "clicked" for students, when all of a sudden someone "got it" and was able to apply systems approaches not only to the course, but also in other aspects. For example, as you mentioned, we integrated a tool called Mental Modeler throughout the course. We used it to build initial food systems models and refine them over the semester as students were learning more about the material, sifting through the evidence, and running scenarios to figure out which connections are most important. We saw students, like you, say: I can use this tool in my Master's project research! I can use this tool in this economics class I'm taking; I can use this tool to help me sort through a personal issue that I'm dealing with.

I often explain systems thinking as both a way of thinking and a set of tools, and it's wonderful to see how you've progressed with your career in integrating these things. A lot of it comes back to who influenced our own career trajectories. I owe my career to Eleanor, who was an early professor of mine and then became a colleague. We later published together, we taught together, and now you see these things coming full circle. Now I see that in you: You're integrating this into your current teaching and you're publishing with your students and who knows what kind of possibilities are out there for your students who've learned to not only apply a systems-thinking tool within a class, but then think about what it means to communicate it to different audiences, to publish a scientific paper with their professor, to think about different ways to apply what they've learned in the classroom. Can you tell me more about that paper and your experience?

Christian J. Rivera: Of course! Let me start by explaining the origins of the course and how it relates to the paper[1]. After completing my Master's program at Columbia University and finishing up my work at the CBC, I went on to a Ph.D. program at the University of Florida and then to a postdoctoral research and teaching fellowship at Princeton University. I had the opportunity to develop and teach two new courses: Systems Approaches to Conservation and The Wildlife Trade. I didn't think twice: I made it a priority to teach my students about systems thinking, whether to apply it to thinking about the wildlife trade, climate change, or food. I could rely on my own training and learning, as well as my CBC mentors' adaptation of Ostrom's framework to analyze wildlife trade systems[3]. I also recalled the exercise you published with NCEP[4], and I said, okay, now can I adapt this for a semester-long project where students take a wildlife trade issue of interest and then model their interpretation of the wildlife trade system? And similar to the food course, they would be learning about different social and ecological components of wildlife trade systems. And as they're learning about those components throughout the semester, they're refining their models. By the end of the class, they had a wildlife trade system modeled that reflected their understanding of the system, and they can run scenarios through the Mental Modeler software to understand, for example, if they were to propose having an intervention, whether a demand-side or a supply-side intervention, what would that look like? What would be the system-level effects?

The paper is essentially a report on the course, the course structure and its utility, and about helping students learn about the different language of systems thinking and how they can begin to tackle complex and wicked problems such as the wildlife trade. With patience and perseverance, a couple

[3]Blair et al., 2017
[4] Betley et al., 2021

years later, the paper was published. And so it really is, for me, very special, or "full circle," as you put it. I not only authored this paper with my former students, but we also cite Mary and Eleanor's papers and your paper on the food systems exercise, and I got to synthesize not only the knowledge, but also my entire experience and my connection to you and to the other folks at the CBC.

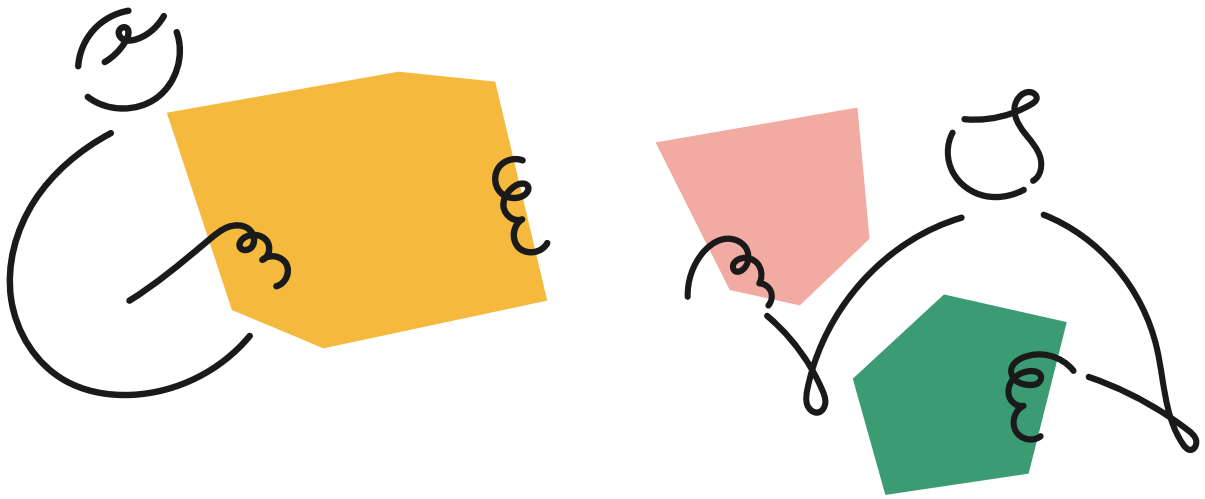
Erin Betley: One of the ways Eleanor was a visionary was that she saw the power of taking interdisciplinary systems-thinking approaches to ask questions about a whole variety of things. These are approaches that you could carry through your career, integrate into new courses, and open new areas of inquiry.

Another aspect of the course that was so powerful, at least for me as I was learning about systems thinking and how to take this approach, is: It's not necessarily giving you answers, but it's helping you think about what questions to ask and how to "think in systems," as framed by educator Donnella Meadows. How do you think about not only the connections between parts of a system and the feedbacks, but how the systems are changing over time, how they are adaptive, how they exhibit emergent behavior, and, importantly, how systems thinking can help us step back and think about our own thinking and understand what assumptions we are bringing.

During the course, we continually reinforced the importance of critical systems thinking, of asking deeper-level questions about who has power in a system and who does not, who is marginalized in a system and who is not. We employed critical systems thinking approaches to center equity and inform a thoughtful way to teach these difficult, wicked problems.

One of the wonderful outcomes of the course that we developed was the creation of a community of practice of sustainable food system educators who were using systems thinking in their approaches. This collaboration resulted, among many other things, in a set of competencies that illustrate what food system education looks like when it's taking a systems thinking approach, when it's asking critical questions. It can be intimidating to think, "Okay, I'm going to take a different approach. I'm going to redesign my course." It takes courage to do what you did, to step back and ask, "How can I integrate all these complex concepts in a way that makes sense?"

How has this journey affected you as an educator, as a researcher, as a colleague, as a mentor?



Christian J. Rivera: I'm still learning. I think being an educator, it's also a lifelong journey; I'm going to continue learning how to teach, right? And, and I'm learning that more and more every day, especially now as a professor. In the classroom, I have students from all walks of life who have so many different interests. It's different from what I experienced when I was starting out as an undergraduate, where in the environmental realm, well, you might just have to focus on training in ecology, and you didn't always see how the social dimension fit with what we were trying to do in conservation biology or ecology. But now that's different. I have students who are majoring in sustainability or environmental science. And so my class is a mix of backgrounds and interests. What systems-thinking and social-ecological frameworks allow me to do is highlight how all of their interests could fit into the bigger puzzle.

When we look at an environmental issue or a conservation problem, I try to show how there's a seat at this table for everyone. I tell them, let's use these tools to find out how your interests and the skills that you're going to develop as you become a professional might contribute, because you can. It really allows those connections, that may be less visible, to become more visible. Systems thinking allows me to engage students with different perspectives and also allows them to appreciate different perspectives and ways of knowing. And that's been really valuable. I never have to say, "Oh, you have an interest in a certain discipline? Yeah, no, we don't know how that really fits into the environmental field." That's not true. What I say instead is "Let's work together to uncover and see how it does fit." And how it's one piece of a bigger puzzle that we can work on solving together.

Erin Betley: That's wonderful. Have you encouraged your colleagues to consider how to integrate systems thinking into their teaching?

Christian J. Rivera: I've been engaging with my colleagues. I think that there are still some challenges that stem from the disciplinary training that a lot of my colleagues have had, and being trained at institutions or programs at a time when we weren't embracing systems thinking within the environmental sciences and studies in the same way. So I think conversations that I have with my colleagues are very valuable.

It eventually comes back to, well, "let's keep talking." Because then we can hopefully see together how these systems thinking approaches and frameworks might lead to a shared language for us. But it will take time.

With students, it's great because I can structure a syllabus and scaffold and build off of skills and concepts. Whereas with my colleagues, we might have to actively be working on a project together for me to engage with them on the topic. But how do you get to that point and to this type of collaboration when our fields are so different? It does require maybe an interest in or a little bit of an understanding of this way of thinking. There are certainly opportunities for other ways of engaging colleagues, perhaps through workshops or through sharing materials like the NCEP systems thinking collection.

Erin Betley: I agree: the more students are excited by the possibilities of taking this approach, the more they're talking with their peers, the more they're integrating these ideas into other courses they're taking, the more educators are thinking differently about how they might approach how they teach something; that's where change happens. There is no one way of taking a systems-thinking approach. That's what makes me most excited about what we're building with NCEP with the systems-thinking collection, but also with those unanticipated future outcomes. Who would have guessed when we first met that ten years later we'd be talking this afternoon about all these different applications that have spanned our work in so many different dimensions? One of Eleanor's most

profound legacies is in who she mentored and how she mentored, and all of us taking those lessons and passing them forward to our mentees. I'm grateful to know your work and how it's impacting so many different others out there who are going to carry it forward.

Christian, what are your final thoughts?

Christian J. Rivera: I just want to say that I agree, and that I'm just grateful. I'm grateful for the mentors I've had. I'm grateful for the connection I have to you and to my colleagues. I also would not have imagined that ten years later we would be sitting here having this conversation. And it's so important for us to keep reflecting moving forward because we are a testament to how profound and impactful good mentorship can be. I'm excited to continue that legacy and continue the conversation.

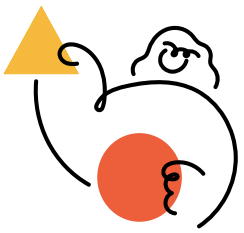


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Becoming a Voice for the Visuals

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When I first heard about visual literacy—while training as an undergraduate learning assistant at Penn State—my three worlds collided: science, art, and pedagogy.

As someone who grew up drawing, I naturally gravitated towards visuals in my early science classes in middle school. Graphs represented numbers; flowcharts represented processes; illustrations represented observations. I remember trying to replicate these drawings myself. And every time I drew to learn, I became better at understanding and applying the science. But only later did I realize that *visual literacy* exists to describe our ability to identify, interpret, create, use, and evaluate visual media.

Visuals guide us through a model-based reasoning process by depicting "a hypothesis about structures, functions, or relationships" (Heideman et al 2017). Imagine creating a map to navigate a new place. We may start by consulting others' maps and formulating our own using some known landmarks and paths between them. However, as we explore the area further, we may find ourselves updating our map so it better reflects our findings and provides more useful directions for our destinations. Similarly, we can develop visual literacy by referencing sample drawings, learning drawing techniques, producing multiple iterations of drawings, aligning them with specific learning objectives, and revising them as our understanding evolves.

Yet, when I shared these findings with my peers in class, drawing as a learning tool appeared foreign to many. I realized that despite the prevalence of visuals in science, students are disconnected from the *why* and *how* to leverage them.

With dedicated faculty support, I started *Draw with Me!* workshops in a human physiology class during my second year of college. In that peer-to-peer instructional environment, we discussed our reactions to understand what we saw; we analyzed the techniques to recreate what we saw; we picked up our pencils to innovate what we saw. As we drew a series of connected visuals—each one more zoomed in—of muscle fibers at different levels of organization, we visually dissected muscle physiology by seeing structures both as individuals and interconnected systems. We successfully translated changes at one organizational level to changes at others because we understood their relationships.

Visuals that connect concepts also connect people.

Throughout my college career, I collaborated with researchers, practitioners, and educators across conservation, anthropology, medicine, public health, and public policy to develop effective communication strategies. Visuals centered our conversations.

When we teach students how to draw, we not only teach them the scientific principles but also the communication skills to connect with diverse stakeholders (Figure 1). In a society increasingly interconnected through media, visual literacy emerges as an essential skill we all need to navigate today's fast-changing world with critical thinking, problem-solving, and collaboration.

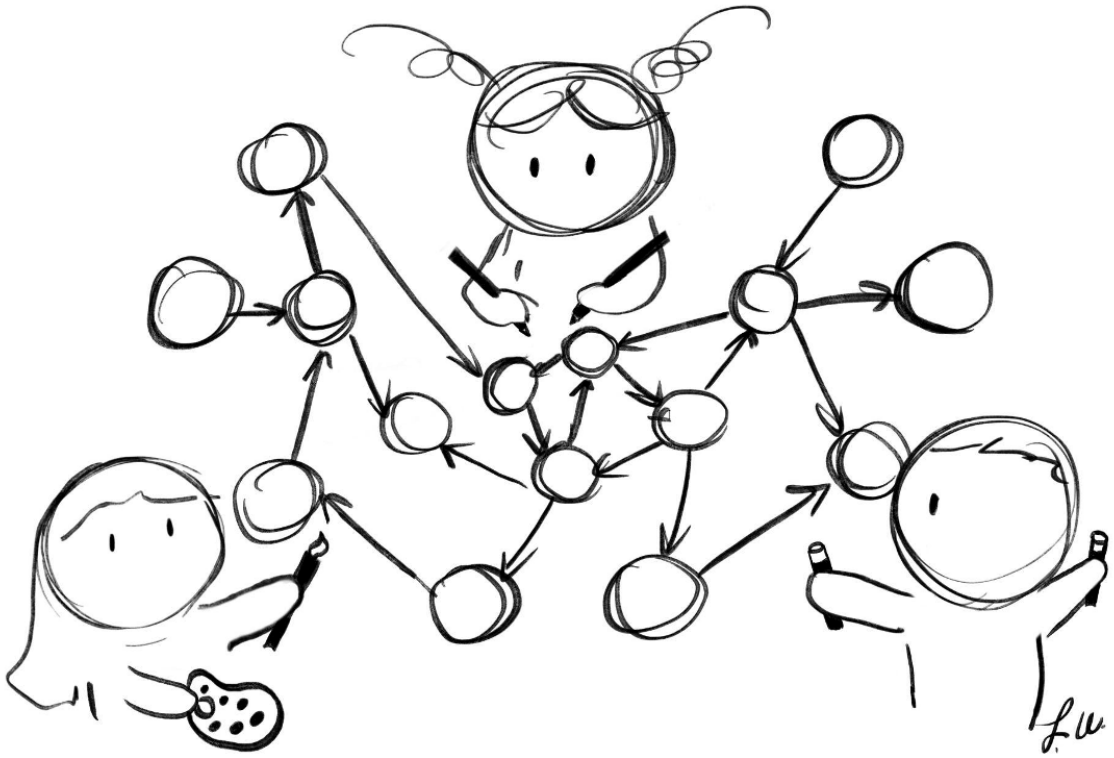


Figure 1. Collaborative drawing process of a concept map. Image credit: Lisa Wang.

I started *Draw with Me!* to promote more accessible and approachable visual education in science. As I close out my undergraduate chapter, I am excited to continue building on this initiative and help students understand broader issues in more classrooms with the Center for Biodiversity and Conservation. Check out our newest exercise, "*Draw with Me!* Using Systems-Thinking Tools to Examine Interconnected Health Systems" (https://doi.org/10.5531/cbc.linc.15.1.3).

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Draw With Me! Using Systems-Thinking Tools to Examine Interconnected Health Systems

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ABSTRACT

In this exercise, students will use drawing as a learning tool within the context of systems thinking and the use of concept mapping. They will apply this tool to learn about the One Health approach and explore relationships between human, animal, and environmental health. Students will explore how systems-thinking approaches can increase their understanding of the complexities of One Health, with a focus on antimicrobial resistance. Working in groups, students will synthesize literature and create a hand-drawn concept map of the dynamic relationships between antimicrobial resistance and climate change, based on a classical One Health Venn diagram. Students will present their work to the class and discuss a series of reflective questions.

LEARNING OBJECTIVES

After this exercise, students will be able to:

1. Understand the flexibility of drawings and how to use them as adaptable systems-thinking and learning tools;
2. Create concept maps to represent and analyze key relationships between climate change and antimicrobial resistance through a One Health approach;
3. Gain an understanding of the synergies and trade-offs related to the complexity of how human health connects with the health of animals and plants, and our shared environment.

Exercise Outline/Overview

Prior to class, students will review background content and required articles/video on systems-thinking approaches, One Health, and antimicrobial resistance (AMR). In addition, they will be sorted into groups, with each group assigned to review up to four articles on the relationships between climate change and AMR, followed by independent research.

Before class, each student will first work individually to apply their understanding of their readings to identify key variables relating to human, environmental, and animal health domains and resulting microbial properties. They will integrate these variables into a concept map that is adapted from a classical One Health Venn diagram and build out relationships between variables. In class, they will then present their map to their group for discussion, and the group will create a consensus concept map. Each group will present its consensus concept map to the class and then discuss a series of reflective questions.

PART 1. WHY DRAW?

Systems-Thinking Background

Systems thinking is a powerful tool for understanding and influencing the world around us, especially when the path towards a more just and sustainable world depends on navigating complexity. Systems

thinking can be both an approach to seeing the world—in a way that makes connections and relationships more visible and improves our decision-making abilities (Box 1)—and a set of methods and tools. In education, systems thinking has increasingly become a core Science, Technology, Engineering, and Mathematics (STEM) skill related to a learner's capacity to engage with complexity and participate meaningfully in identifying pathways for positive change (Gray et al., 2019). For a deeper dive on systems thinking, see the NCEP module "Introduction to Systems and Systems Thinking" (https://doi.org/10.5531/cbc.linc.11.1.2; Betley et al., 2021).

Box 1. Key systems-thinking concepts and example questions that systems thinkers can ask when faced with a complex issue (adapted from Betley et al., 2021)

System Structure: Systems thinkers use a combination of logical relationships, conceptual understanding, and credible evidence to discern system structure. They can identify the boundaries of a system and the relationships between parts. Both the parts of the system and the relationships between the parts influence how a system functions. For example, your heart, blood vessels, and blood comprise the structure of your circulatory system.

System Function: The structure of a system influences how a system operates or functions, and function can be evaluated by measuring changes in quality or quantity of the system's components and connections over time or through qualitative descriptions of system function. For example, the circulatory system's function is to deliver oxygen, nutrients, and hormones to the cells of your body, remove waste products, and help regulate body temperature. You can assess the function of your circulatory system with a blood test, or by measuring your blood pressure.

Identification and Negotiation of Leverage Points: Once a systems thinker is able to demonstrate understanding of the structure and function of a system, they can then identify places to intervene in a system that can leverage improvement or change throughout the system. Maintaining the health of our circulatory system can involve many leverage points, such as regular cardiovascular exercise and a heart-healthy diet. It is important to note that especially for social systems, preference for a system's function is value-laden and may vary across stakeholders (or systems thinkers) depending on their values and worldviews.

Trade-off Analysis: Systems thinkers recognize that any change to a system will cause changes to other structures and within that system—i.e., trade-offs. They can anticipate potential trade-offs and foresee adverse effects when trying to modify a system to achieve desired outcomes. For example, if a physician prescribes blood pressure medications to prevent life-threatening complications, they would also consider and discuss the possible side-effects of the medication and mitigation strategies.

Example Questions for Systems Thinkers

- What happened? What recurring events are we noticing?
- What system structures may be determining the functions we see?
- What underlying beliefs, values, or assumptions are at play, including from or within ourselves?
- What are the feedbacks in this system?
- How can we define a boundary around this system? What is appropriate and useful for our goals?
- What other perspectives, methodologies, or disciplines might help us more fully understand this issue?
- Where in this system could we make small shifts that would make a big difference? What trade-offs exist? Is there a potential for unintended consequences?

Drawing as a Learning Tool for Systems Thinkers

A synthesis of educational literature describes "drawings" as something two-dimensional that 1. is primarily learner-generated, 2. translates structures, relationships, and/or processes originally presented in a different format (e.g., text), and 3. achieves a learning goal. In essence, drawing is a process that provides students a hands-on opportunity to translate and interpret complex and abstract information visually.

As a communication tool, drawings are by no means foreign to science; they are utilized to communicate complex processes, abstract models, and intricate hypotheses all the time—in textbooks, publications, articles, and beyond—but the skill of drawing is rarely taught in classrooms (Gansemer-Topf et al., 2021). While many instructors use drawings to supplement their verbal explanations, the purpose and value of this visual literacy—the ability to find, interpret, evaluate, use, and create visual media—are not well emphasized to students (Brown et al., 2013).

The Value of Drawing

A comprehensive review by Van Meter & Garner (2005) on the theory and practice of learner-generated drawings proposed the generative theory of drawing construction (GTDC)—the prevailing theory on the cognitive process behind student-initiated drawings. It postulates that students learn better when they generate drawings on their own, compared to viewing drawings made by others. To produce a drawing that facilitates their own learning, students need to 1. draw on prior knowledge to extract key components and actors from a text/information given, 2. examine the relationships between them, and 3. arrange them spatially. This initial process of drawing-to-learn (Figure 1) requires students to create external visual synthesis reflective of their internal cognitive models (Quillin & Thomas, 2015). Extending this process to classroom exercises adds on the additional steps of 4. applying the model to solve problems and 5. revising the model (cognitively and/or physically) based on lessons learned from application.

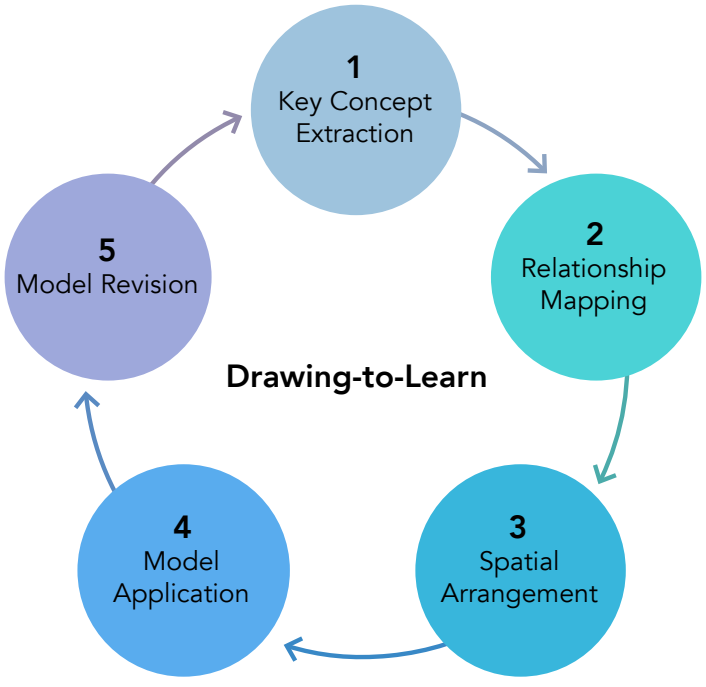


Figure 1. Five steps in the iterative Drawing-to-Learn process: 1. Key Concept Extraction, 2. Relationship Mapping, 3. Spatial Arrangement, 4. Model Application, 5. Model Revision. Image Credit: Lisa Wang

Dechamps & Skulmowski (2025) further characterized the act of drawing as an embodiment process—connecting physical activity, cognition, and environmental interactions in learning—that profoundly elevates students' learning experiences (for a more in-depth overview on the embodiment process, see Faella et al., 2025). Students manage aspects of learning by integrating instructions (learning environment), understanding and selecting relevant information (cognition), and synthesizing a pictorial representation (physical activity). Through this process, students activate prior knowledge, monitor their learning metacognitively, and consolidate information in a way that facilitates long-term retention (Fiorella & Jaeger, 2023; Van Meter & Garner, 2005).

Research and classroom practice likewise support the benefits of drawing in learning. Fiorella & Zhang (2018) found that strategies requiring students to create drawings consistently outperformed other reading and text-based learning strategies when examining student comprehension and application. In another series of studies, Fernandes et al. (2018) investigated whether drawing-to-learn boosts memory and performance relative to other learning strategies. Researchers instructed students to learn terms and definitions through different methods (e.g., drawing, writing, mental imagery, semantic elaboration, visualization, and tracing to-be-remembered information) and compared how those tasks impacted recall. They found that information drawn by students was better recalled compared to other teaching methods, as the authors explained that drawing integrates elaborative, pictorial, and motoric memory to create a context-rich representation.

Furthermore, the act of drawing extends beyond its functions in pure comprehension, representation, and communication; it facilitates analysis. After students generate their drawings, they have a roadmap for model-based reasoning and problem solving. Learners can leverage their drawings to generate explanations and predictions for relationships between major concepts and actors, thus applying key systems-thinking skills. Many existing systems-thinking tools that involve connection mapping (such as concept mapping, network mapping/analysis, and stakeholder analysis) could also be applied to drawing exercises to engage students with analyzing micro- and macro-relationships (Betley et al., 2021; Peters, 2014). Ultimately, the act of creating drawings can train students to depict system interactions and understand the overall picture without neglecting the individual parts—quite like what is needed to dissect and address the complex frameworks and topics such as the One Health approach, climate change, food systems, and biodiversity loss.

A well-known aphorism by statistician George Box, "All models are wrong, but some are useful," has direct applications for drawing-to-learn. Complex adaptive systems have interacting, adapting components whose collective behavior produces unpredictable, emergent outcomes. Since these systems don't remain static, nor should the drawings that represent them. Quillin & Thomas (2015) explained that an understanding of drawing's flexibility and diverse utility differentiates novice from expert learners (Table 1). Effective learners recognize that since no one model defines reality, they need to employ multiple models and revise iteratively, which is key to the act of drawing to learn and think about underlying relationships and systems. Tytler et al. (2019) further championed drawing opportunities that allow students to engage with multiple representations, assess the advantages and limitations of their models, and reconcile with changes in the represented processes. Embracing a flexible and iterative drawing process in learning can help students develop critical reasoning skills critical to problem-solving in science and beyond.

Facilitating the Drawing Process

Despite its documented benefits, the use of drawing-to-learn in classrooms/by educators tends to be

Table 1. Novice versus expert learners using drawing (adapted from Quillin & Thomas, 2015)

Novice	Expert
Static and fixed process	Dynamic and iterative process
Utilize a singular model	Utilize multiple models
There is a "right model" and a 1:1 correspondence between drawing and reality	There is no one "right model" because the reality is simply too complicated to represent with one drawing
Create models only when asked and may not use it to solve problems	Create models and utilize them to problem-solve without being asked
Not self-aware of the cognitive process behind model creation	Self-evaluates the content and quality of the model

restricted to discipline-specific and educational level-specific settings. Activities are more commonly incorporated in K-12 curriculum than in higher education and in Chemistry and Physics courses than other science subjects (Kunze & Cromley, 2021). The imbalance again suggests most students lack access to visual literacy, a critical learning tool, for much, if not all, of their education. This unfamiliarity also means that instructors need to be especially intentional about providing appropriate scaffolding during drawing-to-learn activities so that students get the most value from the exercise. Increased cognitive load presents a major issue that instructors need to address when they implement drawing-to-learn. Leutner et al. (2009) found that asking students to draw while they read expository science text in fact reduced comprehension due to increased cognitive load. Dechamps & Skulmowski (2025) also stressed the importance of distinguishing different types of drawings and standardizing instructions in drawing-to-learn activities to alleviate cognitive demand on students.

As such, while instructors can teach their students to draw to enhance learning, the relative lack of practical guidance/information makes it hard to lead students through the process. Beyond stressing that artistic capabilities are not a prerequisite for drawing-to-learn and that effective drawings do not need to be complex, instructors need to give students a starting point and opportunities for continued practice to produce visuals that fit the learning context. Instructors can alleviate initial unfamiliarity with drawing by explaining to students the intended use of simpler visual components, such as describing what a box represents in a drawing (Quillin & Thomas, 2015). Further, Gray et al. (2019) highlighted the importance of recognizing that visual competencies in students are achieved over time. They argued that visualization activities like drawing should align with the sequence through which students develop systems-thinking abilities (see Box 1): identifying system archetypes (structure), evaluating influences within the system (functions), generating multiple scenarios with crossovers in management (leverage points), and analyzing consequences of a decision at various system scales (trade-offs). Chang & Binali (2025) focused on scaffolding reflective questions on collaboration, content, and representation during group drawing-to-learn activities studying the carbon cycle. After the intervention, students demonstrated metacognitive self-and-co-regulation, meaning they could evaluate both the learning process of their own and their peers. Quillin & Thomas (2015) also proposed scaffolding prompts for drawing that explicitly led students to evaluate their emotional state, visual literacy, and model-based reasoning. Other studies have provided students with examples of visual building blocks and step-by-step visual libraries to directly support and engage students' creation (Gansemer-Topf et al., 2021). Fiorella & Zhang (2018) supported this by finding that students were better trained to produce drawings from text when they were provided with partial visual models.

PART 2: INTERCONNECTED HEALTH SYSTEMS AND SYSTEMS THINKING

Introduction to One Health

Humanity faces growing environmental and social crises that often interconnect, presenting unprecedented challenges for human economies, well-being, and health. The modern One Health strategic framework, first operationalized in the 2000s by international organizations such as the World Health Organization, was designed to navigate the interconnected relationships at the interface of human, animal/plant, and environmental health holistically and synergize collaborations and solutions across sectors.

The World Health Organization (2023a) defines One Health as "an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems" (see Figure 2 for an overview of this approach). While One Health is typically employed in the context of emerging zoonosis (diseases that can be passed from animals to humans), confronting modern-day challenges of increasing complexity and magnitude—climate change, biodiversity depletion, land and water pollution, antimicrobial resistance, food insecurity, neglected tropical diseases—requires growing attention to the need for holistic solutions.

However, understanding how applications of One Health have evolved and will evolve alongside these challenges requires a bit more digging. Although this human-animal-environment interaction is not new, new definitions, dimensions, and awareness of it emerged throughout history. Regarding

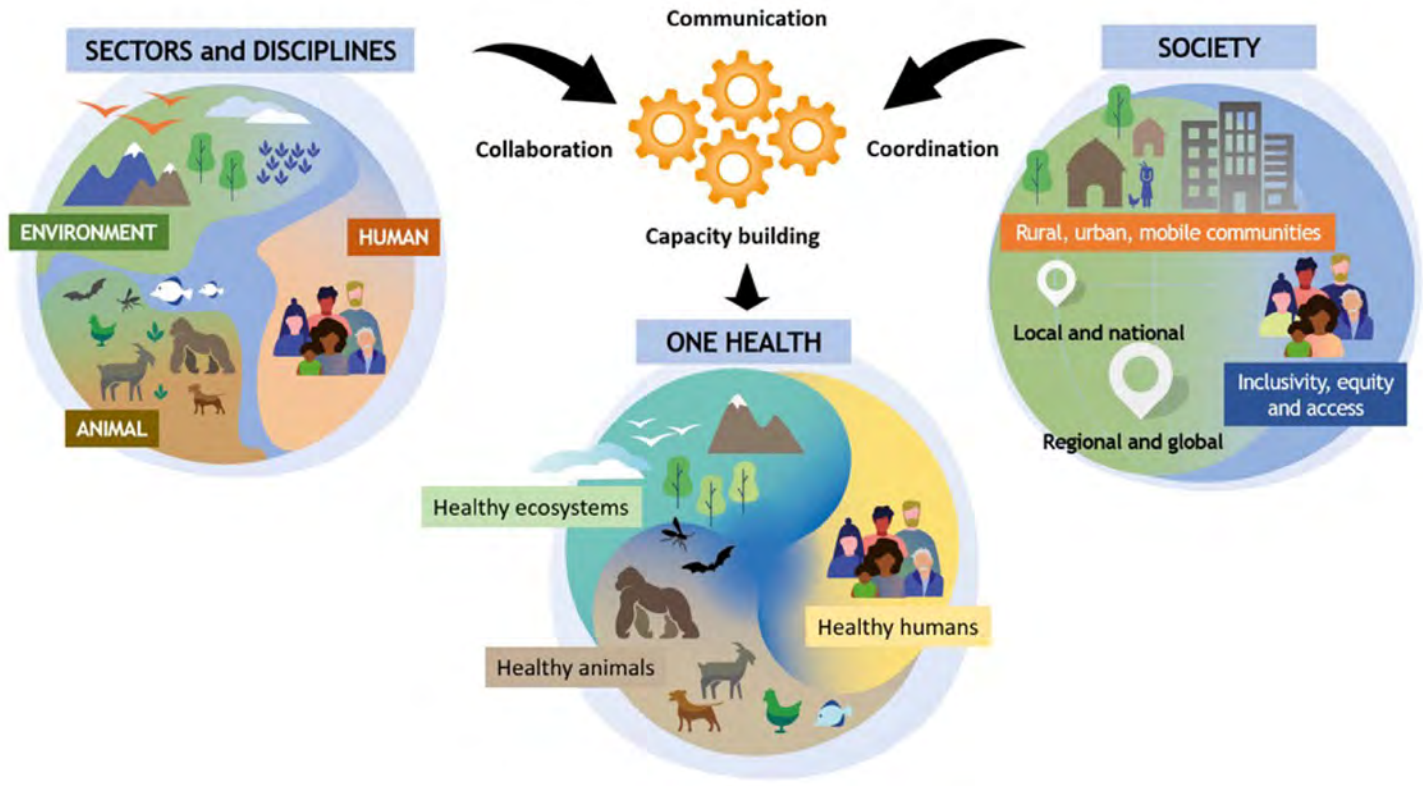


Figure 2. A graphic from the One Health Joint Plan of Action, 2022–2026. Proponents of One Health suggest that through collaboration, communication, coordination, and capacity building, the One Health approach promotes a sustainable and healthy future. Image credit: FAO; UNEP; WHO; WOAH (CC BY-SA 3.0 IGO) https://commons.wikimedia.org/wiki/File:One_Health.svg

the One Health interface as a "basic condition of life on Earth," Evans & Leighton (2014) pinpointed changing environments and population structures as stimuli for the discovery of new relationships among the three key domains. They argued, for instance, the first measles outbreak may not have occurred if large-scale urbanization had not fostered close-settlement environments adequate for the proliferation and spread of this common cattle disease with which humans had likely already been in contact. For more historical context of One Health as a concept, see Evans & Leighton (2014).

The Complexity of One Health

The complexity of many issues that One Health seeks to address, such as poverty, pandemics, and climate change, renders them virtually impossible to clearly define or solve. One Health problems have multiple (and often undefined) causes, many stakeholders, conflicting priorities, and complex interdependencies—so every intervention often creates new challenges. As a result, those who bring differing values and understandings of the problem often struggle to agree on a collective action. Despite these challenges, the One Health approach offers a way to understand complexity and make decisions that can move systems towards more desired outcomes. For example, grassroots groups in places like Latin America and Africa have long implemented initiatives of "One Health" (e.g., collaboration between agricultural and health professionals in Indigenous, rural, and medically underserved communities in Brazil) before the term was formally coined (Pettan-Brewer et al., 2024). More recently, LeBlanc et al. (2022) envisioned a public-private-academic partnership that approached One Health with pragmatic ethical thinking and reflexive governance that maps, frames, and shapes the dynamics of actors working towards a more just and sustainable future for issues related to intersecting health systems.

Critics argue that the One Health framework risks prioritizing human interests over those of nonhuman animals (especially in the context of zoonosis), calling into question its sustainability and righteousness (Johnson et al., 2024). A review of One Health literature in the past 20 years found a predominant focus on human/veterinary health, concurring with the aforementioned concern regarding the framework's human-centric tendency (Brown et al., 2024).

Systems Thinking in One Health Education

"That my health is causally connected to yours inevitably invites questions about how we take our shared or opposing interests into account."
- Karen M. Meagher, AMA Journal of Ethics

The foundational Rome synthesis—a Global One Health Core Competency Framework by an international multiagency workgroup in 2012—identified seven core competencies for practitioners using the One Health approach: management, communication, ethics, leadership, teamwork, collaboration, and, last but not least, systems thinking (Frankson et al., 2016). Several other publications have also advocated for utilizing systems thinking in health (Lueddeke et al., 2017; Peters, 2014; Swanson et al., 2012).

Gaps in Systems-Thinking Education in One Health

While policymakers, researchers, and practitioners have recognized systems thinking as a valuable tool in One Health education, a gap persists between theory and application (Gadsby & Wilding, 2024). The authors argue that the lack of any standardized curricula or accrediting organizations for degree programs worldwide is due to a persistent perception that One Health is more of an

interdisciplinary approach than a unique/specific discipline. This fragmented educational framework renders One Health implementation sporadic and ineffective. A review of 14 One Health doctoral degree programs across the world found that only 3 programs included systems, and only one clearly presented the study of systems science, as part of their academic training (Rocheleau et al., 2022). Another assessment of 15 One Health initiatives across the world found that systems evaluation approaches were unfamiliar to most participants, leading the authors to conclude that systems thinking must be integrated into One Health education to drive broader competency and participation (Hitziger et al., 2021). Gadsby and Wilding (2024) contend that abstraction, vagueness, and the lack of discourse around systems thinking among public health professionals translates to discipline-wide neglect of collaboration. They observed that many practitioners and educators adopt the terms of systems thinking but do not actually apply it in practice, arguing that while systems thinking is a core competency, educational initiatives often fail to promote systems-based critical thinking actively.

Thus, current curricula on convergent relationships among human, animal, and environmental health domains fail to equip students with skills to address society's dire needs. This shortfall hampers ethical solutions and exacerbates the magnitude of social inequities, inequalities, and pressures (Rocheleau et al., 2022). Evidently, advancing a One Health approach requires an educational framework to develop a workforce that is better prepared and ready to take needed action. Given the complexity of the current problems facing humanity, Haxton et al. (2015) recommended that educators across levels take a collaborative approach akin to that of One Health, incorporating concepts and practices throughout educational levels from K-12 to post-secondary education. They especially pointed to the lack of opportunities in secondary and higher education for students to interact with One Health content. Some efforts are already underway for expanding systems thinking in One Health-related fields; for instance, Acosta et al. (2024) implemented a One Health simulation activity in an undergraduate global health course, and Rivera et al. (2026) integrated systems thinking skills and modeling into an interdisciplinary undergraduate course on the harvest and trade of wildlife by humans. In both cases, the students gained an enhanced systems understanding of stakeholder relationships through stimulated collaborative learning, which in turn improved learning attitudes and encouraged knowledge application. However, much more coordinated efforts are needed to integrate systems thinking across One Health education.

PART 3: AN EXERCISE USING ONE HEALTH AND SYSTEMS THINKING FOR UNDERSTANDING ANTIMICROBIAL RESISTANCE

Setting the Scene: Antimicrobial Resistance

Antimicrobials (e.g., antibiotics, fungicides, antiviral agents, parasiticides, heavy metals, disinfectants, antiseptics, pharmaceuticals, natural products) are used in a variety of settings (e.g., healthcare, agriculture, ecosystems) to prevent and treat infectious diseases. These treatments are intended to lengthen the life expectancies of individuals and improve the quality of health in humans, animals/plants, and the environment (World Health Organization, 2023b).

Antimicrobial Resistance (AMR) occurs when bacteria, viruses, fungi, and parasites previously susceptible to antimicrobials develop resistance to them, leading to greater difficulty in treating diseases, wider spread and exposure, and higher rates of morbidity and mortality (Figure 3). AMR can develop intrinsically in microorganisms or be acquired through evolutionary response to antimicrobials (Salam et al., 2023).

Rising levels of intensive antimicrobial use and misuse have accelerated the generation of favorable conditions for microorganisms to develop and spread resistance. In 2019, AMR directly caused 1.3 million deaths and indirectly contributed to 5 million deaths globally (World Health Organization, 2023b). The UN characterizes this "invisible killer" as one of the top global public health threats. AMR's health impacts translate into economic and social instability by costing up to $3.4 trillion

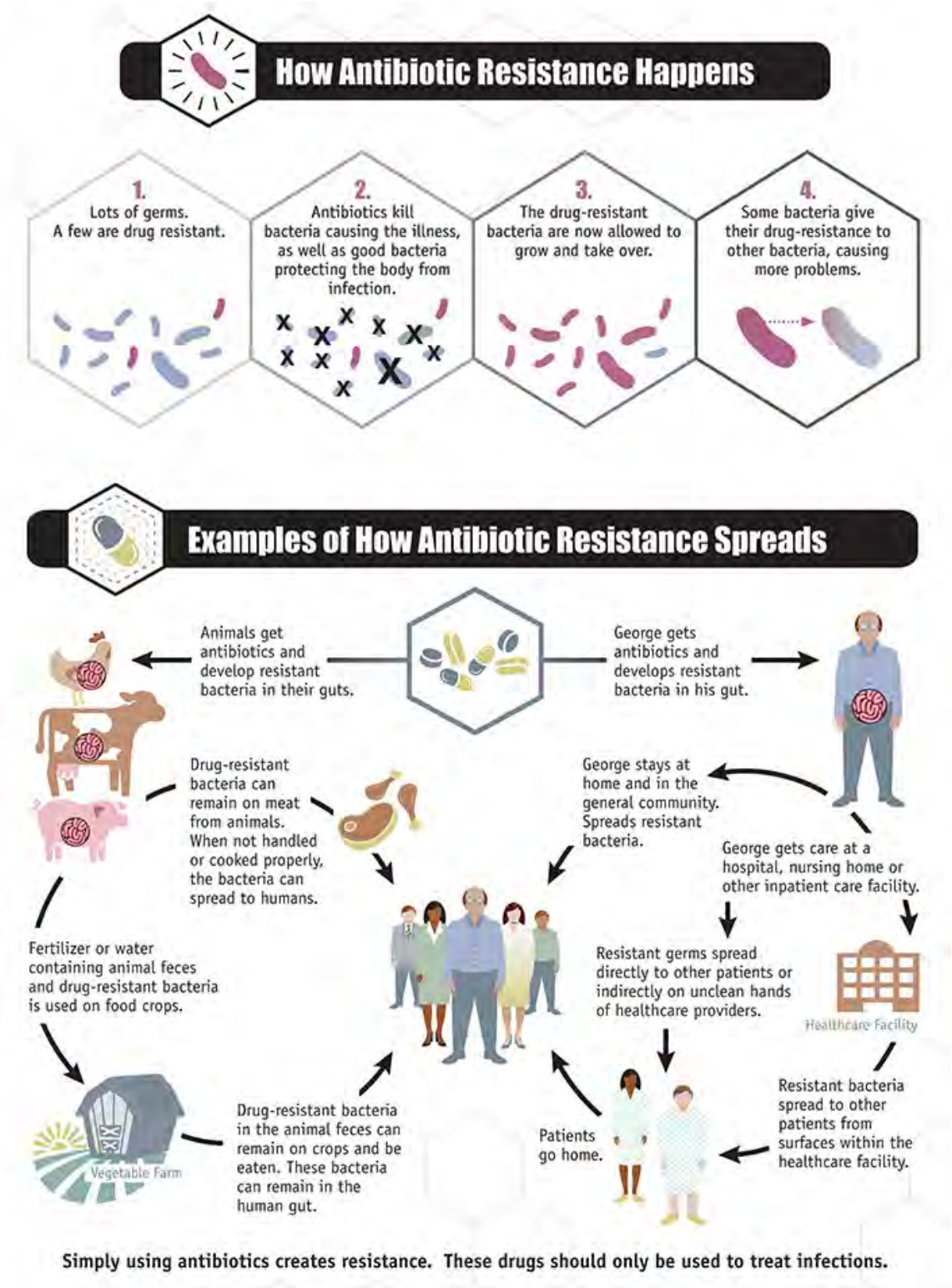


Figure 3. An infographic on how antibiotic resistance (a major type of antimicrobial resistance) happens and spreads. Image Credit: CDC (Public Domain) https://www.cdc.gov/narms/resistance/index.html

annually by 2030 and pushing nearly 28 million individuals into poverty by 2050 (Travers, 2024).

AMR impacts the human, animal, and environmental health domains; it is a quintessential One Health problem, but existing post-secondary educational curricula have failed to emphasize it. A review by the National Academy of Medicine of 45 total programs related to One Health in the U.S. (bachelor's, master's, and doctorate) identified learning about AMR as a key objective in less than 25% of the programs (Togami et al., 2018). Further, with a growing base of literature shedding light on the relationship between AMR and climate change (reviewed in van Bavel et al., 2024), students need the skills and knowledge to be able to understand unprecedented challenges implicating the health of humans, animals/plants, and the environment.

Exercise Instructions

Visual Library: A Classic Representation of One Health

A common visual representation of the One Health framework employs a Venn diagram (Figure 4A). Each circle is called a set, representing a distinct domain. Fundamentally, a Venn diagram compares and contrasts between domains: overlapping areas show shared elements and non-overlapping areas show unique characteristics. All domains converge in the center of a Venn diagram; this intersection represents elements shared by all. However, classical Venn diagrams tend to be static, do not necessarily emphasize relationships and processes, and may struggle to communicate more complex links in One Health.

Adapting the Venn Diagram

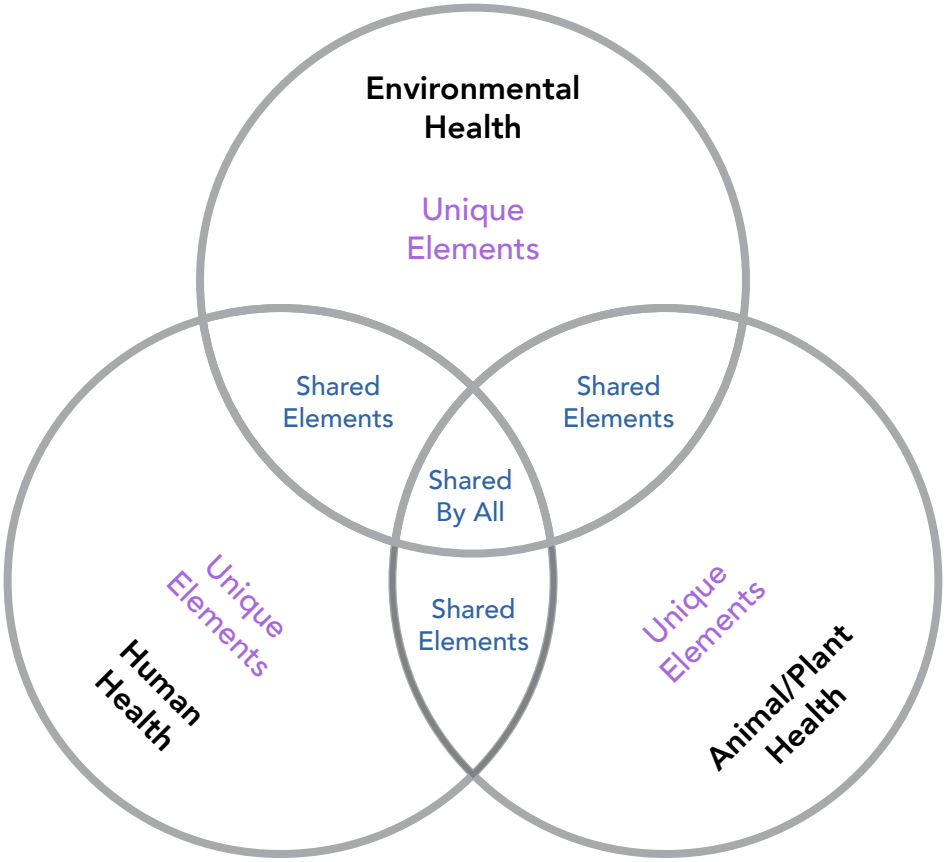
Our goal in this exercise is to explore the system in which intertwining concepts in the human, animal, and environmental health domains contribute to the relationship between climate change and AMR. To begin thinking about the system, students will adapt the Venn diagram to show underlying relationships and processes among interacting domains.

Concept mapping is an effective drawing strategy for organizing these processes. The Learning Strategies Center at Cornell University has an example and a simple overview of this technique (https://lsc.cornell.edu/how-to-study/concept-maps/). We will adapt our Venn diagram by "overlaying" a concept map so that we not only understand the shared/unique variables among One Health domains, but also how the variables interact with each other.

Arrows are critical for representing the relationships in a concept map. We will utilize two types of arrows (Figure 4B):

- **Unidirectional (dark blue arrows in adapted Venn diagram):** We can visualize how changes in a One Health domain (independent variable) may lead to or cause changes in the element shared by all (intersection) and thus lead to or cause changes to the dependent variables in the other domains.
  - Visualizing processes like these makes it easier to represent the intersection of the Venn diagram with a tangible object, especially since changes in variables may be abstract. In our case, the intersection is represented by microbes developing the AMR, which affects all three One Health domains.
- **Bidirectional (purple arrows in adapted Venn diagram):** We can illustrate how commonalities between 2 domains may act as interfaces of exchange in the One Health framework.

A. Classic Venn Diagram



B. Adapted Venn Diagram

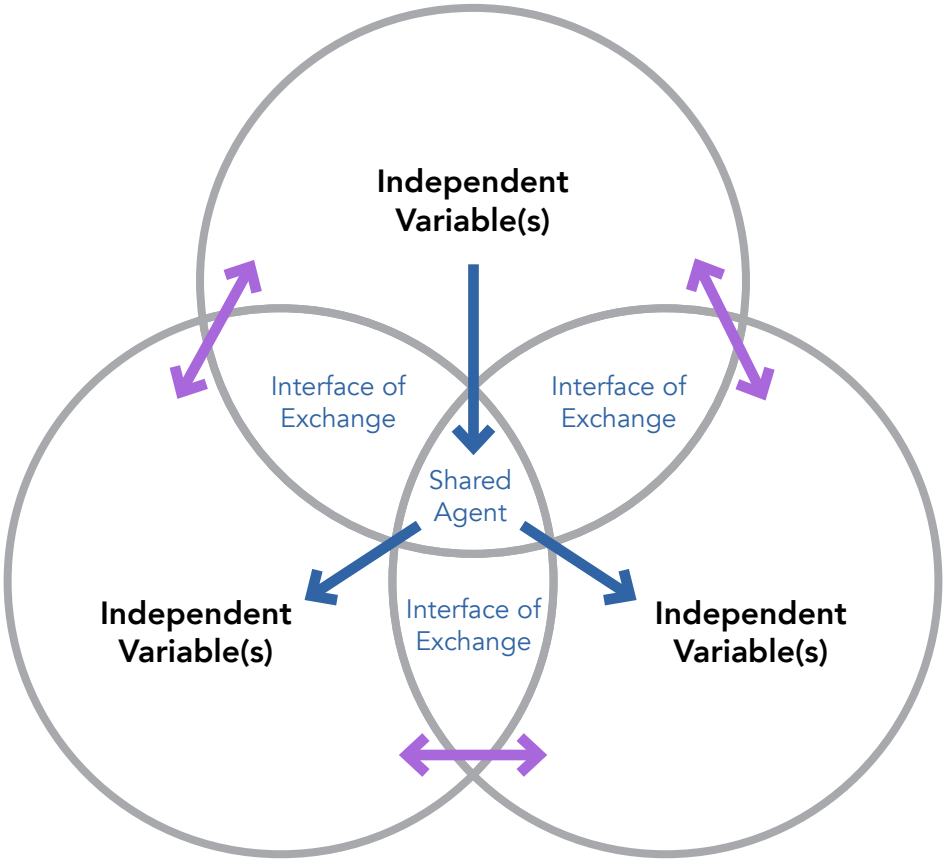


Figure 4: (A) A classic One Health Venn diagram and what each area represents, for the purposes of this exercise. (B) A generic adapted Venn diagram based on arrow usage. Image Credit: Lisa Wang

- For instance, under what context could humans and animals exchange microbes with AMR?

Sample Systems Archetypes

Literature on the relationships between climate change and AMR most commonly observes:
- "Climate Change" refers to changes in environmental health
- "Antimicrobial Resistance (AMR)" refers to changes in human and animal/plant health

Based on these definitions (though, by no means the only definitions), we will examine two types of relationships using concept mapping (Table 2).

Procedure for Students

Review instructions for ALL phases BEFORE you start the exercise in class.

Phase 0: Required readings/video

- Drawing as a Learning Tool: https://newsroom.unl.edu/announce/csmce/9972/58389
- One Health: https://www.youtube.com/watch?v=z1iYBpP_Zt0
- AMR: https://news.un.org/en/story/2024/09/1154891

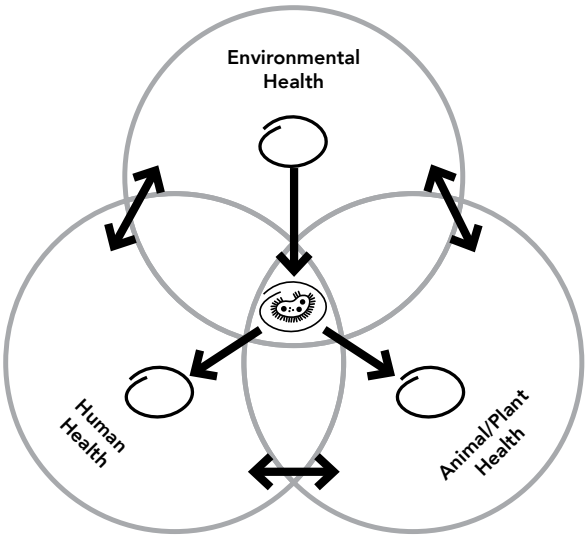
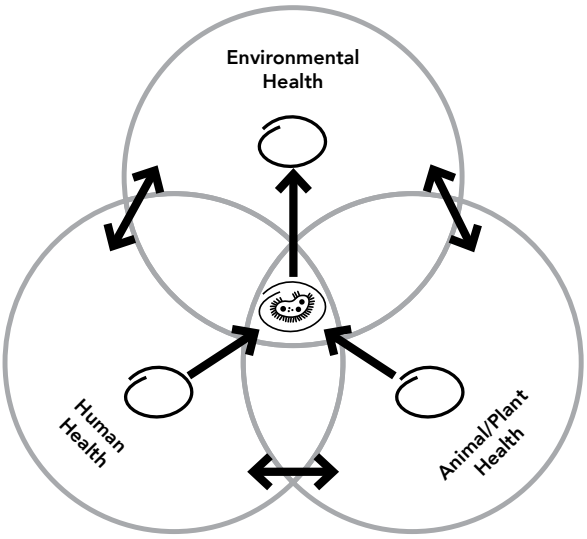
Phase 1: Literature review and synthesis (individual)

Record all your drawings and answers in the answer sheet provided (See Appendix). Attach additional paper if you need more space.

1. Students will be divided into groups of 4. Each group will be assigned one of the two relationships between climate change and AMR shown in Table 2.
2. Each student will read the following literature review on their own as homework. As you read through each article, think about the relationship between the One Health domains to which you are assigned.
   a. Van Bavel, B., Berrang-Ford, L., Moon, K., Gudda, F., Thornton, A. J., Robinson, R. F. S., & King, R. (2024). Intersections between climate change and antimicrobial resistance: A systematic scoping review. The Lancet Planetary Health, 8(12), e1118–e1128. https://doi.org/10.1016/S2542-5196(24)00273-0
      - Tip: You might find it helpful to reference Figures 2–4 (specific examples of relationships between climate change and AMR among different systems) and Figure 4B (a summary overview of all examples).
   b. Altevogt, B. M., Taylor, P., Akwar, H. T., Graham, D. W., Ogilvie, L. A., Duffy, E., & Essack, S. Y. (2025). A One Health framework for global and local stewardship across the antimicrobial lifecycle. Communications Medicine, 5(1), 414. https://doi.org/10.1038/s43856-025-01090-4
      - Tip: You might find it helpful to reference the section titled AMR drivers.
   c. Fernández Salgueiro, M., Cernuda Martínez, J. A., Gan, R. K., & Arcos González, P. (2024). Climate change and antibiotic resistance: A scoping review. Environmental Microbiology Reports, 16(5), 70008. https://doi.org/10.1111/1758-2229.70008
      - Tip: You might find it helpful to reference results and discussion.
   d. Endale, H., Mathewos, M., & Abdeta, D. (2023). Potential causes of spread of antimicrobial resistance and preventive measures in One Health perspective-a review. Infection and Drug Resistance, 16, 7515–7545. https://doi.org/10.2147/idr.s428837
      - Tip: You might find it helpful to reference Figures 3 and 4B for the spread of AMR in various pathways.

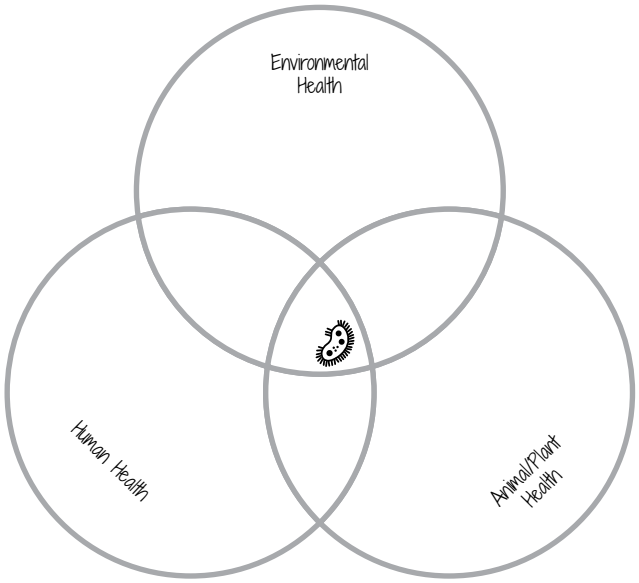
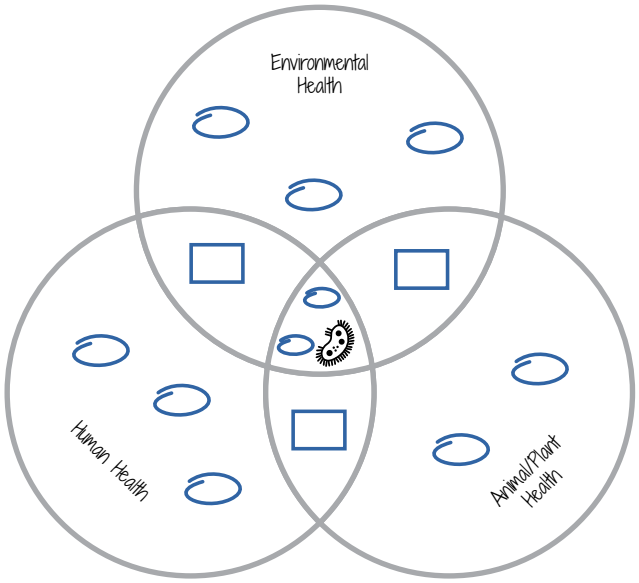
3. Write down relevant concepts based on these guidelines:
   a. Identify at least 2 but no more than 5 independent or dependent variables in each domain (human, animal/plant, environment)
      - Tip: All variables you identify here need to include a descriptive verb (e.g., increased, decreased, altered, expanded).
      - For example, accelerated climate change, increased antimicrobial resistance, elevated risk of exposure, intensified antimicrobial usage, increased greenhouse gas emission, altered ecosystem biogeochemistry, elevated sea-level, increased aerosol pollution, intensified aquaculture/agriculture
   b. Identify at least 1 but no more than 3 altered microbial properties
      - Tip: All variables you identify here need to include a descriptive verb (e.g., increased, decreased, altered, expanded).
      - For example, expanded geographical range, enhanced diversity, increased virulence, increased pathogenicity, increased infectivity
   c. Identify at least 1 but no more than 2 interfaces of exchange between each group
      - Tip: Variables you identify here can be theoretical processes or physical locations.
      - For example, direct contact, food consumption, agricultural practices, wastewater/floodwater, shared contaminated space, food production/transportation
   d. Tip: Note that all concepts you identify need to include a descriptive verb (e.g., increased, decreased, altered, expanded).
4. Once you complete all readings, you now have a collection of variables that together are termed a "concept bank." As the exercise proceeds, you can take items from your concept bank to inform your drawings.

Table 2. The independent variable, dependent variables, and systems archetype for 2 types of climate change and AMR relationships.

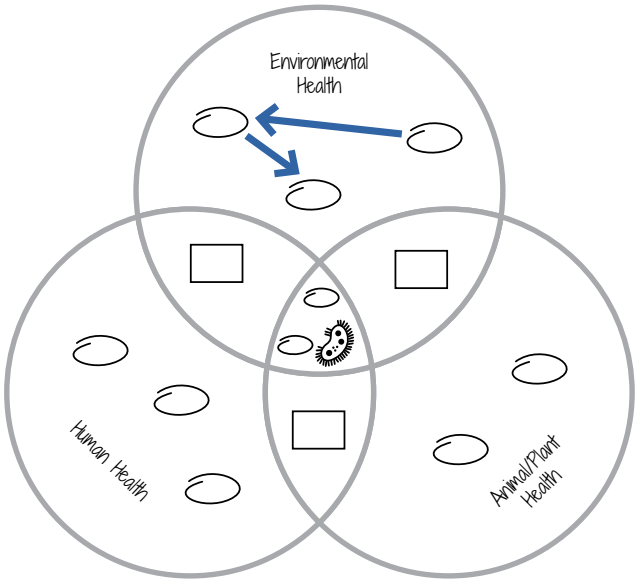
	Climate change driving/influencing AMR	**AMR driving/influencing Climate Change**
Independent Variables	Climate change/related to the environment	AMR/related changes in humans and animals/plants
Dependent Variables	AMR/related changes in humans and animals/plants	Climate change/related to the environment
Systems Archetype		

Phase 2: Concept map creation (individual)

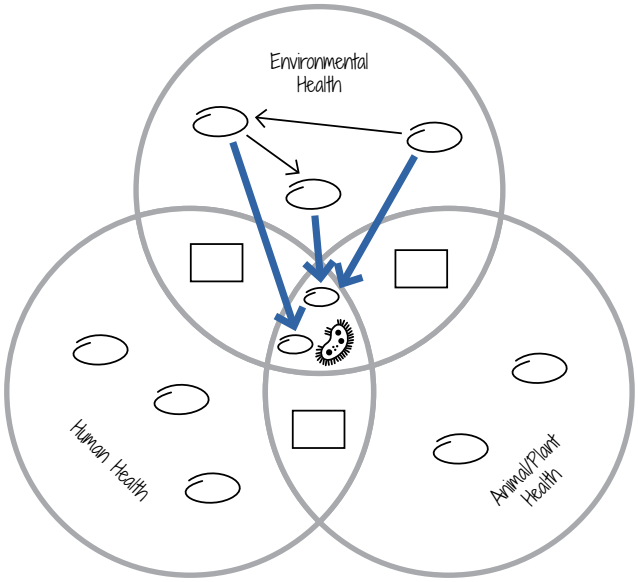
Note: The following visual instructions represent a hypothetical mapping for a relationship showing climate change driving/influencing AMR. Actions associated with each step are in blue. You need to create your drawing based on the actual relationship you are assigned and the variables you extracted.

1. Reproduce the Venn diagram on a piece of paper (or tablet) by hand-drawing it. You may write the domain names (Environmental Health, Human Health, Animal/Plant Health) outside of the circles to leave more space for the concepts.	
2. Fill in the Venn diagram by sorting the variables you noted above into their respective areas. Circle the independent and dependent variables and altered microbial properties and box the interfaces of exchange. Make sure to leave enough space between the variables so you can add arrows to the diagram.	

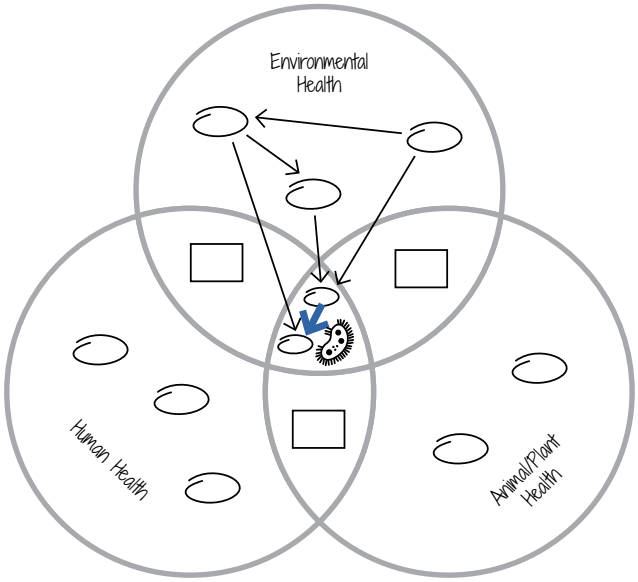
3. Start in the circle that represents the domain of your independent variable. Do some variables contribute/lead to another? Draw unidirectional arrows that show the direction of impact.



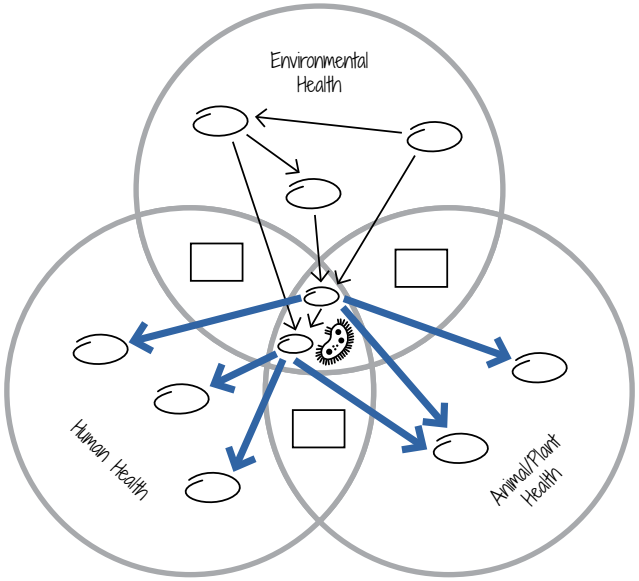
4. Now we move from the domain of the independent variable to the microbe in the center. Draw unidirectional arrows from each independent variable to whichever microbial properties they contribute/lead to. Multiple arrows may point to one microbial property if it is impacted by multiple independent variables.



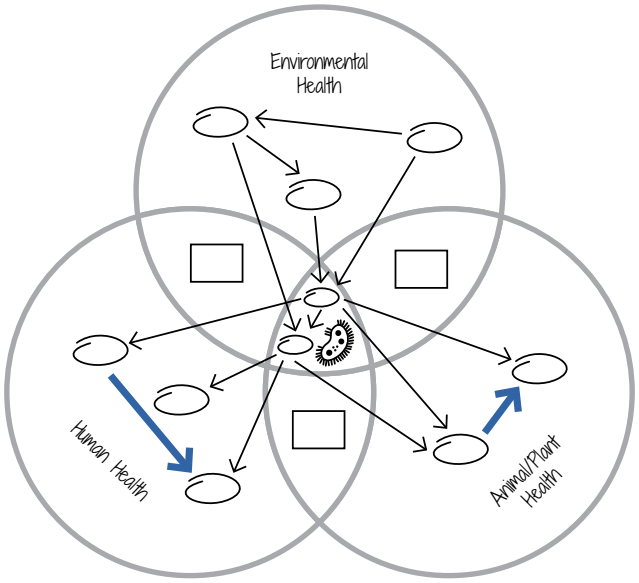
5. Do some microbial properties contribute/lead to another? Draw unidirectional arrows that show the direction of impact.



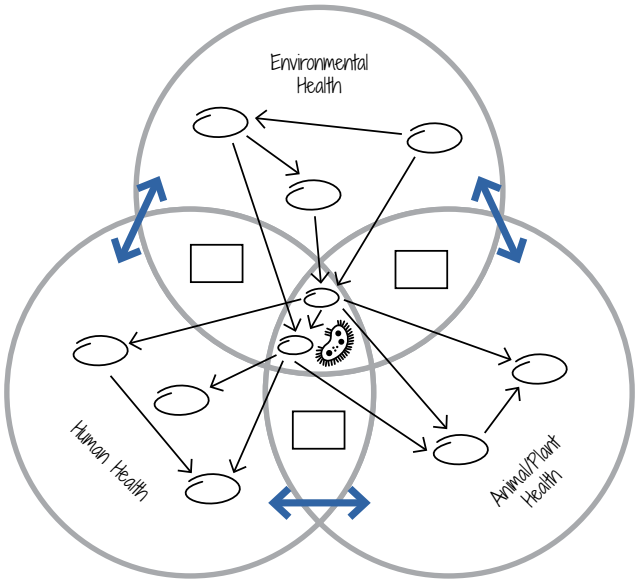
6. Now we move from the microbe to the domain of the dependent variables. Draw unidirectional arrows from each microbial property to whichever dependent variable they contribute/lead to. Again, multiple arrows may point to one variable if it is impacted by multiple microbial properties.



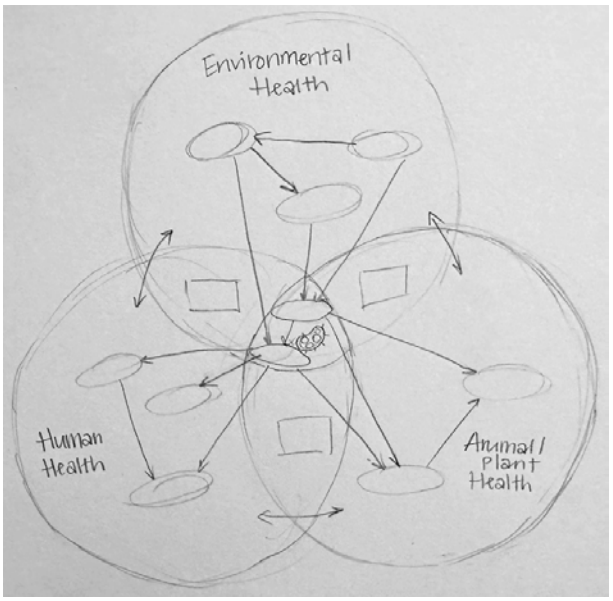
7. Do some dependent variables contribute/lead to another? Draw unidirectional arrows that show the direction of impact.



8. Now we add context to the drawing by revisiting the shared interface. Draw bidirectional arrows next to each interface of exchanges.



8. Continued, hand drawn example.



Phase 3: Varying perspectives analysis (group)

1. Once all members of your small group have finalized their drawings, you will present your drawings to each other as if you were teaching each other.
   - Tip: Do not simply show the diagram to others; explain it. Follow the arrows as you walk others through all the relationships you visualized.
2. Compare and contrast your drawings within the group, and answer the following reflection question individually:
   a. How were your drawings similar/different? Consider the overall relationships, the variables you identified, the directions the arrows point, etc.
   b. How would you revise your drawing after hearing from the group? Why or why not?
   c. Did your drawing reflect a bias towards the health interests of one domain over those of any others?
3. Work together as a group to consolidate your drawings into one drawing. You should have ~15 total circled and boxed concepts in your drawing. Consider grouping similar variables together if you have too many.
4. Based explicitly on your group drawing, answer the following reflection questions as a group:
   a. What did you learn about drawing from this collaborative process?
   b. Explain how your group's drawing shows a relationship between climate change and antimicrobial resistance through the interface of human, animal, and environmental health in 5–6 sentences.
   c. Propose an intervention for alleviating the impacts of this relationship. Address specific arrows to discuss the synergies and trade-offs among the three domains of One Health. Discuss the role(s) that interface(s) of exchange between domains play in this intervention.
      - Tip: The literature reviews you read provide great context for potential intervention.
5. Each group will have 5 minutes to present their drawing to the class, again, as if you were teaching each other. You will also share your answers to step 4.
6. After all groups present, answer the following reflection questions individually:
   a. How was your group's drawing aligned with/different from that of other groups? Consider the overall relationship, the variables you identified, the directions the arrows point, etc. Did this change your considerations for synergies and trade-offs for interventions?

b. Do you think your group drawing is representative of the overall dynamic between AMR and climate change as a whole? Why or why not? What changes would you make to it?
c. Did the individual drawings within your group reflect biases towards the health of one domain as compared to the others? Did these biases go away when the group drawing was synthesized?
d. What were the limitations of the template systems' archetypes in representing what you wanted, if any? How would you revise the templates?
e. How has your understanding of One Health and/or drawing as a systems-thinking tool changed through this exercise?

ACKNOWLEDGMENTS

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APPENDIX: ANSWER SHEET

Phase 1: Literature Review and Synthesis (Individual)

Concept Bank (Note: ranges at the top indicate the number of concepts you should aim to have in each category). Think of this exercise as a puzzle—you will need to see the pieces before putting together the whole picture!

Independent/ Dependent Variables (Environment)	Aim for 2-5 concepts per category:	
Independent/ Dependent Variables (Animal/Plant)		
Independent/ Dependent Variables (Human)		
Altered Microbial Properties	Aim for 1-3 concepts:	
Interfaces of Exchange (Environment & Animal/Plant)	Aim for 1-2 concepts per category:	
Interfaces of Exchange (Environment & Human)		
Interfaces of Exchange (Human & Animal/Plant)		

Phase 2: Concept Map Creation (Individual)

Remember to use scrap paper to practice drawing before producing the final version for this phase below. Keep all of your practice drawings.

Phase 3: Varying Perspectives Analysis (Group)

Compare and contrast your drawings within the group, and answer the following reflection questions individually:

How were your drawings similar/different? Consider the overall relationships, the variables you identified, the directions the arrows point, etc.

How would you revise your drawing after hearing from the group? Why or why not?

Did your drawing reflect a bias towards the health interests of one domain over those of any others?

Group Venn Diagram (you should have ~15 total circled and boxed concepts in your drawing)

Remember to use scrap paper to practice drawing before producing the final version for this phase below. Keep all of your practice drawings.

Based explicitly on your group drawing, answer the following reflection questions as a group:

What did you learn about drawing from this collaborative process?

Explain how your group's drawing shows a relationship between climate change and antimicrobial resistance through the interface of human, animal, and environmental health in 5-6 sentences.

Propose an intervention for alleviating the impacts of this relationship. Address specific arrows to discuss the synergies and trade-offs among the three domains of One Health. Discuss the role(s) that interface(s) of exchange between domains play in this intervention.

Based explicitly on your group drawing, answer the following reflection questions as a group:

How was your group's drawing aligned with/different from that of other groups? Consider the overall relationship, the variables you identified, the directions the arrows point, etc. Did this change your considerations for synergies and trade-offs for interventions?

Do you think your group drawing is representative of the overall dynamic between AMR and climate change as a whole? Why or why not? What changes would you make to it?

Did the individual drawings within your group reflect biases towards the health of one domain as compared to the others? Did these biases go away when the group drawing was synthesized?

What were the limitations of the template systems' archetypes in representing what you wanted, if any? How would you revise the templates?

How has your understanding of One Health and/or drawing as a systems thinking tool changed through this exercise?

Poetry Writing for Conservation

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ABSTRACT

In this lesson, you will learn how poetry and conservation science can complement each other. You will see some examples of conservation-related poetry and try your hand at writing conservation poems. Do poetry and science seem unrelated to each other? We think they have more in common than they might appear to at first glance. They both rely on close observation, emotional connection, curiosity, creative and critical thinking, and effective communication. The practice of poetry is also an excellent way to slow down and reconnect with ourselves, with each other, and with the environments and organisms around us. The activities in this lesson provide step-by-step instructions for applying three different techniques to writing poems using conservation-related source materials (provided by your instructor, or by you). Using these techniques you can create poems of many kinds: short, long, simple, complex, intriguing, profound, emotional, humorous, and more.

LEARNING OBJECTIVES

In successfully completing this exercise, students will:

1. Practice close reading and close observation skills that underpin good science and good literature.
2. Examine, create, and compare three types of poems:
   a. Found poems that explore and convey conservation concepts.
   b. Erasure poems that subvert the meaning of conservation-related texts.
   c. Ekphrastic ("observe-reflect") poems that build connection between the poet and an image, item, species, or place.
3. Discuss how approaching conservation materials through poetry engaged your critical thinking, communication, and emotions, and affected your understanding of course content and concepts.

INTRODUCTION: THE BONUS BENEFITS OF COMBINING POETRY AND SCIENCE

Creating a poem, like doing conservation work, is the art of observing, experiencing, inquiring, creating, and communicating (Figure 1). Connecting conservation and poetry might initially seem surprising. But conservation and poetry are natural partners for several reasons (see Wonham et al., 2025 for details).

First, conservation work is interdisciplinary and transdisciplinary. Approaching conservation through poetry strengthens your interdisciplinary and intercultural capacities of flexibility, humility, curiosity, and empathy.

Second, conservation involves making recommendations based on values, ethical considerations, or desired outcomes, and therefore is laden with emotional experience. What do you feel about what you are studying? Hope, joy, grief, anger, awe, confusion? All of these and more? Can combining poetry and conservation could make you happier and smarter? Yes: Creating poetry about conservation gives you the opportunity to explore and express and reflect on these emotions, a process that contributes to well-being and cognitive development (Mezirow, 2009; Kegan, 2009; Cuzzolino, 2021; Jiang et al., 2024).

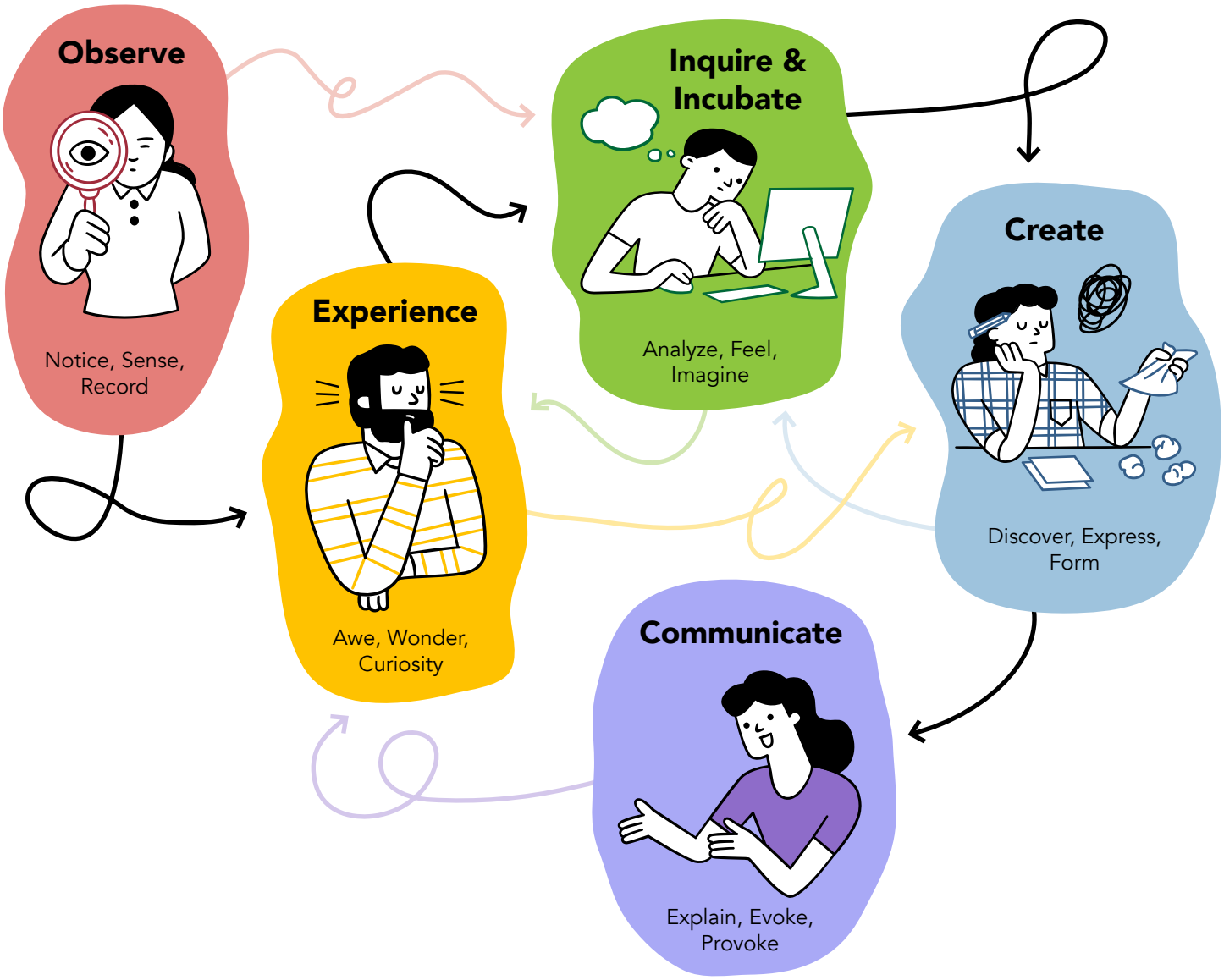


Figure 1. Parallel inquiry and practice in poetry and sciences. Inquiry in both poetry and the sciences can take a linear or non-linear trajectory through observing (such as sensing, and recording, among others), to experiencing (awe, wonder, curiosity), to inquiring (analyzing, feeling, imagining), to creating (discovering, expressing, forming), to communicating (explaining, evoking, provoking). Image credit: Adapted from Wonham et al., 2025 by Nadav Gazit using jesadaphorn illustrations via Adobe Stock Photo/Standard License

Third, creating science and poetry demands similar practices: careful noticing, critical and creative inquiry, creation, and effective communication (Figure 1). Both benefit from imagination, analogy, and metaphor. Creating poetry enhances your scientific skills, and vice-versa (see Anand, 2022).

There is, in addition, a particular advantage to entering into a poem-writing space. The practice of creating and reading poetry can slow us down for a moment amid the physically, mentally, and emotionally demanding work of conservation. It can suspend our analytical minds, allowing our affective and associative minds to make creative leaps from the concrete to the metaphorical (Wuppuluri & Grayling, 2022). It can make space for new ideas and insights, connect us to ourselves and each other and to nature, and expand our resilience as conservation practitioners. If the idea of writing poetry gives you pause, check out Box 1 for some poetry myth-busting. Otherwise, jump right into the activities.

Box 1: Poetry myth-busting

If poetry gives you pause, fear not! Poetry writing is teachable and learnable, and anyone can do it. In fact, the prompts that follow are especially designed to make it easy. You might wish to review the myths listed in this box to convince yourself that they are not true.

- Poems arise spontaneously.
  Not so. Good news: Good poems do not spontaneously generate. They are the result of observation and reflection, two things that scientists already know how to do, followed by revision—which scientists also know how to do.

- Poems are only about beautiful things.
  Not so. Good news: Poems can be about anything, including pollution, habitat loss, extinction, and more. They can be uplifting or despairing, funny or wry, angry or happy, or any combination of those and more.

- Poems are always profound and incomprehensible.
  Not so. Good news: Poems can run the gamut from humorous to deep, from simple to layered, from concrete to abstract. They do not need to measure up to centuries of literary canon.

- Poems are always flowery.
  Not so. Good news: Poems can be written in everyday language. They do not have to use big words or classic contractions (o'er, oft, 'twas, ne'er).

- Poems have to follow a form.
  Not so. Good news: Poems don't need to follow established poetic forms. Forms can provide fun constraints (e.g., cento, ghazal, haiku, pantoum, sestina, sonnet, villanelle), but the poetry activities here are designed to be written in plain language (also called free verse). Free-verse poems can be broken into stanzas of several lines (i.e., sections, similar to verses in a song) but there are no requirements. Whatever form emerges from your creative thought process is the poem that you should write.

- Poems need structured meter and rhyme.
  Not so. Good news: Poems don't need a formal meter or rhyming scheme. Free-verse may contain rhyming or partially rhyming elements, but there are no requirements to do so.

- Revising poems kills their spirit.
  Not so. Good news: Your poem improves with editing by you and others. The most impactful first-pass edit is often to cut out unnecessary words so the poem explains less, leaving more to the reader's imagination.

- Analyzing poems kills their spirit.
  Not so. Good news. The more poems you read and analyze, the more deeply you will understand them, the more poem ideas you will have, and the more effective your poems will become as you learn more elements of the craft.

PART 1: EXPERIMENTING WITH POETRY-SCIENCE

Guidelines

Below are three conservation poem writing activities. To skip over the writer's block that a blank page can sometimes induce, all three start from other texts or images. In the first two activities your job is simply to find the words you want to use to create a poem. In the third one, you do some prose writing and then find in your own work the words you want to use to create a poem. The resulting poems can be of any length and format. For these activities, we encourage you to write in free verse, which is unstructured, everyday language, as opposed to trying to meet the stringent requirements of metered poetry that follows formal rhythms and rhyming patterns.

Each of these activities is expected to take approximately 35 minutes to complete. Allow additional time to share your poems with each other, and to discuss the experience of creating them. We recommend you try the activities in order, as they build from one to the next, but you can choose to start anywhere.

Activity 1: Explore Through a Found Poem

Explanation

A found poem is a poetic technique that takes words and fragments from another source text to use as a vocabulary for a poem. In this situation, the poet is limited by the words in the chosen text, and has to creatively make new meaning from them. In doing so, you might find yourself playing with definitions, connotations, or combining fragments into new words. Using words from other sources to create your own poem is not copying or plagiarizing as long as you clearly indicate the source text(s).

Examples

The first example of a found poem ('Cooper's Hawk Identification') makes use of the close attention and descriptive language found in a field guide. The second ('Cheetah Context') highlights the findings of a conservation study reported in a peer-reviewed scientific article. The third ('DATA COLLECTION') uses the power of imperative language often found in scientific protocols. Click on the links to view the source materials and see how the poems were created from the original texts.

Cooper's Hawk Identification

Iris changes from
Whitish-gray in young nestlings
To clear yellow of intensity in fledgling,
Thence through orange
To red adults.

Of the head, in profile,
The curve of bill follows,
For a seamless interface,
Unlike the jutting
Sharp-shinned Hawk.

Plumage brown with random white.
Chestnut feather edges that fade.
Streaks, few crossbars

Crown ranges charcoal to black.
Tails of adults are less graduated,
Rectrices tipped in fresh plumage.
Individuals raise their hackles
(Nape feathers)
Resulting in a different shape
And exposing white feathers.

– Joelle Cook
Found poem based on "Field Identification - Cooper's Hawk," Birds of the World, Cornell Lab of Ornithology: https://birdsoftheworld.org/bow/species/coohaw/cur/introduction

Cheetah context

Apex predator facing
lethal persecution and
bush encroachment in
encompassing matrix.

Indexed by step length,
small prey remained
constant whereas
large prey declined.

Cheetahs appeared
flexible at the interface
between environment
and history.

– Marjorie Wonham
Found poem based on the abstract of the article "Rewilding landscapes with apex predators: cheetah (*Acinonyx jubatus*) movements reveal the importance of environmental and individual contexts": https://doi.org/10.3389/fcosc.2024.1351366

DATA COLLECTION

Begin with delineating the
best available representation
of interest. Within reach, kick

immediately upstream of a
non-truncated net. Truncated
nets are not recommended.

Flow toward the net. Avoid
disturbing upstream except
for a reason. Avoid crosscurrents.

Be cognizant of invertebrate
drift. Be very close without
being in the same location.

Riffle, run slow, flow deep.

– Marjorie Wonham.
Found poem based on "Data Collection" in Macroinvertebrate Monitoring, Pennsylvania Department of Environmental Protection Office of Water Programs Bureau of Clean Water Water Quality Monitoring Protocols for Surface Waters 2023, pp. 3-4–3-5.

Process

(Times are given for a 35-minute activity.)

1. Slowly read the source text your instructor has provided for you. Re-read it a few times, to get a new sense of the argument, tone, vocabulary, and other choices of the author with each reading. Sit with the ideas that come to you as you read the work and consider possible connections to other course content or your own experiences. (10 minutes)
2. Highlight, circle, or mark potent words and strong phrases. Notice how these pieces of the writing make you feel and what they remind you of. Consider how they might fit together on their own, outside the context of the original text. (10 minutes)
3. Copy out the words you want to use in your poem. You may choose to preserve the original word order, or reorder the words to fit the needs of your poem. (5 minutes)
4. Go back and forth between the source text and your emerging poem to add or remove words. Adjust syntax and punctuation as needed. (10 minutes)
5. Add a complete attribution to the source text(s) at the top or bottom of your poem.

Reflection and Discussion

Engage in a think-pair-share discussion about creating your found poem (10–30 minutes).
1. Think: Consider the questions below and jot down answers to each one.
2. Pair: Trade notes about some of your responses with your neighbor. Be curious, ask questions.
3. Share: Contribute your thoughts to larger group discussion.

Reflection questions. In writing your found poem:
1. What did you learn about your conservation subject?
2. What surprised you most about creating your found poem?
3. What did you enjoy most about creating your found poem?
4. What sorts of emotions did you notice while creating your poem?
5. How did your understanding of your subject change as you wrote?
6. Did any questions arise that you want to go and look up answers to?
7. When you read/heard others' poems, what did you like, and why?
8. What kind of found-poem source text would you like to use next?

Activity 2: React Through an Erasure Poem

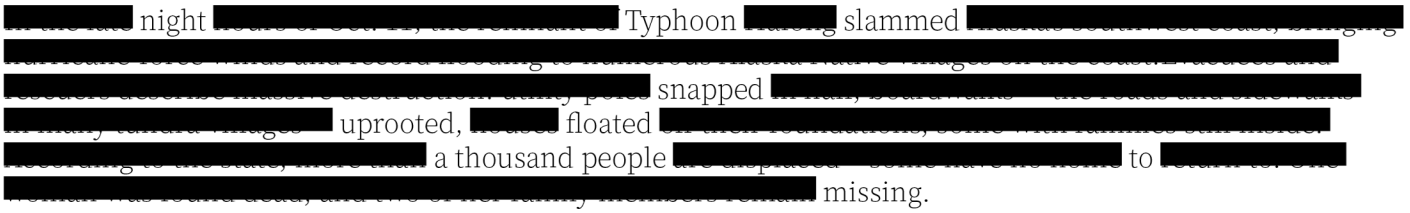
Explanation

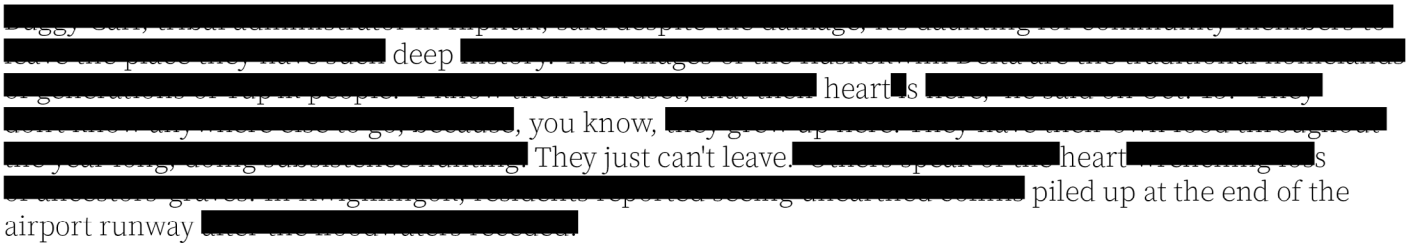
The process of creating an erasure poem is a mirror image of creating a found poem. While found poems pull words from a text and place them into new contexts, erasure poems select pieces of a text to remain in place while the rest of the text is crossed out, creating a work of both words and visual art. Erasure poems work very well for texts that are particularly emotionally heavy, prompting feelings of anger, fear, or despair. The technique can be used to emphasize the darkness of a story, to highlight bright spots in an otherwise dark story, or to subvert, critique, or alter the meaning of a text that conveys a message with which you disagree.

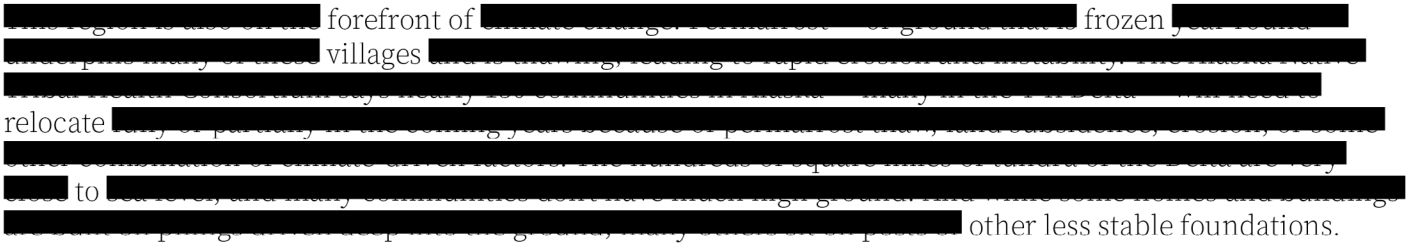
Some poets and scholars use the term "erasure" for any works that obscure or remove sections of an original (usually black-on-white) text—whether by erasing (whiteout), darkening (blackout), blocking (with objects), decorating (with colors, drawings), or excising (with scissors). Some reject the term "erasure" on the basis of its colonial connotations while others embrace it as empowering for the same reason. Some consider "blackout" an inherently political technique and genre distinct from erasure. Here we use "erasure" for any poem that obscures parts of the original text, and "blackout" for the particular method of doing so with a black marker on a white page.

Examples

The first example ('Night Typhoon'), based on a news report of a typhoon's impact, uses the blackout technique to reinforce the emotional impact of the event. The second ('Announced') does the same while also changing the meaning of the text. Both examples are shown with black bars covering the underlying text.







Night Typhoon

Slammed snapped
uprooted floated
a thousand people
to missing.

Hearts piled up
at the end of
the airport runway.

Forefront of frozen,
villages relocate
to other less stable
foundations.

Deep hearts, you know,
they just can't leave.

– Marjorie Wonham
Erasure poem based on the NPR news article "What we know about the devastating storm in Western Alaska:" https://www.npr.org/2025/10/17/nx-s1-5577974/typhoon-halong-western-alaska-villages-damaged-yukon-kuskokwim-delta.

[redacted] announced [redacted] greatest [redacted] most consequential day [redacted] most momentous [redacted]

[redacted] dagger [redacted] drive down [redacted] living [redacted] America [redacted]

[redacted] promise [redacted]

[redacted] trillions [redacted] to [redacted] manufacturing [redacted] communities while individual [redacted]

[redacted] American [redacted] reconsider [redacted] suffocate [redacted].

Announced

Greatest most
consequential day

most momentous
dagger. Drive down

living America.
Promise to unleash

trillions to man-
ufacturing while

individual Americans
reconsider, suffocate.

– Marjorie Wonham
Erasure poem based on the US EPA announcement "EPA Launches Biggest Deregulatory Action in U.S. History:" https://www.epa.gov/newsreleases/epa-launches-biggest-deregulatory-action-us-history.

Process

(Times are given for a 35-minute activity.)

1. Slowly read the source text your instructor has provided for you. Re-read it a few times to get a new sense of the argument, tone, vocabulary, and other choices of the author with each reading. Sit with the emotions and ideas that come to you as you read the work and consider whether you want to amplify or alter the meaning of the original text. (10 minutes)
2. Using a pencil, gently cross out the words you don't want in your poem. Notice how these pieces of writing make you feel and what they remind you of. Notice the words that remain and consider how they might fit together on their own, outside the context of the original text. (10 minutes)
3. Go back and forth between the source text and your emerging poem to cross out or restore words as needed. See how meanings vanish and appear as you change your selection. (10 minutes)
4. Finally, with a thick black marker, cross out the words you don't want and let your poem emerge onto the page. Keep this text, also and copy your poem below it to compare the effect of the spatial blackout version and the regular text version. (5 minutes)

Reflection and Discussion

Engage in a think-pair-share discussion about creating your erasure poem (10–30 minutes).
1. Think: Consider the questions below and jot down answers to each one.
2. Pair: Trade notes about some of your responses with your neighbor. Be curious, ask questions.
3. Share: Contribute your thoughts to larger group discussion.

Reflection questions. In writing your erasure poem:
1. What did you learn about your conservation subject?
2. What surprised you most about creating your erasure poem?
3. What did you enjoy most about creating your erasure poem?

4. What sort of emotions did you notice while creating your poem?
5. How did your poem amplify or subvert the message of the original?
6. Did any questions arise that you want to go and look up answers to?
7. When you saw/heard others' poems, what did you like, and why?
8. What kind of erasure-poem source text would you like to use next?

Activity 3: Build Connection Through an Ekphrastic Poem

Explanation

Ekphrastic writing is a well-known genre with origins stretching back to ancient times. Classically, it referred to describing anything in vivid detail. Today, it refers mostly to written description about and reflection on a piece of visual art. Here we are combining elements of these usages to mean a vivid description of something (not only visual art) and a reflection on it. This is a two-part exercise, each with two parts. First, you write a close prose description of something (only describe what you see or sense!), and then you write what it made you think, imagine, remember, or reflect on. Second, you treat each section of the prose you just wrote as a source text in which to find the words of a poem. To start, aim for two stanzas: the first to describe your subject and the second to reflect on what it prompted you to consider. (A stanza in poetry is similar to a verse in a song: it's a spatially distinct section of text separated by a blank line.)

Creating this two-stanza structure will lead you to discover one of the most powerful devices in poetry: the turn (see Theune, 2007). A turn is where a poem shifts gears—in its tone, meaning, topic, or direction—in a way that may initially be surprising but ultimately makes sense. (Not unlike a U-turn when driving!) A good turn gives the reader a fun puzzle to figure out, in a "Whoa, wait, what? Ohhh, I get it…, that's cool!" kind of way. Whether a turn is more gentle or abrupt, the surprise factor gives the poem zhuzh, energy, and additional layers of meaning. A turn is not unique to ekphrastic poetry, and ekphrastic poetry does not require a turn, but a poem with one observation stanza and one reflection stanza ends up with a natural turn in the space between the two stanzas.

Examples

The first ekphrastic poem example ('Shrimp Anatomy Lesson') was written by an artist-poet while observing the dock shrimp *Pandalus danae* (Figure 2), a fishery species managed on the West coasts of Canada and the U.S.A. The second ('Leafy Sea Dragon') was written by a visual artist and poet about the leafy sea dragon *Phycodurus eques* (Figure 3), a protected species in its native Australia. Both poems alternate between description and reflection. Compare each poem to the image of the species. Consider the description sections of the poem: which features of the species are described? Consider the reflection sections of each poem (highlighted): how did the author leap from their observations to their reflections?

Shrimp Anatomy Lesson

A streamlined fuselage, plated in glass,
Gives rise to spindly legs and underwater whiskers.
Down the back of the shrimp
Are streaks of amber brown
Against a blue-tinged hull,
Yellow in places that let the light in.

Is there a back to a being
That does not have a backbone?
The feathery paddles underneath and
Opposite the ball bearing eyes spin like
Flowery pedals, rhythmic as bicycle spokes.
The shrimp glides through the water
On its own merit, gravity-freed.

What need do they have of anything
Besides towards and away?
We are being defined relative to
The things we need and
The things we fear.

– Joelle Cook

Leafy Sea Dragon

in the creasing light
she pulls ornate paddles
through tangle of weed
are they a burden?
yet, how could that be—

her leaves are dappled purple
to mirror the kelp folds
and her back meanders like a river

the canopy sways under ocean winds
stirring her tail and heavy with boughs
fins drift into arbours

bony abdomen patterned gold with ripples
and the shadow of ripples, as if
something was passing over her

her dragon mind fronds with the seaforest—
limbed leafed gilded

– Sophie Finlay
Reprinted with author's permission from "Toward a littoral poetics:" https://doi.org/10.52086/001c.155454.

Process

(Times are given for a 35-minute activity.)

1. Select from the images, items, or places your instructor has provided for you. Examine your selection closely.



Figure 2: Dock shrimp, *Pandalus danae*. Image credit: Gregory C. Jensen, University of Washington.



Figure 3: Leafy Sea Dragon, *Phycodurus eques*. Image credit: James Rosindell, via Wikimedia/CC 4.0

2. Free-write* continuously on what it is that you notice while studying your chosen subject. (10 minutes)
3. Use all of your senses, as much as you can. Ask yourself: What do you see? What do you hear, smell, touch?
4. Resist the temptation to interpret, speculate, or reflect: make yourself only describe what you experience directly through your senses. Consider shapes, colors, textures, sizes, arrangements, light, shadow, etc.

*Free-writing means you don't stop writing! Set a timer, and keep your pen on the page, or your fingers on the keys. Don't delete or edit anything: if you want to change what you've written just start writing your new ideas. Don't wait for the perfect words or phrases to come to you: just keep describing what you see and sense. If you get stuck, write that you are stuck and then write what you should examine next and then keep writing as you examine that.

Example: Here is a free-write passage observing a red-winged blackbird

> Long and dark, but also rounded, with the tail coming out as a sash from a tapering of the wings. Black as shadows, then with a flash of hibiscus red. Astute brown eyes. A beak sharply pointed. One could tell this bird from beak alone, because nothing else has a shape like that. Usually pictured with mouth wide open in song, and when I see that picture I can hear that song in my mind. It is the sound of the marsh, the melody of the cattails. Feathers puff and ruffle in anticipation of flight. The head pulls in and the silhouette changes. You look ready for snow, bracing yourself to stand out against the white. Boldness is a pastime that suits you. You will not be mistaken for anything else. *Agelaius phoeniceus* means gregarious and red-crimson. Slide down a branch like it's a skate rail to show off your moves, get the audience ready for your performance. Shoulders flash in high contrast. Way to steal the spotlight. A dark bird that does not stick to the shadows.

5. Free-write continuously on what you notice in yourself as you consider your subject. (10 minutes) Ask yourself:
   a. What emotions arise from this close study?
   b. What does this subject make you imagine?
   c. What kinds of memories does it stir?
   d. What else does it make you wonder about?
   e. If you were this image/item/place, what would you be thinking about?

Example: Here is a free-write passage reflecting on the same bird:

> You were my dad's favorite bird. Everyone has a bird. And here I sit, knowing too much about all of them to ever pick a side. I wonder why the red-winged blackbird was his favorite. I like them as a bird, but what made him choose them? What parts did he relate to? It is nice when your inheritance is birds. I like having something in the wild to see and remember my dad. Was it the song? I like the song, but the birding consensus is that the screeching is annoying. It's beautiful, though. It's like nothing else. So full of personality and sharp, too. There is clarity to that call that I do not hear in many things. Something about the forwardness of red-winged blackbirds and the vibrant nature of their feathers makes me think they are confrontational. Further research reveals that the epaulets are for defending their territory. Like, this is my terr-i-toRRRRRRRRRYYY. Shoulders swung out, like a guy flexing the impressive results of a life lived at the gym. You could live a quiet life, if only the world wasn't constantly testing your boundaries. Is that what it is? Is the song of the marsh a hand on the hilt of a blade?

6. Now, reread your two pieces of writing, descriptive and reflective. Circle potent or interesting words and phrases. Notice themes that stand out in each piece, and themes that might connect the two pieces. (5 minutes)
7. Treat your writing as a source for a found poem. Select the words from the first piece to create the description stanza of your poem. Select words from the second piece to create the reflection

stanza of your poem. Go back and forth as needed to fine-tune your selection. (10 minutes)
8. Reflection and Discussion: See Part 2.

Example: Here is a poem "found" in the free-write passages above:

The tail comes as a sweeping sash
Out from the tapering of wings
Black as shadows, then with a flash:
Hibiscus red, and a chorus to sing.

One could tell this bird
From shape of beak alone:
The sharp ends self-assured
Open wide in the marsh's song.

You were my dad's favorite bird.
Each time I see you I wonder at that.
It is nice when my inheritance is a bird.
There is clarity in that screeching call.

Something about the forwardness
The sharp and vibrant feathers feels
Confrontational, bold and fearless.
Epaulets defend territory, research reveals.

Reflection and Discussion

Engage in a think-pair-share discussion about creating your ekphrastic poem. (10–30 minutes)
1. Think: Consider the questions below and jot down answers to each one.
2. Pair: Trade notes about some of your responses with your neighbor. Be curious, ask questions.
3. Share: Contribute your thoughts to larger group discussion.

Reflection questions. In writing your ekphrastic poem:
1. What did you learn about your conservation subject?
2. What surprised you most about creating your ekphrastic poem?
3. What did you enjoy most about creating your ekphrastic poem?
4. What sorts of emotions did you notice while creating your poem?
5. What are some insights, ideas, or connections that you made?
6. How did your understanding of your subject change as you wrote?
7. Where did your poem turn, and how?
8. When you read/heard others' poems, what did you like, and why?
9. What kind of ekphrastic poem source material would you like to use next?
10. Which of the three poem prompts was your favorite and why?

PART 2: SHARING & FEEDBACK (EXTENDED)

If time permits, pause after writing and reflecting on the process of creating each type of poem—found, erasure, ekphrastic. Share your poems following the prompts below, either after each one

or after you have created all three types. Remember that you all created your poems in a short time period and perhaps many of you wrote poems for the first time! So enjoy listening to, and reading each other's work, knowing that these are all preliminary first drafts. Good poems take revision and editing, which you may choose to do on your own later.

Instructions

Depending on space and time available (suggested time: 10–30 minutes), and the size of your group:

1. Take turns reading your poems aloud.
2. Post your poems on the wall and walk around your poetry gallery to read them.
3. Post your poems to an online class repository.
4. Exchange feedback on each other's poems:
    a. Which parts of the poem are the most powerful, and why? (Perhaps they use particularly compelling words and imagery, or an interesting turn.)
    b. Which parts of the poem are the least powerful, and why? (Perhaps they are overly wordy, unclear, or use bland words that could be replaced.)
    c. Which parts of the poem best interpret or re-interpret the conservation meaning of the source text(s)?
    d. Which parts of the poem miss or confound important conservation meaning?
5. Consider the feedback from others with openness and curiosity, and revise your poem(s) based on their input and your goals.

CONCLUSION

Congratulations, you have just created at least three new conservation-science poems! To do so, you read and observed conservation materials closely, considered their impact on you, sparked your curiosity, creativity, and critical thinking, and communicated your ideas. How did these activities affect your understanding of course content and concepts? How did the process compare to the process of doing science? What similarities and differences did you encounter? Viewing science through a poetry lens helps challenge existing thought structures, making you a more versatile and nimble conservation biology thinker. The resources below introduce you to some exciting and useful conservation-poetry resources for further reading and writing. What area of science-arts overlap would you like to explore next?

RESOURCES AND WRITINGS

These resources are selected for their conservation-biology content, for being written in or translated into English, and (as many as possible) for being readily accessible online. A broader selection of general biology-poetry resources is also available in Wonham & Wasson (2025).

Some Conservation-Related Poetry Collections & Anthologies

Some of these collections and anthologies are entirely focused on conservation issues; others include conservation-related poems as part of a broader selection.

- Anand, Madhur. (2015). A New Index For Predicting Catastrophes. McLelland and Stewart.
- Brown, Nickole & Erin Coughlin Hollowell, Eds. (2023). The More-Than-Human World. About Place Journal VII: IV.
- Cook, Stuart. (2019). Lyre. University of Western Australia Press.
- Day, Lucille Lang & Ruth Nolan, Eds. (2018). Fire and Rain: Ecopoetry of California. Scarlet Tanager Books.

- Deming, Alison Hawthorne. (1997). The Monarchs. Louisiana State University Press.
- Dungy, Camille, Ed. (2009). Black Nature: Four Centuries of African American Nature Poetry. University of Georgia Press.
- Gorman, Amelia. (2021). Field Guide to Invasive Species of Minnesota: Poems. Interstellar Flight Press.
- Hahn, Kimiko. (2010). Toxic Flora. W. W. Norton, Kindle edition.
- Igloria, Luisa A., Aileen Cassinetto, and David Hassler, Eds. (2025). The Nature of Our Times: Poems on America's Lands, Waters, Wildlife, and Other Natural Wonders. Paloma Press.
- Kondrich, Christopher, Spelman, Lucy, Tacent, Susan, Eds. (2024). Creature Needs: Writers Respond to the Science of Animal Conservation. University of Minnesota Press. [discussion and teaching guide online: https://dhjhkxawhe8q4.cloudfront.net/minup-wp/wp-content/uploads/2025/04/18133824/Kondrich_disc_guide.pdf]
- Limón, Ada., Ed. (2024). You are Here: Poetry in the Natural World. Milkweed Press, with the Library of Congress.
- Magrane, Eric, & Christopher Cokinos, Eds. (2016). The Sonoran Desert: A Literary Field Guide. University of Arizona Press. [poems also available online: https://spiralorb.net/poeticinventory.html]
- Martin, David. (2018). Tar Swan. NeWest Press.
- Mohabir, Rajiv. (2023). Whale Aria. Four Way Books. [listen to reading: https://www.youtube.com/watch?v=6fWbMDbOVaU]
- Okpik, dg nanouk (2012). Corpse Whale. University of Arizona Press.
- Preston, Jane, Ed. (2013). Poetry in Conservation: Poetry in Library and Zoo Collaborations. Poets House.
- Priest, Rena, Ed. (2023). I Sing the Salmon Home: Poems from Washington State. Empty Bowl.
- Roehl, Renee, and Kelly Chadwick, Eds. (2011). Decomposition: An Anthology of Fungi-Inspired Poems. Washington State University Press.
- Ryoichi, Wago (2018). Since Fukushima. Translated by Ayako Takahashi and Judy Halebsky. Vagabond Press.
- Santos Perez, Craig. (2019). Habitat Threshold. University of Chicago Press.
- Walsh, Michael, Ed. (2022). Queer Nature: A Poetry Anthology. Autumn House Press.

Some Online Conservation-Poetry Projects

- About Place Journal [literary-environment journal]: https://aboutplacejournal.org/
- Climate change science 2013: Haiku [by Gregory Johnson]: https://www.sightline.org/2018/12/05/climate-change-told-in-19-heartbreaking-haiku
- Consilience [science-poetry journal; some conservation]: https://www.consilience-journal.com/
- Emerge [interactive site for creating biology-themed erasure poems online; some conservation]: https://emergepoems.com/
- Extinction Elegies [endangered and extinct species]: https://redroompoetry.org/projects/extinction-elegies/
- Field/Nature Journaling [good tips for generating raw material for poems]: https://johnmuirlaws.com/
- The Nature of Our Times [a living anthology on America's nature]: https://natureofourtimes.poetsforscience.org/the-anthology/
- Poetry Foundation [searchable for conservation-related poems]: https://www.poetryfoundation.org/
  - Poetry and the Environment [Poetry Foundation collection]: https://www.poetryfoundation.org/collections/146462/poetry-and-the-environment
- The Poetry of Science [public art installation; features BIPOC contributors]: https://www.poetryofscience.org/

- The Poetry of Science Blog [blog featuring poems written in response to scientific research; some conservation]: https://thepoetryofscience.scienceblog.com/
- Poets for Science [collection of poetry-science projects; some conservation]: https://poetsforscience.org/
- Project Conservation Haiku: https://conservationhaiku.org/
- Science Write Now [a science-poetry journal; some conservation]: https://www.sciencewritenow.com/
- Sciku Project [scientific discoveries in haiku form]: https://thescikuproject.com/
- We are Mycelium [Poetry Society 2021 poem and lesson plan]: https://resources.poetrysociety.org.uk/wp-content/uploads/2022/12/About-Us-We-Are-Mycelium.pdf

Conservation-Focused Image Databases For Ekphrastic Poems

- Algae portraits: Josie Iselin (https://www.josieiselin.com/curious-world-of-seaweed-prints)
- Animal (and more) portraits: Susan Middleton (https://www.susanmiddleton.com/Susan_Middleton/Galleries/Galleries.html)
- Anthropogenic impacts: Edward Burtynsky (https://www.edwardburtynsky.com/home-page)
- Birds and more: Cornell Lab's Macaulay Library (https://www.macaulaylibrary.org/)
- Conservation: International League of Conservation Photographers (https://blog.conservationphotographers.org/views-from-the-photo-desk-endangered-species/)
- Ocean: Blue Planet Archive (https://www.blueplanetarchive.com/)
- Plants and algae: Burke Museum Herbarium Image Collection, UW (https://www.burkeherbarium.org/imagecollection/)
- Species at risk: PhotoArk (https://www.joelsartore.com/photo-ark/)

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Cuzzolino, M. P. (2021). " The Awe is In the Process ": The nature and impact of professional scientists' experiences of awe. Science Education, 105(4), 681–706. https://doi.org/10.1002/sce.21625

Finlay, S. (2026). Towards a littoral poetics. TEXT: Journal of Writing and Writing Courses, 30(Special 76), 2. https://doi.org/10.52086/001c.155454

Jiang, T., Hicks, J. A., Yuan, W., Yin, Y., Needy, L., & Vess, M. (2024). The unique nature and psychosocial implications of awe. Nature Reviews Psychology, 3(7), 475–488. https://doi.org/10.1038/s44159-024-00322-z

Kegan, R. (2009). What "form" transforms? A constructive-developmental approach to transformative learning. In K. Illeris (Ed.), Contemporary Theories of Learning (0 ed., pp. 35–52). Routledge. https://doi.org/10.4324/9780203870426

Mezirow, J. (2009). An Overview on Transformative Learning. In K. Illeris (Ed.), Contemporary Theories of Learning (0 ed., pp. 90–105). Routledge. https://doi.org/10.4324/9780203870426

Theune, M. (2007). Structure and Surprise: Engaging Poetic Turns. Teachers and Writers Collaborative. Companion online materials at https://structureandsurprise.com/

Wonham, M., & Wasson, C. (2025). Poetry prompts for biologists. The American Biology Teacher, 87(6), 354–358. https://doi.org/10.1525/abt.2025.87.6.354

Wonham, M., Wasson, C., Milky, U., & Hula, K. (2025). Six reasons to integrate arts and sciences in higher education. BioScience, 75(9), 695–698. https://doi.org/10.1093/biosci/biaf108

Wuppuluri, S., & Grayling, A. C. (Eds.). (2022). Metaphors and Analogies in Sciences and Humanities: Words and Worlds (Vol. 453). Springer International Publishing. https://doi.org/10.1007/978-3-030-90688-7

Sounds of the Tropics: How do Dolphins in Bocas del Toro, Panama Communicate in a Noisy Habitat?

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This case study is adapted from a three-part online interactive module published through OCELOTS (i.e., Online Content for Experiential Learning of Tropical Systems; ocelots.nrem.iastate.edu) on the open interactive learning platform Gala (learngala.com/catalog/libraries/ocelots) and QUEBSHub (ocelots.qubeshub.org/online-modules).

OCELOTS, originally funded by National Science Foundation's Research Coordination Networks in Undergraduate Biology Education Program, is an international network of tropical biologists, educators, media specialists, instructional designers, and software engineers exploring best practices in research-based modules for teaching tropical biology and conservation. For more information about OCELOTS, please see Russell et al. (2026). We encourage you to explore the full-versions of the "Sound of the Tropics" modules (which include interactive exercises, links to audio recordings, podcasts, and additional resources), other modules published in the OCELOTS library, and other libraries on Gala (learngala.com).

ABSTRACT

Detailed and long-term assessments of biodiversity are often limited by costly and labor-intensive survey methods. An innovative and cost-effective solution is to study the sounds of nature and the environment. This approach allows researchers to remotely study how individuals and populations interact with the environment with minimal intervention. Passive acoustic monitoring recorders in the field capture all sounds, i.e., the soundscape. Given that many aquatic and terrestrial animals emit species-specific sounds, we can use this information to study species distributions, behavior, population dynamics, community structure, and the impact of human activity. In this case, you will learn about the basics of sound, who makes sounds, and how we can turn sound into useful information for ecological and conservation studies. Then, you will be introduced to a specific study in Panama investigating how acoustic monitoring can uncover the impact of dolphin-watching boat activities and lead to conservation guidelines and recommendations.

PREFACE: THE SIGNAL IN THE NOISE

Imagine living in a world where your vision is limited to a few tens of meters, a world where you rely mostly on sound to figure out where you are, what to eat, who to partner with, and who out there might eat you. Now imagine having to do it all in a very noisy space! Sound plays a key role in the lives of marine mammals. Whales, including dolphins, have evolved sophisticated ways to use sound in conveying and extracting information from the environment and conspecifics (members of the same species). Most whales use echolocation signals to navigate, locate food, and detect predators, and all species have evolved a wide repertoire of social sounds for finding mates, coordinating group formation, and building alliances by identifying family groups and individuals.

Over the last 60 years, the acoustic space in which whales communicate has been changing. Man-made underwater noise from activities like shipping is increasing noise levels by 3.3 dB per decade.

Given the role that sound plays in the survival and reproduction of these animals, there are growing concerns about the interference of man-made noise, such as boat traffic, on whale communication and habitat quality.

Why should we care about the impact of boat traffic on dolphins? Dolphins are an integral part of marine ecosystems. They are top predators, and as such are important indicators of ecosystem health. They are also economically valuable. Dolphin-watching activities in Latin America are growing 3 times faster than in the rest of the world, providing coastal communities with an economic alternative to fishing.

In this case, we will introduce the basics of sound, who makes sounds, and how we can turn sound into useful information for ecological and conservation studies. Then, we dive deeper into a specific study case where we evaluate the status of a resident population of bottlenose dolphins in Bocas del Toro, Panama. These dolphins were saved from extraction (to supply dolphinariums) only to become the number one target of unregulated dolphin-watching activities in Panama. We will share the findings from an acoustic monitoring study about the impact of unregulated dolphin-watching boat activities and discuss a number of mitigation efforts. We end with specific recommendations for hands-on data-driven activities and additional multimedia resources to explore.

LEARNING OBJECTIVES

In this case study, students will:
1. Review the terminology of sound and concepts of acoustic monitoring.
2. Explore the diversity of sounds produced by animals.
3. Understand how researchers study soundscapes.
4. Learn how humans are modifying soundscapes around the world.
5. Recognize the importance of sound in dolphin societies.
6. Explore applications of acoustic ecology for tropical biodiversity conservation.

INTRODUCTION

Animals acquire information using their five senses (sight, smell, hearing, touch, and taste). Hearing and making sounds provide several advantages to animals trying to navigate their environment and communicate. Sound can transmit information at any time of day and travels fast in all directions. Sound also has low attenuation, meaning the power of the signal does not easily degrade. Animal species communicate using sounds in a variety of ecological and behavioral contexts, for example: to attract partners, defend their territories, maintain group cohesion, alert family members to potential predators, search for prey, and navigate. Sound is particularly useful for nocturnal or aquatic species that cannot rely on visual cues.

What Do We Need to Know About Sound?

Sound is a mechanical disturbance caused by a vibrating object. For example, a sound can be produced by forcing air through vocal cords, like in humans, or by rubbing two hard surfaces against each other, like the forewings in katydids or the tymbals in cicadas. Sound travels in waves, and its main characteristics are:

- Amplitude: the change in pressure by a sound wave at a specific location. High and low amplitudes are perceived as loud or soft sounds, respectively. Amplitude is measured in decibels (dB).
- Frequency: the number of sound waves repeated in (or cycles during) a period of time. Frequency is the inverse of wavelength and our perception of it is referred to as pitch. As the number of

cycles/time increases you get a higher pitch. For example, a sound with 12 cycles per second is perceived as a high pitch while a sound with 3 cycles per second will be perceived as a low pitch by us. Frequency is commonly measured in kilohertz (kHz), in which 1 kHz equals 1,000 cycles (or waves) per second.

To learn more about sound and sound characteristics visit Discovery of Sound in the Sea (see: https://dosits.org/).

The Range of Animal Sound Frequencies

Humans can only hear some of the sound frequencies animals use to communicate [20 Hz–20 kHz (Jacewicz, 2023); and examine Figure 1 to explore the range of hearing among different species—including humans]. Low-frequency sounds propagate longer distances than high-frequency sounds. This is particularly true in the ocean, where sounds below 1 kHz travel much farther than high-frequency sounds. For example, blue whales emit infrasonic (low) frequency sounds, and their calls can be heard by other whales 10–100s of kilometers away. In contrast, bats and dolphins use ultrasonic (high) frequency sounds (>20 kHz, above what humans can hear) to detect prey within relatively short distances (3–4 m in bats, 10–100s m in dolphins).

The Voices of Nature: Who Makes Sounds and Why?

Virtually all animal species make sounds, and they do so in a variety of ways, for a variety of reasons. A single species can produce different sounds depending on the context (e.g., trying to attract a mate, communicating with an infant or juvenile, or warning others of a predator). These calls are usually species-specific, which means that the frequency range, dominant frequency, duration, and pattern of sound production are unique to each species. Species-specific calls maximize communication within a species and avoid confusion between species. Below, some of the different sounds that different taxa make are described. You can find more resources—including links to example recordings—in the Appendix.

Insects

Insects emit sounds at a wide range of frequencies, including calling songs, advertisement calls, aggressive calls, and rivalry songs. The three major contexts of sound emission in insects are (a) female attraction, (b) male-male competition, and (c) female-male communication.

The mechanisms of sound production in insects include tremulation, percussion, stridulation, buckling, and expulsion of air. Among the loudest insects are the cicadas and water boatmen (Figure 2A & 2B). Some cicadas can emit sounds up to 150 dB, which is louder than a jet engine! Insects do not have to be large to produce loud sounds. Male water boatmen are small aquatic insects only 2 mm long, and a male can produce a courtship call up to 99 dB by stridulating a ridge of its penis across corrugations on its abdomen. Insects can also emit high-frequency sounds not audible to humans (> 20 kHz).

Fish

Fish emit a variety of 'soft' and low frequency (~1 kHz) sounds including grunts, moans, calls, and clicks. These sounds are associated with courtship and spawning, territoriality, and stress behaviors. Most sounds are produced by males to attract females. In many species, the males aggregate in spawning sites at night and call for hours.

The most common mechanisms of sound production in fish are stridulation and drumming. Fish

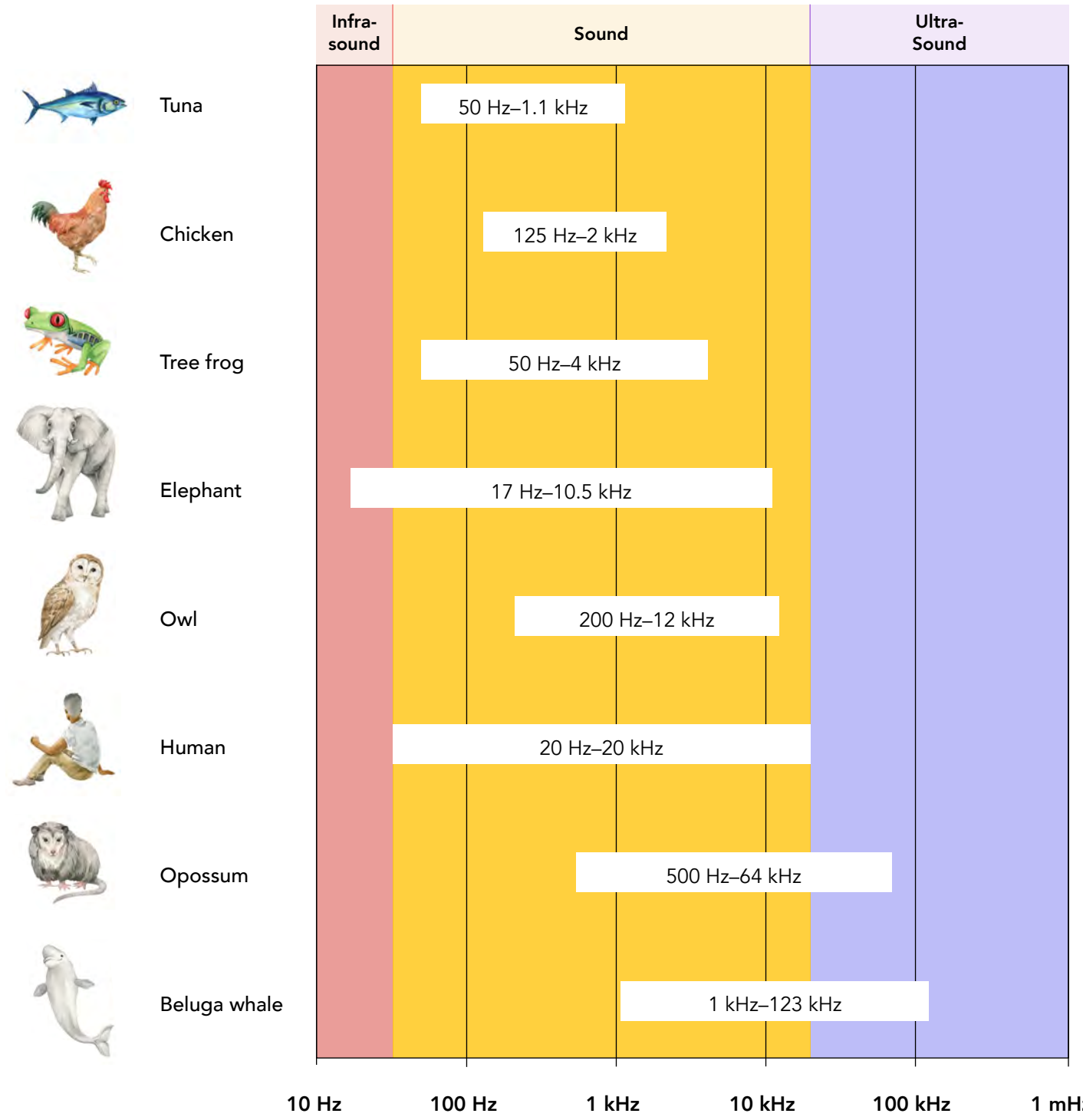


Figure 1. Examples of different animals' hearing range in log-linear plot. Colors in chart represent: Infrasound (red), Sound (yellow), and Ultrasound (purple). Figure: Nadav Gazit; Image credit: Adapted from "Animal hearing frequency range" by Cmglee via Wikimedia Commons/CC-BY-3.0; using Kate K watercolor sets, PYRAMIS "Watercolor Tuna fish", and anitapol "Young man sitting back view" via Adobe Stock Photo/Standard License.

stridulate by rubbing together their jaw or pharyngeal teeth, specialized spines (in catfish), or bony edges of the skull (in seahorses). Many fish have specialized sonic muscles that expand and contract the swim bladder to generate drumming sounds. These are the fastest contracting muscles known for vertebrates!

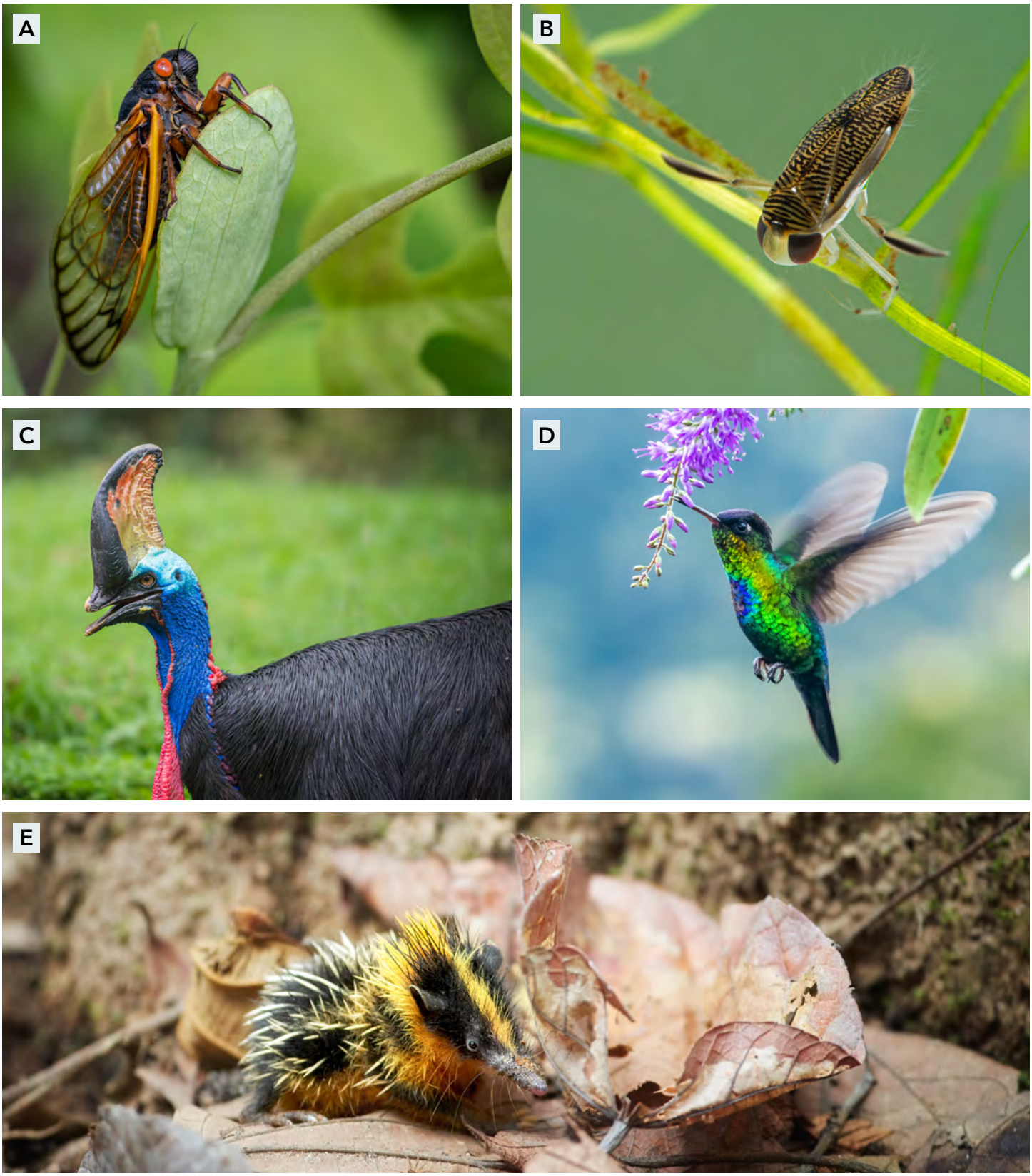


Figure 2. (A) A water boatman (family: Corixidae); (B) Pharaoh cicada (*Magicicada septendecim*); (C) Southern Cassowary Bird (*Casuarius casuarius*); (D) Green Violet-ear (*Colibri thalassinus*) hummingbird (E) Lowland streaked tenrec (*Hemicentetes semispinosus*). Image Credits (via Adobe Stock Photo/Standard License): (A) Ernie Cooper "P1010023 water boatman"; (B) Gary Riegel "A large red-eyed 17-year cicada"; (C) Krzysztof Wiktor "Southern Cassowary Bird"; (D) Vaclav "Green Violet-ear (*Colibri thalassinus*)"; (E) Martin Mecnarowski "Lowland streaked tenrec" via Adobe Stock Photo/ Standard License.

Birds

Birds are prodigious singers that emit simple and complex vocalizations. Sound production involves the lungs, air sacs, and the syrinx (an organ located at the junction of the trachea). Many species learn the calls from conspecifics, and a few species, like mockingbirds and lyrebirds, can also mimic the calls of other species. Many species of birds also emit distress and warning calls when a predator is nearby. Song/call frequency ranges from infrasonic (30 Hz) in Cassowaries (Figure 2C) to ~10 kHz in passerine species. Hummingbirds (Figure 2D) can produce high-frequency (~13 kHz) chirps when calling mates.

Amphibians

Amphibians are the singers of the night, although some species are diurnal and call during the daytime. Their calls are not as complex as those of birds, but they are persistent. Amphibians can call for hours with hardly a break.

Sound emission in amphibians involves the lungs, vocal cords, and vocal sacs (when present). In most species, males are the primary sound emitters, relaying information to females and competitors about their location, species identity, and readiness to mate. Their calls are often a chirp or a series of chirps with frequencies between 2 to 6 kHz. However, some species can emit calls with the ultrasonic range (above 20 kHz), for example, the concave-eared torrent frog (*Odorrana tormota*).

Mammals

Mammals use sound for close and long-range communication. They emit sound in a variety of contexts, including species and individual identification, advertisement of reproductive or social status, defense of territories, detection of predators, localization of prey, and social interactions.

Most sounds are generated with the larynx and vocal cords and range from 10 Hz to above 50 kHz. Exceptions are some bat species and the toothed whales, including dolphins. Bats use echolocation for navigating and hunting prey. They also produce sounds for social interactions. Because the sounds are in the ultrasonic range, recordings must be slowed down for humans to hear them. Toothed whales, like dolphins, can produce sounds above 100 kHz using specialized structures called phonic lips near their blowhole. Mammals can also produce non-vocal sounds for communication. For example, tenrecs (Figure 2E) rub quills on their backs generating a high-frequency sound, and some species of deers and bovids produce clicking or cracking sounds with their joints and knees as they walk.

Soundscapes: More Than a Collection of Sounds

What is a Soundscape?

A soundscape is a collection of all biological, geophysical, and anthropogenic sound sources that are present in a habitat (e.g., coral reef, seagrass, forest, grassland) at a given time (Figure 3).

- Geophysical sounds (geophony): made by weather and natural elements and includes rain, wind, thunder, and waves.
- Biological sounds (biophony): made by animals (described in the previous section).
- Anthropogenic sounds (anthropony): made by humans, and includes sounds generated by machines (e.g., cars, boats, generators, chainsaws, airplanes).

The integration of sounds from all these sources in one place is the soundscape (Pijanowski, Farina, et al., 2011; Pijanowski, Villanueva-Rivera, et al., 2011; Weidenabum, 2024).

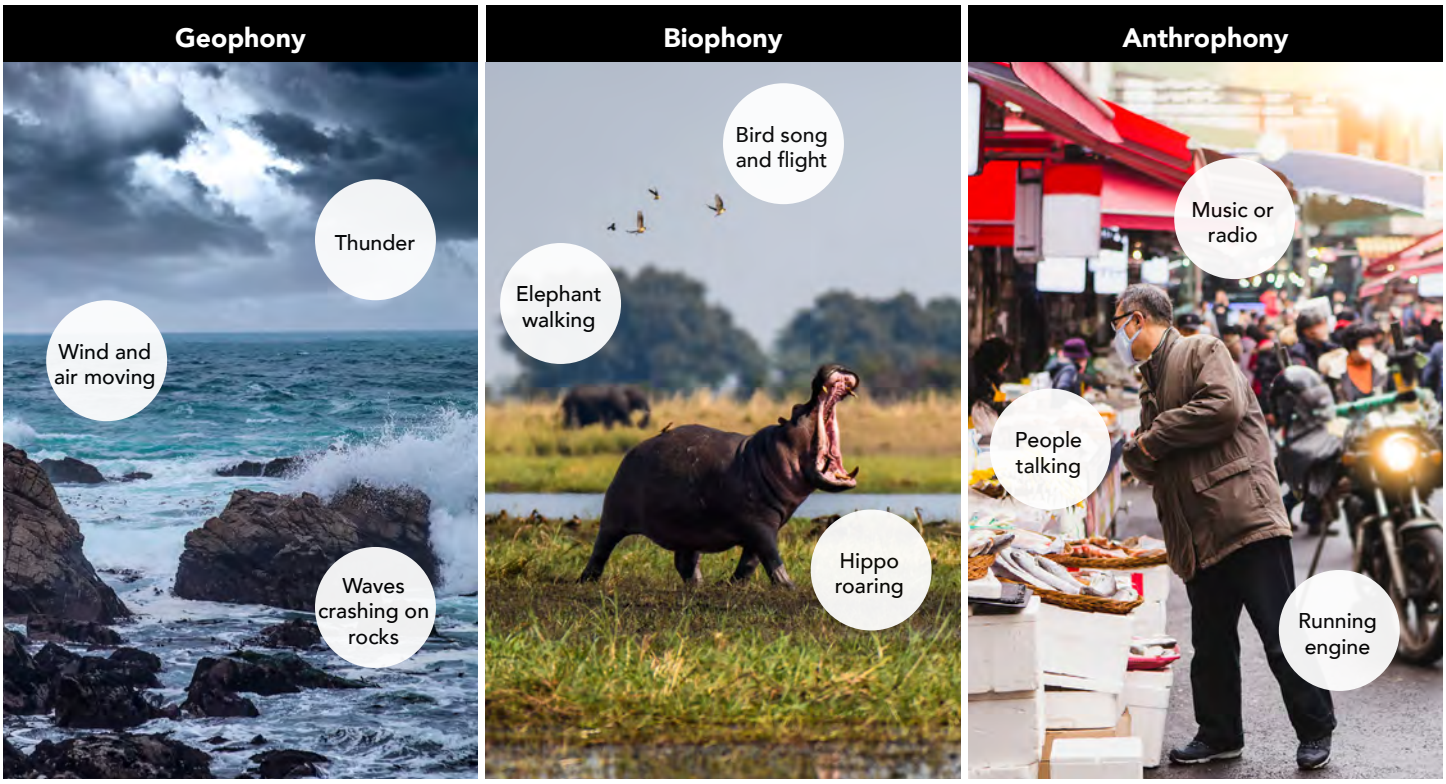


Figure 3. Examples of soundscapes: Geophony (Left), or geophysical sounds, can be exemplified by the sounds of waves crashing on rocks, wind and air movement, and thunder; Biophony (Center), or biological sounds, can be exemplified by the sounds made by hippos roaring or honks, elephants walking, and bird song or the sounds of their wings as they fly; and Anthropony (Right), or sounds made by humans, can be exemplified by the sounds of a busy market, from vendors and customers conversing, the sounds a vehicle's motor, or music being played by radio. Figure: Nadav Gazit; Image Credit: (Left) Innovated Captures "Foggy view of Pebble Beach;" (Middle) knelson20 "Hippo, with mouth wide open;" (Right) scharfsinn86 "Market in Asia" via Adobe Stock Photo/Standard License.

How do Scientists Analyze Soundscapes?

Soundscapes include a wealth of information that researchers and practitioners might want to study and analyze. However, even if a study focuses on the sounds of a single species, the audio recorder will capture many other sounds. An important challenge for researchers is to extract useful behavioral or ecological information from thousands of soundscape recordings.

There is not just one way to analyze soundscapes. As in all studies, the research questions (including objectives and hypotheses) guide the experimental design and analyses of soundscape studies. For example, it is important to recognize that soundscape dynamics vary greatly in time and space. Consider the Arctic Ocean: the main sounds contributing to the overall soundscape are ice melting (1–3 kHz), wind (0.5–2 kHz), walruses (0.2–4 kHz), bearded seals (0.35 and 1.2 kHz), and boats (0.1 and 0.7 kHz), but the contribution of these sounds varies between seasons (Latha et al., 2020). In the summer, the soundscape was dominated by the sound of wind, ice melting and cracking, while in the winter, the breeding calls of walrus and bearded seals were the most dominant.

One way to study soundscapes is to aggregate recordings by the time of day, month, or season and determine when different frequencies are being used (Aide et al., 2017). To measure acoustic space use (ASU), researchers may produce a 3D map of the soundscape, where the x-axis is time, the y-axis is the frequency, and the z-axis is the proportion of recordings occupying each time/frequency bin. By summing the time/frequency bins of the figure, they can calculate the ASU. This methodology

was used in Aide et al.'s (2017; Figure 4) comparative study of eight tropical forest sites in Central and South America, and the researchers found a positive correlation between ASU and bird species richness, meaning ASU can be used as an indirect measure of species richness. The researchers also found that insects were the most common source of sounds in these tropical soundscapes.

Navigating Noise

What Sounds are Considered Noise?

"Noise is any concurrent sound that obscures receipt of a sound signal by a receiver" (Bradbury & Vehrencamp, 2011). This obscuring of a sound signal is called "acoustic masking." Acoustic masking occurs when noise reduces an animal's ability to detect, process, or respond to a conspecific signal (Francis & Barber, 2013). For this to happen, the background noise and the animal's signal must overlap significantly in both frequency (pitch) and timing.

For many species, noise can be the call of another animal, as well as geophysical and anthropogenic sounds. For example, the loud, searing sounds of cicada are noise for the bird trying to call in the same frequency range. The severity of noise and its acoustic masking effects depend on the amplitude, frequency range, and whether it is continuous or intermittent.

Can Animals Adapt to Noise?

Animals are not defenseless against noise; many species are used to communicating in noisy environments. In a review of the effects of noise on invertebrates, Raboian and Elias (2019) showed

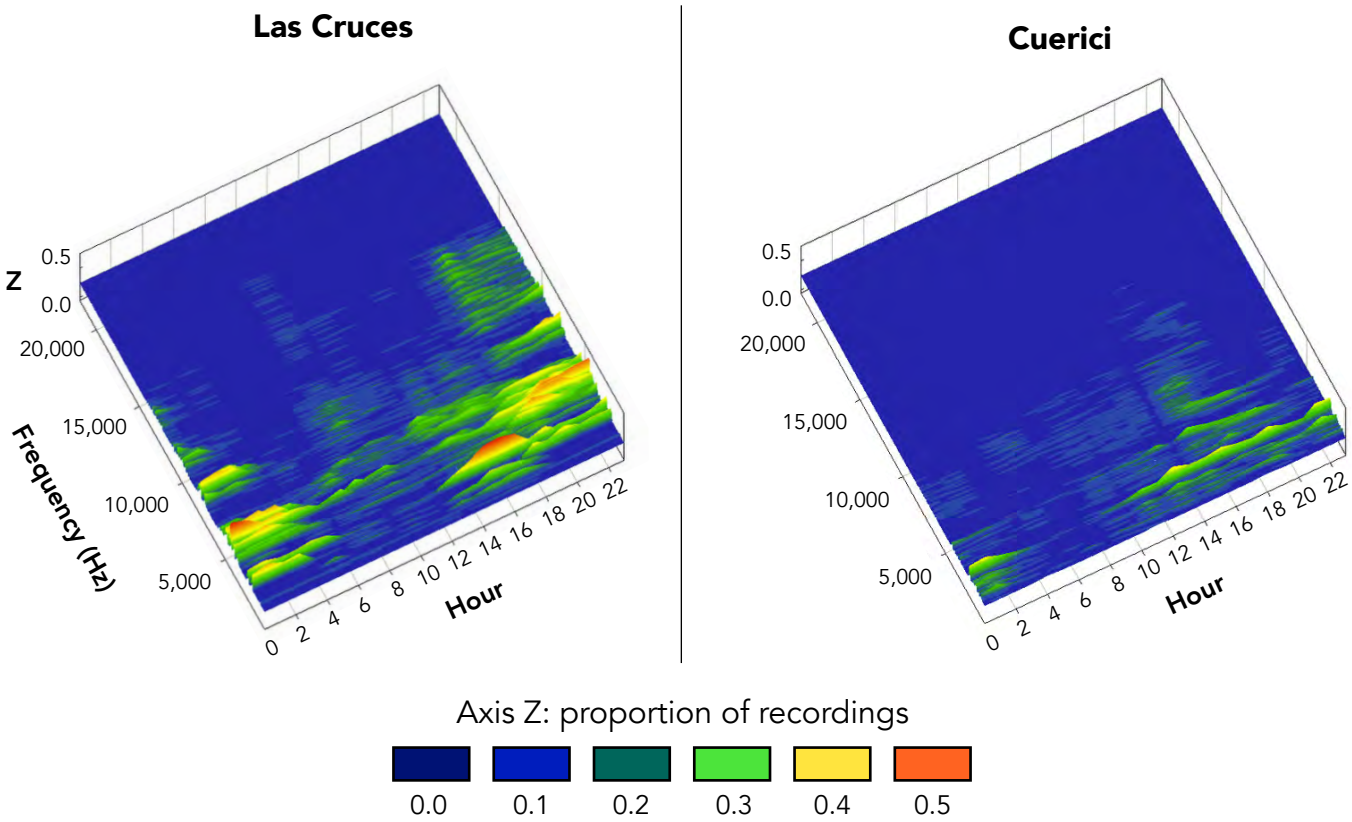


Figure 4. 3D maps of the soundscapes (including geophony, biophony, and anthrophony) of two forest sites in Costa Rica: Las Cruces (Left) and Cuerici (Right). Adapted from Aide, T.M.; Hernández-Serna, A.; Campos-Cerqueira, M.; Acevedo-Charry, O.; Deichmann, J.L. Species Richness (of Insects) Drives the Use of Acoustic Space in the Tropics. Remote Sens. 2017, 9, 1096. https://doi.org/10.3390/rs9111096

which characteristics of calls were most effective in the presence of noise. If the noise is intermittent, animals may limit acoustic communication when the noise is not present. Animals can also adapt to noise by changing the frequency and timing of their singing behavior to minimize the impact of acoustic masking.

Vocal communication can be energetically costly and may increase the risk of detection by predators and competitors. Therefore, it is important that calls are heard and detected by the intended receiver. In addition, vocalizing animals share their acoustic environment with conspecifics and other species, creating the potential for signal interference. To reduce acoustic overlap and masking, acoustically similar species may partition the soundscape by calling at the same frequency but at different times of the day, or by calling simultaneously at different frequencies.

This raises the question: do species compete for acoustic niche space[1]? If so, does this result in frequency partitioning? A study of marine organisms in the Hauraki Gulf in northeastern New Zealand (Putland et al., 2017) supports the hypothesis of frequency partitioning. Baleen whales used frequencies between 15 and 150 Hz, fish between 100 and 2000 Hz, urchins between 800 and 2500 Hz, and snapping shrimps and dolphins occupied the highest frequency bands between 2000 and >20,000 Hz.

Similar results were found in a community of frogs in Puerto Rico (Dewry & Rand, 1983). Even though the five most common species call at the same time of day, each species calls at a different frequency, which may help avoid confusion and improves intraspecies communication.

Anthropogenic Noise: How Does Human Activity Impact Soundscapes?

Beyond Biophony & Geophony

Geophysical and biological sources of noise (e.g., wind and other animals) can have ecological (real-time) and evolutionary (long-term) consequences. However, more and more animals are facing another source of noise: humans.

Humans produce noise in many forms and in virtually every habitat on earth. Noise from human sources (e.g., drilling, sonar, boat and car traffic) can have severe impacts on animals.

A Pervasive Global Pollutant

In 1999, the World Health Organization (WHO) declared, "worldwide, noise-induced hearing impairment is the most prevalent irreversible occupational hazard, and it is estimated that 120 million people worldwide have disabling hearing difficulties" (Berglund et al., 1999).

Noise pollution (e.g., excessive, persistent, disruptive noise) from human activities has many harmful effects on human health: it can affect sleep, increase stress, reduce performance, and change social behavior (WHO-Europe, 2021). Every day we all experience a variety of sounds in our living and working spaces. However, some are at higher risk for the negative effects of noise pollution. For example, a study showed that 90% of coal miners have a hearing impairment by the age of 52 (Chepesiuk, 2005).

[1]Acoustic niche space refers to the portion of the acoustic environment that could be occupied by a species to minimize overlap with other sound sources; the acoustic use space (as mentioned above) refers more to the actual acoustic space occupied by the species.

Noise pollution also impacts wildlife in both terrestrial and aquatic biomes. One study found that car traffic noise affects birds more than frogs because there is less traffic at night when frogs are active (Herrera-Montes and Aide, 2011). Noise is also a problem in the ocean (some examples of underwater sound sources are shown in Figure 5, along with the hearing and sound production ranges of low-, mid-, and high-frequency cetaceans for comparison). Due to an increase in ocean shipping, which is closely linked to the growing global economy (Frisk, 2012), anthropogenic ocean noise is increasing at a rate of ~3.3 dB per decade.

Anthropogenic Noise in Aquatic Ecosystems

Kunc et al. (2016) reviewed the literature on the impacts of noise pollution in the aquatic environment and the major findings were: human-produced noise had negative impacts on virtually all species. Noise affected different species in different ways, and the effects were diverse and include: hearing damage, developmental abnormalities, increased stress levels, and decreased mating success.

Researchers have also compared the effects of acute and chronic noise. For example, Masud et al. (2020) studied the susceptibility of guppies (*Gyrodactylus turnbulli*) to parasitic infections exposed to different acoustic environments (acute noise and chronic noise). The results: the guppies in the acute noise treatment had a significant increase in parasites and the guppies in the chronic noise treatment died sooner. Their conclusion is that any type of noise is detrimental to guppy health.

What Does the Impact of COVID-19 Shutdowns Reveal About the Impact of Humans on the Acoustic World?

Beginning in 2020, public health measures around the world attempted to reduce the spread of the novel coronavirus disease, COVID-19. Widespread shutdowns of travel and social and economic activity significantly changed human behavior, including the noise we produce.

In one study, Derryberry et al. (2020) compared the soundscape before and during the shutdowns across several urban areas, focusing on breeding areas for white-crowned sparrows. Motor vehicles emit high-energy and low-frequency sounds. Before the shutdown, urban sparrows that had to compete with car traffic noise sang three times louder than the same species in rural areas. During the shutdown, with much less traffic, urban sparrows sang more like rural sparrows—more softly and using lower frequencies.

Some regions of the world's oceans also became quieter during the shutdowns. In the Hauraki Gulf, New Zealand, ambient noise levels decreased by nearly threefold during COVID-19 lockdowns, increasing the communication ranges of dolphins and fish by as much as 65% (Pine et al., 2021). Similarly, lockdown-related reductions in vessel traffic were associated with increased vocal repertoire diversity in dolphins in Bocas del Toro, Panama (Gagne et al., 2021), as well as enhanced detection of humpback whale songs near Caño Island, Costa Rica (May-Collado et al., 2023). These effects were particularly evident in areas that are typically exposed to high levels of vessel traffic.

CASE STUDY: BOTTLENOSE DOLPHINS IN BOCAS DEL TORO, PANAMA

Introduction: How do Bottlenose Dolphins Communicate?

Being able to recognize your mom, relatives, friends, and allies is fundamentally important in a dolphin society, and dolphins do so with acoustic signals called signature whistles. Signature whistles are narrow-banded frequency-modulated sounds (the variation of the frequency of a given sound

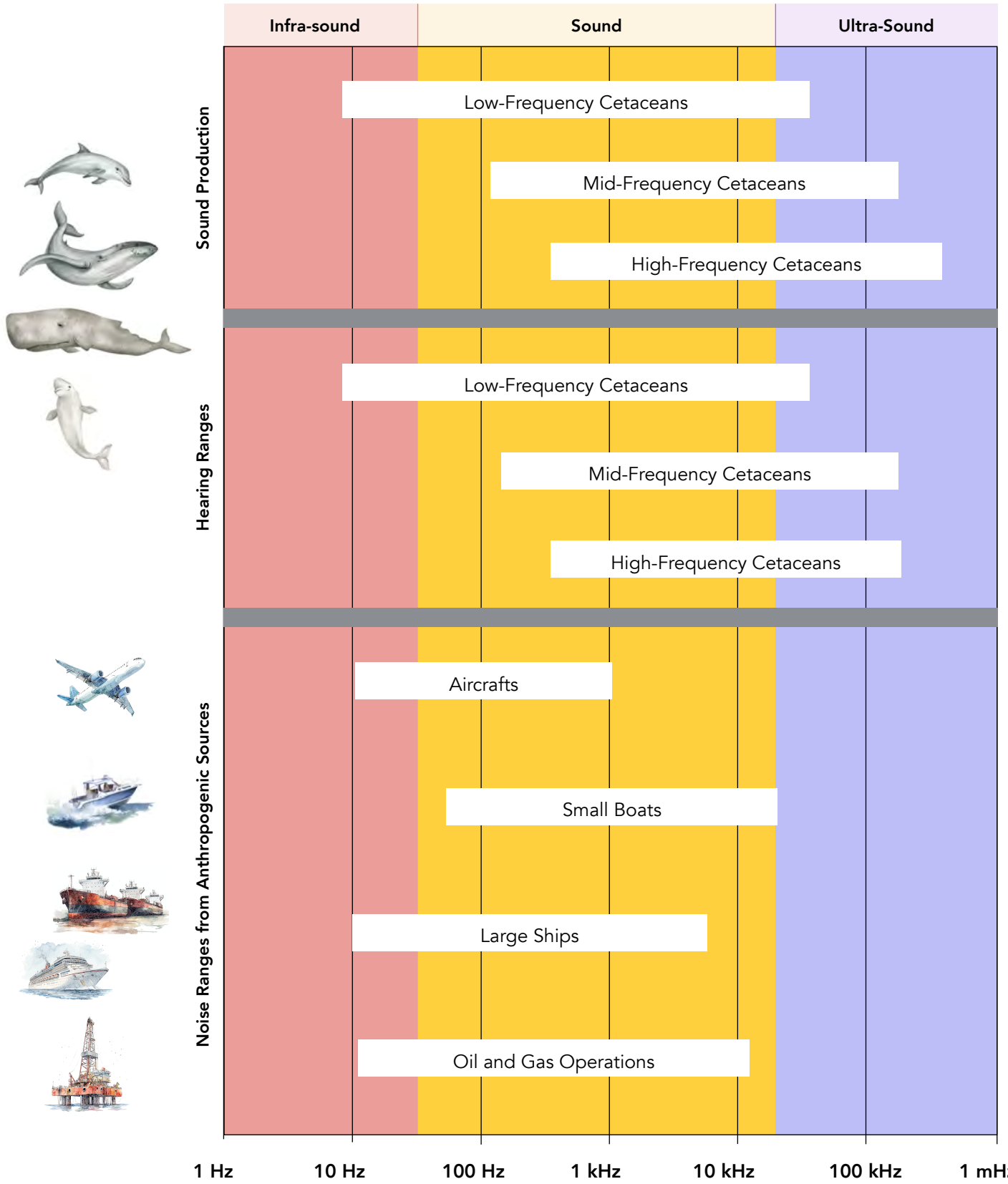


Figure 5. The sound production (Top) and hearing ranges (middle) of cetaceans and the noise ranges from different anthropogenic sources (bottom). Colors in the chart represent: infrasound (red), sound (yellow), and ultrasound (purple). Figure: Nadav Gazit; Image Credit Adapted from Duarte et al. 2021; using Kate K watercolor sets, Zizak "blue airplane painting," Tatiana "A speedboat," Hasan Art "Colorful cargo shipping," Tanvir Rana "Cruise Ship," AMIDCO "Drilling Equipment" via Adobe Stock Photo/Standard License.

wave) that are unique to each bottlenose dolphin and are used as contact calls when separated (Caldwell et al., 1990). Dolphins develop their signature whistles within days of being born, and once developed, the signal remains stable through life (Janik, 2009).

Males and females model their signature whistles using different sources. Male calves develop their signature whistles after their moms, while female calves use other group members' signature whistles as their template (Sayigh et al., 1995). In dolphin societies, female calves tend to stay with their mothers for several years (Figure 6), and therefore, having sufficiently different signature whistles is important to avoid misidentifications (Fripp et al., 2005). What is most fascinating about dolphin communication is their ability to mimic those with whom they interact the most (King et al., 2013). It is like calling your mom or a close friend by their name!

The Study Site, the Dolphins, and the Problem

The Study Site

The archipelago of Bocas del Toro is located on the Caribbean coast of Panama (Figure 7). The archipelago consists of shallow and clear waters less than 20m in depth with coral reefs, mangrove forests, and seagrass meadows surrounding several islands. The main mode of transportation between the mainland and the islands is by boat. There are three taxi-boat companies that run every 30 minutes each way between the mainland in Almirante and the archipelago from 6 a.m. to 6 p.m (blue dotted line in Figure 7).



Figure 6. Mother and calf bottlenose dolphins (*Tursiops truncatus*). Image Credit: Vkilikov "Pair (parent and child) wild bottlenose dolphins swimming in the deep blue sea near coral reef" via Adobe Stock Photo/Standard License.

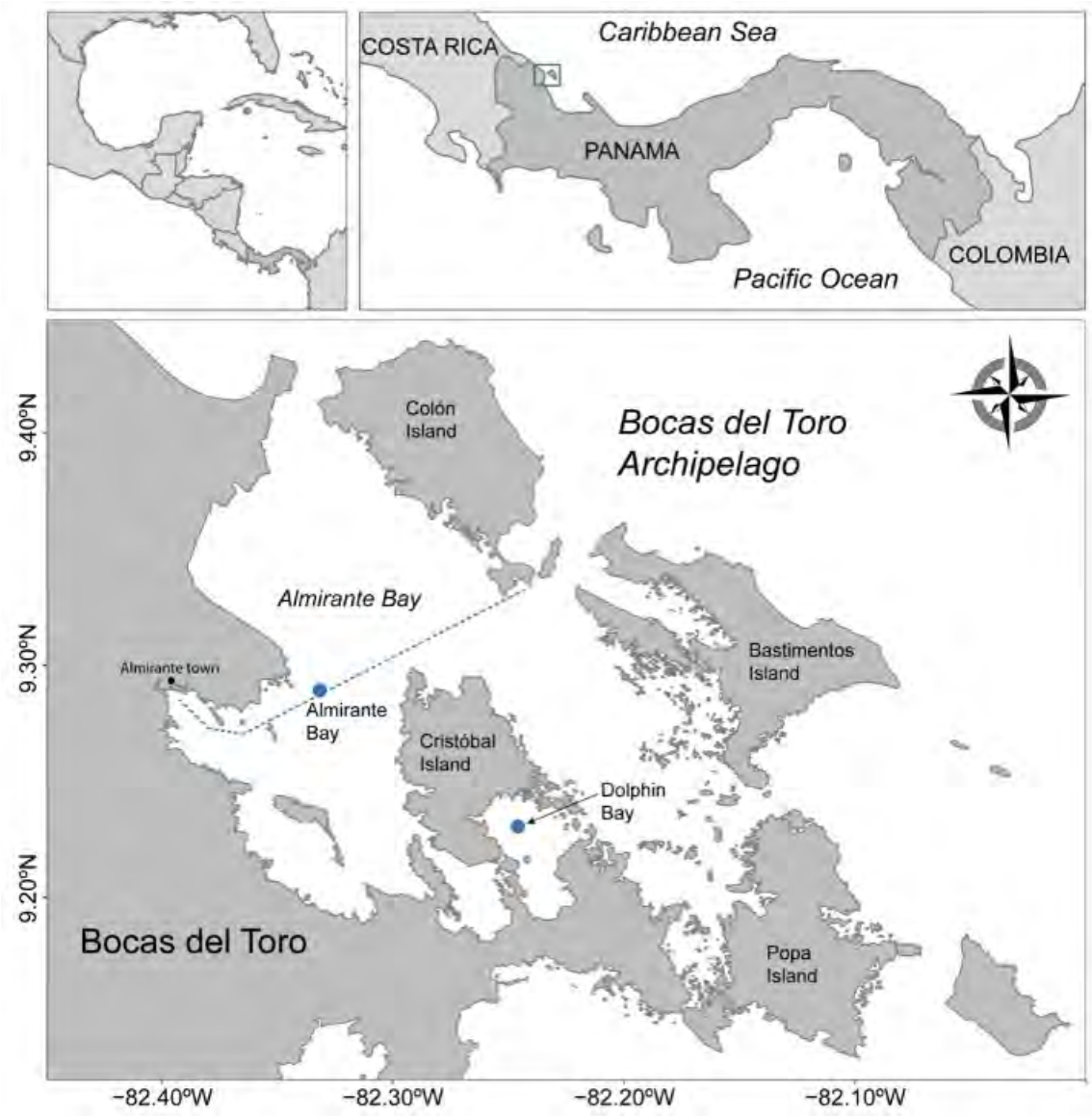


Figure 7. Map of the Bocas del Toro Archipelago situated in the Caribbean coast of Panama. The top left panel shows where Panama is situated in Central America; the top right panel is a closer view of Panama, with its eastern border with Colombia, and western border with Costa Rica. In blue square, the location of the Bocas del Toro Archipelago, and what is shown in the bottom panel, is highlighted. Dolphin Bay is located south of Cristóbal Island, and the dotted line in Almirante Bay, north of Cristóbal Island, represents the taxi-boat line. Figure credit: Perez-Ortega et al., 2021

Another highly transited area is Bocastorito's Bay, also known as Dolphin Bay. Tour companies offer one-day tours around the archipelago, and one of the highlights is dolphin watching in Dolphin Bay between 9 a.m. and 2 p.m. every day. Figure 8 shows a typical aggregation of tour-boats inside Dolphin Bay.



Figure 8. Eleven tour-boats following the same group of dolphins within Dolphin Bay. Image Credit: Laura J. May Collado

The Resident Dolphins

Although bottlenose dolphins are found throughout the archipelago, Dolphin Bay is seemingly their most valuable habitat. The bay is a semi-closed area that protects females and their calves against predators, providing a safe place for resting and finding prey. Dolphin Bay also serves as a place for social activities for more than 50% of the dolphins in the archipelago (May-Collado et al., 2018). Like many 'inshore' populations, the Bocas bottlenose dolphin population is genetically isolated, small (effective population size n=73 individuals), and both males and females show high levels of habitat fidelity, meaning they consistently remain or return to the same area (Barragán-Barrera et al., 2017). It is the predictability of these dolphins within Dolphin Bay that has fueled the dolphin-watching activities in this area.

The Problem

Between 2006 and 2007, the dolphins of Bocas del Toro were in the headlines of newspapers and online news. The government at the time had given permission to a private company to extract dolphins from this population to be sold for entertainment. The premise was that this dolphin population was likely connected to offshore populations and thus extracting dolphins from this area would not impact the population. At the time, Dr. Laura May-Collado and her research team had collected photographs of the natural marks on the dolphin's dorsal fins to estimate population size using capture-recapture models. The population was estimated to be between 88 and 150 dolphins, meaning that an extraction of 85 animals (as proposed) would have severely impacted this population. Furthermore, the team's previous genetic studies rejected the premise that this was part of an open population and there was a high degree of genetic isolation from neighboring coastal and oceanic populations.

Soon after these results were shared and the publicity of dolphins in the area increased, the government canceled the extraction and the dolphins became a novel attraction. Unfortunately, the expansion of tours to Dolphin Bay grew more rapidly than the training required to develop sustainable dolphin watching activities. By 2012, the number of tour-boats inside the bay simultaneously was up to 40 boats. The increase in the number of boats resulted in competition for close access to the dolphins (Sitar et al., 2016). This resulted in aggressive interactions between boat operators and the dolphins, which disrupted important behaviors like foraging (Kassamali-Fox et al., 2019) and caused injury and death (Trejos & May-Collado, 2015). Due to the intensity of the situation the International Whale Commission "expressed concern over the impacts of ineffectively managed dolphin watching in Bocas del Toro, on the Caribbean coast of Panama, and recommended continued monitoring of the impacts of dolphin watching activities on this population (IWC, 2013, 2014, 2015, 2019)" to the government of Panama and highlighted this case study in their Whale Watching Handbook.

In collaboration with Panacetacea, The Ministry of the Environment "Mi Amiente," and the Universidad Maritima Internacional de Panama, May-Collado's team has offered workshops to educate dolphin watching tour operators. Unfortunately, the high turnover of tour-boat captains has made it difficult to generate consistency in compliance with regulations. A lingering problem is that anyone that moves to Bocas can start a tour-company because licensing for dolphin-watching activities is not required, and compliance with regulations in situ is not enforced by the government. Up until now, the workshops have had little impact and the number of boats has continued to increase. This lack of regulations and enforcement has resulted in an increase in the noise levels generated by the boats in a critical dolphin habitat, which is likely to negatively affect the long-term health of this dolphin population.

The Scientists, Their Tools, and Their Methods

Above, we've detailed some of the impacts the rising tourism drive to Dolphin Bay has had on the resident dolphins. Here, we look more closely at the noise pollution aspect by explaining the work of our team, led by Dr. Laura May-Collado. Dr. May-Collado is a marine biologist who uses sound as a tool to study marine mammals and the health of their habitat. She has been studying marine mammals since 1997 and is currently a Lecturer at the University of Vermont, a Research Associate at the Smithsonian Tropical Research Institute in Panama, and co-founder of Pananacetacea, a non-profit organization for research and outreach.

To study how the dolphins respond to tour-boats and the contribution of boat noise to the soundscape, our team deploys autonomous underwater recorders called RUDARs (Cetacean Research Technology) and 300–600 SD Soundtraps (Ocean Instruments) in various sites in the archipelago that vary in intensity and type of boat activity. These recorders are attached to a pole 1.5 m above the seafloor and anchored with a ~30 kg block at 12 m depth. They are programmed to record the acoustic environment for 24-hour cycles at a sampling rate of 48 kHz. After we recover the recorders we download the data and process it for two types of analysis: (1) soundscape analysis and (2) dolphin whistle extraction of standard acoustic variables.

For the soundscape analysis, we take a 1-minute audio sample every 10 minutes and upload them to the online platform called RFCx Arbimon (Rainforest Connection, 2020). For each 1-minute recording, we determined the presence (1) or absence (0) of boats and dolphin sounds. With this information, we estimated when and where boats and dolphins were detected and calculated the acoustic space in the area with tour-boats (Dolphin Bay) and taxi boats (Almirante Bay). More recently, we use Long-Term Spectral Average (LTSA) analyses to generate average spectrograms at various time scales (weeks, months, years) allowing us to detect diel and season cycles in the acoustic make of the habitat. To determine if dolphins modify their whistles in the presence of different types of boat activity, we use the acoustic software RAVEN to extract the standard acoustic variables discussed in the introduction.

To learn more details of this project, watch Dr. Betzi Perez's explanation in this video: https://youtu.be/smdfmQ30K-g.

Boat and Dolphin Acoustic Detections

Pre-COVID–19 Shutdowns

Before COVID-19 shutdowns, our data showed that the acoustic presence of dolphins was higher in Almirante Bay, where taxi-boats dominate the soundscape, than in Dolphin Bay, where tour-boats concentrate. Additionally, in Almirante Bay, dolphin detections were slightly higher in the early morning when there were fewer boats present, whereas in Dolphin Bay, no significant patterns were found throughout the day.

We also found that dolphins in Almirante Bay (taxi-boat dominated) produced whistles with frequency and modulation characteristics expected to reduce acoustic masking (low frequency and low modulation). In contrast, in Dolphin Bay (tour-boat concentrated), dolphins produced whistles with an increase in the frequency of 2–4kHz, an average increase of 30s in duration, and were nine times more modulated than the whistles of dolphins recorded in Almirante Bay. Similar shifts in frequency have been reported in other dolphin populations when interacting with tour-boats. However, the most

telling difference between boat activities was modulation, a characteristic of the whistle that has been associated with alertness and stress, indicating that Dolphin Bay (tour-boat concentrated) is a more stressful environment than Almirante Bay (taxi-boat dominated) for these animals.

During COVID-19 Shutdowns and Limitations on Travel and Tourism

Starting in March 2020, the Panama government limited international travel and travel within the country to reduce the spread of COVID-19. Tourism was closed, and boats were not allowed to be in the water unless they had a government permit. Many restrictions began to lift in July 2020, but international and national travel restrictions remained in effect from August to December 2020. Given these restrictions, we were interested in studying whether changes in the dolphins' soundscape would be observable in both when they communicate and in the signals they produce.

In July 2020, our team received a special permit to deploy acoustic recorders in Bocas del Toro. At that time, Panama still had travel restrictions in place, and, importantly, hotels and dolphin-watching operations remained closed until February 2021. Because Bocas del Toro is an archipelago, much of the vessel traffic during this period consisted of transport boats moving people and supplies between islands. We used this opportunity to determine whether the shift from tourism-related boat traffic to primarily transport-boat activity during 2020 resulted in a quieter acoustic environment and, consequently, a less stressful habitat for dolphins.

Indeed, we found that the shift in type of boat activity within the lockdown resulted in lower ambient noise levels and more frequent detections of dolphin sounds. We also found that dolphins produced more diverse whistle repertoires during the lockdown. Pre-COVID-19, most of the boats were following the dolphins, while during the shutdowns, boats were only transiting the bay (e.g., taxi-boats).

How else did the dolphins respond to this change in boat activity? They produced less modulated whistles during COVID-19 shutdowns than before. In fact, the Dolphin Bay dolphins' whistle modulation matched that of dolphins in Almirante Bay. This suggested that during the COVID-19 shutdowns, Dolphin Bay became a less stressful environment, and dolphins only had to make adjustments to cope with acoustic masking (similar to Almirante Bay).

Study Conclusions

In the presence of tour-boats, in comparison to taxi-boats, dolphin detections are lower and whistle modulation is higher. Pre-COVID-19 conditions with many tour-boats created a stressful environment in Dolphin Bay, while in Almirante Bay the dolphins responded differently to taxi-boat traffic. The comparative data between pre- and shutdown times indicates that if tour-boat captains behaved more like taxi-boat captains, there would be a greater presence of dolphins in Dolphin Bay.

From Research to Action

What's the Message?

The comparison of data pre- and during the COVID-19 shutdown highlights that the tools to regulate dolphin-watching activities are simple and effective. Tour-boat operators could mimic taxi-boats in various ways:

- Do not get too close and do not chase the animals.
- Avoid concentrations of boats.

- Give the dolphins a break between boat interactions.
- Reduce the time of interaction with the dolphins to 30 minutes.
- Do not interrupt when they are eating or socializing.

These norms of conduct are already included in Panama's national whale-watching guidelines (Resolution N° DM-0530-2017, 2017).

A Community Plan to Protect the Dolphins of Dolphin Bay

As is frequently the case with ecotourism, there are conflicting interests: the tourism experience, the local economic revenue, and the impact on the fauna. In Dolphin Bay, the rapid increase in tourists and boats is negatively affecting the dolphins. If the population declines or if they leave the area, it will also negatively affect the tourist experience and local economy. The present trajectory is not sustainable. In an effort to address these issues in 2014, we brought together Panamanian scientists and various sectors of the local community to develop a conservation plan. Together we highlight four major points:

1. The tour companies could exclude visits to the bay from their 'see all in one day tours' and instead create 1–2 specialized tours just for dolphin watching.
2. The government must support regular tour operator training on good dolphin watching practices and develop mechanisms to enforce existing regulations in situ.
3. The scientists and the community must advocate Dolphin Bay and this dolphin population to be protected and together lobby government officials.
4. The local NGOs must play a stronger role in education and outreach.

Unfortunately, many of the recommendations in this community plan have not yet been implemented. Conservation is slow, and we need to be persistent.

RECOMMENDED ACOUSTIC DATA ANALYSIS ACTIVITIES

This case study is adapted from a three-part online interactive module published through OCELOTS (i.e., Online Content for Experiential Learning of Tropical Systems, see: https://ocelots.nrem.iastate.edu/) on the open interactive learning platform Gala (see: https://www.learngala.com/catalog/libraries/ocelots) and QUEBSHub (see: https://qubeshub.org/community/groups/ocelots/publications).

The "Sound of the Tropics" module includes:

- more background information, audio clips, short interactive prompts (e.g., podcast, analyzing spectrograph), and more examples for understanding the basics of sound and acoustic monitoring for conservation (Part 1: How can audio recordings improve tropical biodiversity conservation?; https://www.learngala.com/cases/sounds-of-the-tropics-part-1);
- an interactive case study exploring how a frog community in Puerto Rico responds to different types of disturbances with activities to explore soundscape files (Part 2: How are frogs responding to hurricanes, droughts, and climate change?; https://www.learngala.com/cases/sounds-of-the-tropics-part-2);
- and a longer version of the above case study and activities investigating impact of boat activities on dolphins and other whales (Part 3: Can you hear me? How do dolphins in Bocas del Toro, Panama communicate in a noisy habitat?; https://www.learngala.com/cases/sounds-of-the-tropics-part-3).

We encourage you to explore these resources and consider completing the associated activities that use sound recordings and the same software tools the researchers used (such as Audacity, RAVEN Lite, Arbimon, Excel) to summarize data and answer research questions.

Additionally, for another optional activity, consider the NCEP exercise "Bats in the City? An Exploration of Acoustic Monitoring of Bats" (https://doi.org/10.5531/cbc.linc.10.1.6). In this case study, students are introduced to urban biodiversity in New York City, bats in urban areas, bat echolocations/vocalizations, and the monitoring of these species through analyzing acoustic recordings. Students then complete a data analysis exercise where they will be directed on how to visualize and summarize the results of a software analysis.

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APPENDIX 1: ADDITIONAL RESOURCES

Example recordings:

- Cicadas: https://www.youtube.com/watch?v=9ZbRWkeAW9w
- Death's head hawkmoth: https://www.youtube.com/watch?v=Io1DLrrae74
- Atlantic croaker: https://www.youtube.com/watch?v=ZvWJ2WzRKYA&t=1s
- Tenrec quills: https://www.youtube.com/watch?v=n66o9DYCQww
- Panama Frogs: https://www.youtube.com/watch?v=247f43dg4nI

Software:

- Measure noise levels with your phone: https://www.ilovefreesoftware.com/20/iphone/free-noise-meter-iphone-apps.html
- Audiogram database: https://www.animalaudiograms.org/
- Audacity: https://www.audacityteam.org/
- Audacity tutorial: https://www.macaulaylibrary.org/resources/audio-editing-tutorials/editing-in-audacity/
- RAVEN: https://ravensoundsoftware.com/
- RFCx-Arbimon bioacosutic platform: https://support.rfcx.org/
- An extensive list of bioacoustics software: https://github.com/rhine3/bioacoustics-software

Acoustic libraries:

- McCaulay Sound Library: https://www.macaulaylibrary.org/
- William A. Watkins Collection of Marine Mammal Sound Recordings: https://darchive.mblwhoilibrary.org/handle/1912/5877
- Right Whale Listening Network: https://www.orcasound.net/

Podcasts:

- "The voice of the natural world" Ted Talk by Bernie Krause: https://www.ted.com/talks/bernie_krause_the_voice_of_the_natural_world
- "Reef Sounds, Corals and Reef Fishes" Dr. Steve Simpson: https://www.laurelneme.com/podcast-reef-sounds-corals-and-reef-fishes-steve-simpson/
- Me escuchas?: https://youtu.be/zmfDMx4te6w
- Dolphin research and conservation in Panama: https://podcasts.apple.com/us/podcast/marine-mammal-science/id1475692072
- Science Friday: https://www.sciencefriday.com/segments/capturing-the-sounds-of-biodiversity/

Additional:

- Acoustic and Vibration Animations: http://www.acs.psu.edu/drussell/demos.html
- Discovery of Sound in the Sea: https://dosits.org/
- Coral Reefs and climate change: https://iucn.org/resources/issues-brief/coral-reefs-and-climate-change
- Panacetacea: http://www.panacetacea.org/
- Interactive website where all the sightings of bottlenose dolphins are, people can see when and where they interact with boats in relation to their behavior state: https://lmaycollado.github.io/Dolphins-of-Bocas-del-Toro-Map-by-the-Ondas-Lab/

Additional reading:

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Promoting Allyship among Conservation Students and Practitioners

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Biodiversity conservation relies on contributions from many people working together to evaluate, develop, implement, and continually improve conservation efforts. However, most globally recognized conservation efforts are managed by predominately Western institutions and governance systems that often favor a narrow demographic, while sidelining individuals and organizations representing a broader set of identities and experiences (e.g., Johnson, 2019; Miriti, 2020; Schell et al., 2020). Patterns of exclusion are common in global conservation research, with many efforts using extractive practices that are rightly criticized for marginalizing local expertise and reinforcing inequitable power dynamics (e.g., de Vos & Schwartz, 2022). In contrast, many conservation projects and practices around the world have their origins in well-established local communities, and benefit from inclusive practices. Such projects are common among Indigenous Peoples and Local Communities (often referred to as "IPLCs" for short), where conservation projects are both more holistic and effective in their engagements and outcomes (Dawson et al., 2024). Conservation outcomes are improved when more perspectives and types of knowledge are embedded within projects, including collaboration with the communities where projects are situated (Ens et al., 2016).

The workforce for biodiversity conservation remains skewed toward societally-dominant demographics (for example, in North America, predominantly white/European descent, affluent, and male; Johnson, 2019), while student and affected community demographics are much more diverse (Cronin et al., 2021). This mismatch can lead to a sense of isolation among those from underrepresented and marginalized groups, which can reduce their participation and retention in conservation. Research across STEM fields suggests that underrepresented students' persistence is directly shaped by their sense of belonging and access to supportive mentoring, with those lacking these experiences significantly more likely to leave their field of study (Kricorian et al., 2020; O'Brien et al., 2020).

Conservation students and practitioners should receive training that helps cultivate their knowledge of the histories and dynamics that create and perpetuate exclusions to conservation practice. At the extreme, preservation of areas via excluding humans and restrictions of traditional, cultural practices has displaced Indigenous and long-standing local communities—serving as an instrument of colonization (Adams & Hutton, 2007; Holmes & Cavanagh, 2016; Weldemichel, 2021). Thus, we believe it is critically important to actively promote anti-oppressive, multicultural, and pro-diversity attitudes and capacities among our students and fellow practitioners (see also Haynes & Jacobsen, 2015). These goals align with broader movements in anti-oppressive environmental education, which cultivate understanding of how power, identity, and exclusion can shape conservation practice and identifying ways to help transform these patterns toward greater equitability (Kumashiro, 2000; Fritzsche, 2022). Many instructors need more resources and support for these aspects of their

conservation teaching, especially as many instructors are from societally-dominant demographics. Further, the large variation in political and societal support for the full spectrum of human diversity, life circumstances, and experiences can make it complicated for those teaching in areas where opposition to equity and diversity initiatives are rife, and especially when instructors are members of marginalized groups themselves.

Montgomery et al. (2022) demonstrated how explicitly embedding social-justice frameworks into conservation science education can shift student perspectives from biodiversity-first to a more integrated view of biodiversity and human well-being. We suggest also incorporating allyship concepts to strengthen students' capacity for collaborative and inclusive conservation work. Assisting conservation students and practitioners to consider, discuss, and develop skills to ally themselves with those from different identities to their own will help them contribute to making the field more welcoming and supportive, no matter their personal background. Moreover, by cultivating empathy and interest, along with supporting skillsets, students and practitioners can begin to dismantle exclusionary practices and better promote diverse voices and active participants in conservation (Balcarczyk et al., 2015). Here, we reflect on efforts to help undergraduate and graduate students understand allyship, and to consider how they might grow capacities to promote diverse engagements and outcomes across identities in conservation.

OVERVIEW OF TWO APPROACHES TO PROMOTING ALLYSHIP AMONG CONSERVATION STUDENTS

Recently, we collaborated with the Society for Conservation Biology North America (SCBNA)'s Equity, Inclusion, Diversity & Justice and Education committees in using resources developed through an online interactive session "Expanding Boundaries Through Allyship in Conservation" at the North American Congress for Conservation Biology (NACCB) in 2020 (Reid et al., 2020). Following the conference, SCBNA produced a series of six interview-style videos focused on promoting allyship through a greater understanding of the diversity of individual experiences in biodiversity conservation (see Box 1). We used these videos, along with supplementary written and video materials, as the foundation for a classroom learning module on allyship and the importance of human diversity in conservation. Our goals were to foster greater understanding of the diversity of experiences in biodiversity conservation and help students identify strategies for practicing allyship within the field.

To date, we have implemented two versions of a stand-alone allyship module in seven courses at three different universities. Each version was offered twice in an undergraduate and a graduate course setting at University of Hawai'i at Hilo, one undergraduate course at University of Washington Bothell, and in two graduate courses at University of California Irvine. Enrollments ranged in size from 12 to 50 students, with five courses including only students working toward a conservation degree, and the other two including undergraduate conservation majors and those pursuing other degrees. In all course settings, student identities and backgrounds were diverse, including diversity in race and ethnicity, gender expression, age, neurodiversity, economic means, educational background of parents, country of origin, as well as additional categories of identity. The specific module, with the two variations, is included in this issue ("Promoting Allyship in Conservation": https://doi.org/10.5531/cbc.linc.15.1.7)

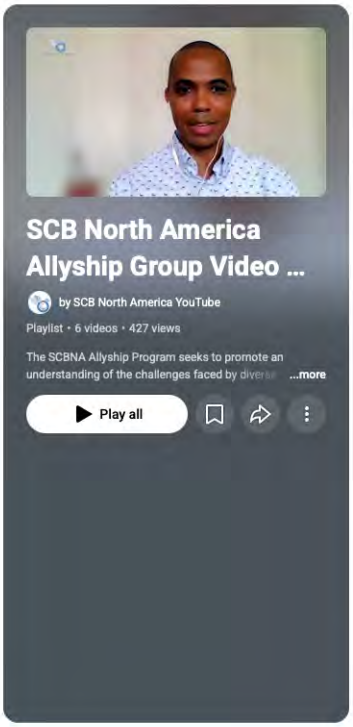
Across all courses, we shared four common learning objectives. After completing the module, students were expected to:

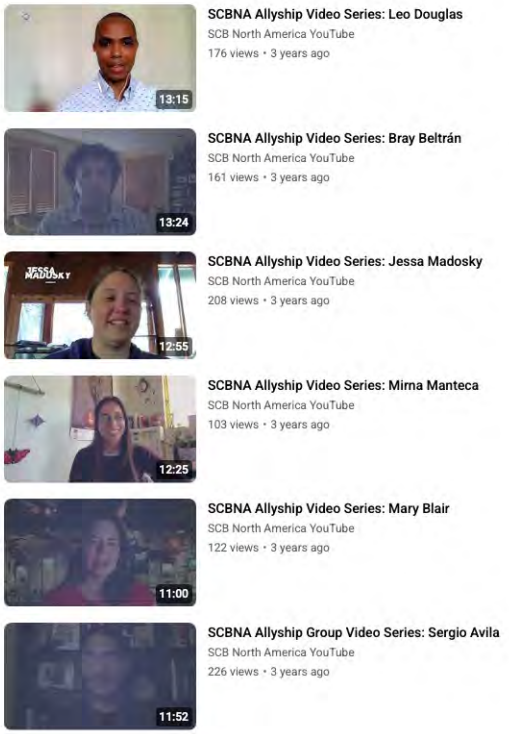
Box 1: SCBNA Allyship Video Series. The graphic below provides brief descriptions of the six videos, including their style and general intent, and core reflections shared.



The video series came from a workshop on allyship at the North American Congress for Conservation Biology 2020.

The series features six conservation professionals in interview-style responses to questions. Each person shared experiences and reflections on how identity influences their work in conservation.





These six video summaries' directly support the module's learning objectives by illustrating the breadth of lived experiences in conservation. They highlight ways that identity, power, and inequity shape participation in the conservation field. These videos act as entry points for students to reflect on diversity, compare experiences, and identify allyship strategies while practicing engagement in challenging conversations.

The six conservationists responded to a set of questions including:

- How has your identity affected your relationship with conservation?
- Would you be willing to describe any experiences that have acted as a barrier to completing your work, research, or collaborative projects?
- Can you give an example of when a colleague stepped up to disrupt an unwelcome behavior or experience or helped to create a safer environment for your work?
- Can you describe your vision for what a truly inclusive conservation community would look like and what would we need to change to get there?

Short summaries for the videos:

- Sergio Avila shares how racial profiling and safety threats from the United States Border Patrol undermined his ability to conduct wildlife research along the U.S.-Mexico border, treatment not experienced by his white colleagues. His account highlights the way that racialized assumptions can shape fieldwork experiences and safety and underscores the importance of allyship within conservation communities.
- Bray Beltrán explains how his identity influenced both his exclusion from academic pathways as well as his current work in private land conservation. His story illustrates how inequitable systems shape who is recognized as a "legitimate" contributor in the field and how allyship can

help counter these dynamics.
- Mary Blair describes how her Sami heritage and context-dependent racial identity have shaped her approach to conservation. She highlights the importance of recognizing colonial histories and making space for diverse worldviews as well as using privilege to support equity in the conservation field.
- Leo Douglas discusses how racialized exclusion during his graduate training shaped his sense of belonging in conservation science. He emphasizes the need for greater allyship and investment in training conservationists from the communities where biodiversity work occurs.
- Jessa Madosky reflects on how gender discrimination and challenges related to an invisible disability have affected her work in conservation. She emphasizes how intersecting identities shape career experiences and ways in which allyship can help mitigate the impacts of exclusion.
- Mirna Manteca shares how conservation challenges in northern Mexico are inseparable from social and political inequities. She also discusses how experiences of racialized profiling and cross-border misunderstandings underscore the need for allyship, context-specific approaches, and awareness of tokenism in conservation work.

1. Appreciate the value of human diversity and inclusion to conservation
2. Gain awareness of the diversity of experiences within biodiversity conservation
3. Find commonalities and differences among experiences of people with varying identities in the field
4. Become more familiar with allyship strategies and techniques

We centered the module around the SCBNA Allyship Video series and supplemented it with additional written and video materials that provided context and extensions of key concepts. The choice between two curriculum variations depended on the course format preferred by instructors. Students either 1. viewed videos together in class followed by structured discussion or 2. watched assigned videos independently at home before participating in jigsaw-style discussions, where they first discuss in groups that all watched the same video before mixing into groups where all had watched a different video. Additional reflection activities and instructor resources are provided in the supplemental Exercise Notes (https://doi.org/10.5531/cbc.ncep.0193).

The first-person narratives in the videos help students appreciate the contributions that are made by individuals with differing backgrounds and experiences in conservation (learning objective 1). The videos helped students move beyond generalities as they learned about specific situations and provided needed complexity to this critical topic. Structured reflection and discussion prompts encouraged students to compare the six speakers' experiences, fostering a deeper understanding of the diversity of experiences in conservation (learning objective 2). Additional activities encouraged students to reflect on their own identities and positionalities, broaden their perceptions, and cultivate empathy across identities (learning objective 3).

We all also included discussion and reflection prompts aimed at developing allyship strategies (learning objective 4). In some cases, this portion of the module consisted of generating ideas within the student group, and in others also derived from suggestions in published literature (e.g., Cronin et al., 2021; Sutton-Lawrence et al., 2017; Halsey et al. 2020; Chadhury & Colla, 2020). In some classes, students were mentored to create community guidelines for discussion or practiced improving their skills in constructive conversations and bystander interventions through role plays (learning objective 4). Several classes also examined how allied engagement can strengthen community-based conservation practice (Yasué et al., 2024).

Importantly, the videos introduced perspectives and lived experiences beyond those represented by the instructors themselves. As instructors, our positionality can amplify our voices relative to those of our students. Also, we can only speak from whatever lived experiences and identities we hold. Therefore, incorporating additional voices through first-person accounts helps broaden classroom dialogue and deepen student engagement with issues of allyship and inclusion in conservation.

REFLECTIONS ON IMPACTS ON STUDENTS AND STUDENT LEARNING OUTCOMES

Our experiences in offering this allyship module in our classes, while not designed as a research study, convinced us that such content can be powerful for students. Students responded extremely positively to these allyship exercises. Many students contributed insights from their own experiences. Further, some of those who engaged most were ones who usually did not put themselves forward in class. Some students mentioned that they wouldn't have been comfortable bringing up their own "story" outside of the context of the very personal stories shown in the videos. Observing these conversations in the classroom led us to incorporate more examples that better aligned with the identities present in our diverse classrooms.

In both class discussion and personal reflection, students showed increased awareness of diverse experiences. They were able to draw connections between barriers that exist for people from many identities in conservation and how these impacts can lead to larger inequities, especially when conservation project design increases exclusion and displacement.

After the allyship module, students became more interested in improving both workplace conditions and conservation practice more broadly to make them more inclusive. Students focused more strongly on the need for societal change, with leadership that is collaborative with members of affected communities. They consistently identified that building a conservation field that is just cannot be separate from addressing societal structures that cause injustice. This can be seen, for example, in two sample student reflection responses from the course run by Pratt at University of California Irvine in Spring 2025:

- *"A just conservation movement requires recognizing that environmental issues are deeply tied to social justice, power, and governance. From [one of the conservationists'] experiences, it's clear that conservation without addressing systemic inequities (land access, resource control, and racial profiling) is incomplete."*
- *"Building a conservation movement that is truly just means building a society that is truly just. I don't think that we can necessarily separate the conservation movement and have a just and perfect field in the context of a society that is not."*

Similar shifts have been documented in other conservation courses that integrate social-justice frameworks, where students began to explicitly connect biodiversity outcomes with equity, community leadership, and human well-being (Montgomery et al., 2022).

These themes then became well integrated into the rest of the course, helping to keep these issues at the forefront, while also making conservation itself seem more of a 'real' endeavor than an academic subject. The curriculum asks students to grapple with and recognize the ways in which conservation is influenced by societal inequities, but this also enhances their motivation to consider how to improve the ways in which conservation is done.

In all of our classes, we felt students largely attained the learning goals we had established, and in classes in which this module was introduced early in the term, core themes from the module arose again and again. Students thought more about how conservation efforts are undertaken, and the critical importance of the myriad social dimensions of conservation practice. Overall, students found more clear connections between social equity and conservation after they had completed this module.

CONCLUSION

Incorporating an allyship module into conservation courses can be an invaluable component for achieving our primary learning objective, helping our students to "Appreciate the value of human diversity and inclusion to conservation." We encourage instructors to consider how they may be able to incorporate elements that promote these values and support student understanding and skill building toward allying with others to promote greater equity and thus, more effective conservation practice. We recognize that adding curricular components such as these can be difficult for many instructors, particularly in settings where diversity and equity initiatives are actively discouraged (see Box 2). Yet, we firmly believe that to best equip our students to thrive in their future work, such components are essential and become even more critical in an environment where such values are not already being promoted.

In addition to promoting discussion of allyship, the allyship videos provided by SCBNA provide

Box 2. Implementing allyship modules where equity work is discouraged

Many institutions have faced pushback against diversity and equity initiatives, which can make offering a curricular module on allyship feel precarious. While each instructor would need to judge what is possible for themselves, we suggest that the core concepts in this curriculum are still critical to introduce to conservation students. One pathway forward is to introduce the concepts as they impact conservation, shedding some of the baggage of DEI frameworks currently (see The Avarna Group blog post: https://theavarnagroup.com/dei-jujitsu-flipping-the-backlash-to-reframe-our-work/). The backlash to equity initiatives is not new, and DEI work is not without fault. It can be helpful to take a step back to think about what is behind the core goals of this module, which is to increase support for individuals from a wide range of backgrounds to work in conservation, and for communities on the ground of conservation projects to be respected and included in the work, or to be given the support needed to lead the work.

A focus on effective conservation practice can motivate exploring the ways in which the participants in any project influence project outcomes. Discussing who is included and in what ways at each stage of a conservation project can allow conservation students to better understand the real dynamics behind conservation work, and to value learning how to foster projects that are meaningfully inclusive. Understanding examples of what can stand in the way of conservation efforts helps students to think about how to overcome those barriers. While diversity initiatives have rightfully been a focus of many workplaces and our educational systems, what is most needed is to teach about the underlying rationale for changing practices, communications, and goals for conservation projects. In becoming more precise about our goals, and more detailed in exploring the social aspects of conservation work, we will help students to become more effective conservation practitioners in the future. Allyship training is a critical piece (and often a first step across learners of all stages of professional development) in the overall larger priority of taking action to catalyze change toward greater equity.

access to insights from diverse viewpoints in conservation that may not be readily available at every institution, which can be especially helpful for students in marginalized groups. The videos provided by SCBNA can help instructors introduce experiences and viewpoints into their classrooms, thereby increasing representation within their curriculum. Such representation can positively influence students' sense of identity and academic performance, particularly among marginalized groups (Iweuno et al., 2024). Using videos such as these is a step towards a more inclusive curriculum that can contribute to increasing inclusivity and diversity in the conservation field as more culturally competent students enter the conservation workforce.

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Promoting Allyship in Conservation

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ABSTRACT

Those in the conservation workforce represent only a subset of the diversity of lived experiences found in broader society. One way to promote greater inclusivity in the field is to cultivate understanding of the history and dynamics that have led to this disparity, while also developing awareness of others' experiences in conservation and building allyship skills to support those people with identities, backgrounds, and lived experiences different from one's own. In addition, conservation projects have at times displaced and disadvantaged people in local communities, which could be prevented if conservation project design and implementation were conducted with communities in the project location. Efforts to make conservation work more inclusive can therefore strengthen both equity and conservation outcomes. In this exercise, students will watch videos of conservation professionals speaking about their own experiences navigating the field and reflect on readings and videos in discussion with fellow classmates.

LEARNING OBJECTIVES

After completing these exercises, students will:
1. Appreciate the value of human diversity and inclusion to conservation
2. Gain awareness of the diversity of experiences within biodiversity conservation
3. Find commonalities and differences among experiences of people with varying identities in the field
4. Become more familiar with allyship strategies and techniques

INTRODUCTION

Biodiversity conservation requires contributions from and collaboration among many individuals to evaluate, develop, implement, and continually improve conservation efforts. However, modern conservation research and actions primarily have been driven by individuals from a relatively narrow breadth of human experience and expertise, while individuals holding a broader set of identities and experiences have often been excluded and/or marginalized. Conservation outcomes can be improved when more perspectives and types of knowledge are included among the members of the conservation workforce and the communities where projects are situated.

The workforce for biodiversity conservation remains skewed toward currently societally-dominant demographics (predominantly white/European descent, affluent, and male), while student and affected community demographics are much more diverse. When only certain voices are prominent in the field, it can lead to a sense of isolation among those who identify as or come from underrepresented groups. This can reduce their participation and retention in conservation. Worse, many conservation activities may exclude and disempower local communities, ignoring concerns, histories, and dynamics within the affected communities. In these cases, the result is both less effective conservation and reductions in the social welfare of community members. Clearly, the narrowness of participation and power in the conservation workforce and projects leads to multiple problems. How can members of the conservation

field seek to address these persistent issues? How might we best help expand who is engaged in conservation, and improve how we practice conservation itself?

To begin to address the impacts of identity marginalization in conservation and in society, we need people to feel welcome, that they belong, and that they are supported and safe. More inclusive environments are facilitated in part by allyship, specifically, when individuals can use what privilege or power they hold to make space, foster safety, and create conditions for those with marginalized identities to thrive. Merriam-Webster defines allyship as "the state or condition of being an ally: supportive association with another person or group" and "specifically: such association with the members of a marginalized or mistreated group to which one does not belong." Allyship requires both awareness and skills to support other people in the face of structural inequities and barriers to participation. This exercise seeks to promote an understanding of the diversity of challenges faced by historically marginalized communities within conservation, and to motivate dominant demographic groups to support marginalized groups based on this new understanding. Most people hold both privileged and marginalized aspects in their identities, and our focus here is on how to extend allyship to others whose identities may differ from yours.

In this exercise, you will hear personal accounts collected as part of the Society for Conservation Biology North America (SCBNA)'s Allyship Video Project. The six videos feature conservation professionals from a wide range of backgrounds detailing how their visible and not visible identities have affected their careers. They share challenges they have faced and suggest ways that those from dominant demographic groups could better support those with less power. Some of these stories may resonate with your own, while some may present experiences that are unfamiliar. We will also read articles that provide additional context to the issues discussed in the videos. We will watch the SBCNA videos (either before or during class) and use the stories presented by the interviewees to initiate a discussion on your own experiences, your assessments of the problems, and your visions for the potential solutions and the future of the field. This may be a difficult conversation with varying viewpoints, but we hope it is ultimately rewarding and uplifting. To this end, we suggest that you follow a simple set of ground rules for ensuring a respectful and healthy discussion, and your instructor will help provide this structure in your classroom (instructors, please see the accompanying Exercise Notes document for guidance and additional recommendations: https://doi.org/10.5531/cbc.ncep.0193).

EXERCISE

Prior Readings and Reflection

Please read the following article and answer the reflection questions. Bring your written reflection to class to use during discussion, and hand it in at the end of class. (Note: Your instructor may assign additional or different materials as part of this exercise).

- Cronin et al. (2021). Anti-racist interventions to transform ecology, evolutionary biology and conservation biology departments. Nature Ecology and Evolution 5: 1213-1223, https://doi.org/10.1038/s41559-021-01522-z. Open access link: https://escholarship.org/content/qt24b9c4qf/qt24b9c4qf.pdf
    - Summarize your understanding of the legacy of past and present discrimination in conservation. Have you or your colleagues had any similar experiences?
    - Which of the authors' recommendations do you think would be helpful for improving equity and inclusion in your department, school, or in workplaces that you are familiar with, and how might they be implemented?

Allyship Video Viewing and Reflection

You will be asked to either watch the videos independently in advance of class or watch them together within the class session. We list the instructions for these two versions next.

Option 1: In-Class Viewing and Discussion

The basis of this activity is a discussion of short ~11–13 min videos of conservationists discussing the impact of their social identity on their experience in conservation. There are six video (Sergio Avila, Bray Beltrán, Mary Blair, Leo Douglas, Jessa Madosky, Mirna Manteca), and we will watch them over two class sessions, watching a group of three each time. First, we will watch the following short videos from the Allyship series during class:

- Leo Douglas: https://youtu.be/PIDrhzK5lqA
- Mirna Manteca: https://youtu.be/mcbKr5xrxy0
- Mary Blair: https://youtu.be/pyEgEReI-ZQ

While you are watching these videos, reflect on the following questions and prepare to discuss them with the class:

- Do any (or all) of their experiences in their careers connect to your experiences so far as early-career scientists?
- How does hearing about the difficulties experienced by others in their career progression influence your attitude toward your own potential career and your plans for moving forward?
- What could be done to make change for the better as we move forward? At what level(s) are you most inspired and currently able to contribute (i.e., as an ally for those in your immediate circle of work, at the local community scale, at the institutional or university scale, at the society and/or structural levels)?

In the next session, we will watch the final three videos from the Allyship series, and ask you to reflect on the same questions listed above:

- Sergio Avila: https://youtu.be/wfiZfjjRSR8
- Jessa Madosky: https://youtu.be/cNoIjreIkYY
- Bray Beltrán: https://youtu.be/_ZvlPwOcAfY

Post-class Individual Reflection

Please compose a reflection after both class discussions are completed. Your reflection can be written, or recorded via an audio or video. Please answer the following in your reflection:

1. Do any (or all) of the interviewees' experiences in their careers connect to your own experiences so far as early-career scientists?
2. How does hearing about the difficulties experienced by others in their career progression influence your attitude toward your own potential career and your plans for moving forward?
3. What could be done to make change for the better as we move forward? At what level(s) are you most inspired to contribute (i.e., as an ally for those in your immediate circle of work, at the local community scale, at the institutional or university scale, at the society and/or structural levels)?
4. What do you feel like you learned from the videos?
5. What was most surprising about the videos?

6. Overall, I felt the videos changed my mind about _____ (fill this in with whatever you would like). Strongly agree (10) to strongly disagree (zero). Please explain why.
7. Overall, I felt the videos were useful. Strongly agree (10) to strongly disagree (zero). Please explain why.
8. Is there anything else you would like to share about the videos or your own experiences?

Option 2: Jigsaw Discussion, Watching 1–2 Videos Before Class, and Discussing Them in Class

Pre-Class Preparation

The basis of this activity is a discussion of short ~11–13 min videos of conservationists who speak about how their experience in conservation is impacted by their identity and people's responses to their identity. There are six videos (Sergio Avila, Bray Beltrán, Mary Blair, Leo Douglas, Jessa Madosky, Mirna Manteca), and to facilitate conversations across these different perspectives, you are randomly assigned to watch 1–2 videos to prepare for in-class work. (You are welcome to watch as many as you wish, but you must watch what is assigned to you!). The goal for the in-class jigsaw discussion is to first discuss the video with others who watched the same video(s) and subsequently split into new groups to share insights across all six.

For the video(s) you are assigned, first watch the video in its entirety, and then write your reflection. Please address the following prompts in a 200–300 word reflection essay, adding any additional thoughts you wish to discuss with the class:

- What did you feel you learned from what was shared by the conservationist?
- What struck you most about their lived experience and how it intersects with their professional experiences in conservation?
- Do you experience any similar dynamics in your life, and as you pursue your education?
- What changes would you recommend for conservationists with similar backgrounds to be fully included in conservation practice?

Your instructor also might ask you to consider the following question(s) related to the specific video you were assigned:

- Sergio Avila faced identity-based threats to his safety while doing his research. While extreme, what other identity-based barriers are people facing, and how do these impact conservation science?
- After watching Mirna Manteca's video, what do you think about the meaning of "public land" in the context of their experiences doing research on the border? How do the experiences she describes compare with your experiences on "public land"?
- Bray Beltrán was told he could not pursue his research interests for his Ph.D. How did he work beyond these limits in conservation? Who are the gatekeepers in conservation biology, and how do they limit career opportunities?
- Does Mary Blair's discussion of multiple identities resonate with you? We all hold multiple identities, which are perceived and imbued with privilege or marginalization depending on the context of the social systems in which we live and work. How might we use privileged vs minoritized aspects of our identities to move forward in our work in conservation?
- Jessa Madosky highlights the importance of allyship in describing a situation where a colleague spoke up in support of her bringing her service dog into a conference. How can we show allyship to and better understand colleagues with "invisible" disabilities that we may not perceive or fully understand?

- Leo Douglas suggests a more comprehensive program of training conservation scientists from all over the world to deal with issues specific to their home regions. How would you implement this? What are potential benefits and potential pitfalls of this approach?

In-Class Jigsaw Discussion Assignment: Three Discussions

Part 1: Initial Groups

In groups composed of all those who watched the same video(s) (Avila, Beltrán, Blair, Douglas, Madosky, and/or Manteca), please discuss your reflections on the video(s).

- What do you think was most important about what was shared by the conservationist?
- What could be done to improve the experience of people such as the person whose video you watched?
- Is there anything else your group wants to share/discuss?

Be sure you all feel ready to share the conclusions of your group about the video you watched. It will be helpful if you all take notes to take with you to Part 2, the jigsaw discussion. Beyond sharing the core content of their remarks, what ideas/perspectives do you want to be sure to share with your classmates? Determine together which issues you want to be sure are shared across the class.

Part 2: Jigsaw Discussion

You will be distributed among the tables such that one person will represent each of the conservationists in the new group discussion.

Please begin by taking turns presenting to one another. First, summarize the perspectives shared in the video you watched and the ideas you discussed within your group from Part 1. Next, once everyone has shared individually, move into discussing the questions below.

- What are the ideas from the whole set of Allyship videos that should be generally understood by people working in or interested in conservation?
- What do you see as priorities to improve the experience of people working in conservation?
- What ideas do you have for practical strategies for improvement? What might we be able to do as individuals, and what might we encourage for change within organizations?

Part 3: Whole Class Discussion

What is needed to build a conservation movement that is just? Before beginning, take a moment to write your own thoughts on how you would answer the following questions, and then discuss with the whole class:

- How would you personally define the concept of being "just" in the context of biodiversity conservation?
- What is essential to developing conservation practice that would contribute to equitable outcomes among peoples and promote greater justice in society?
- How would you explain to someone not in this class why efforts to include a greater span of human experience is important in the conservation field?
- What are some concrete ways you can demonstrate allyship to those with different identities to your own?

Post-class Individual Reflection

Please submit a short summary of what you feel are the most important ideas discussed during class and list any points you feel are especially pertinent to the conservation work you want to do. In addition, please feel free to list any questions or points you think need greater clarification based on our discussion. Finally, include your personal reflection on the questions posed in the whole class discussion. This can be a written or audio or video submission.

EVALUATION

For in-class portions, you will be evaluated based on presence and active participation in the discussion (please see provided Qualitative Rubric in the Appendix). It is also important to note that the evidence of engagement can (and perhaps should) come from a variety of modalities beyond verbal contribution to whole class discussions (e.g., written materials, audio or video recorded responses, contribution to small group discussions), as well as adherence to the community agreements for constructive conversations (if defined). Your post class reflections will be evaluated based on thoughtful and thorough responses to the prompts.

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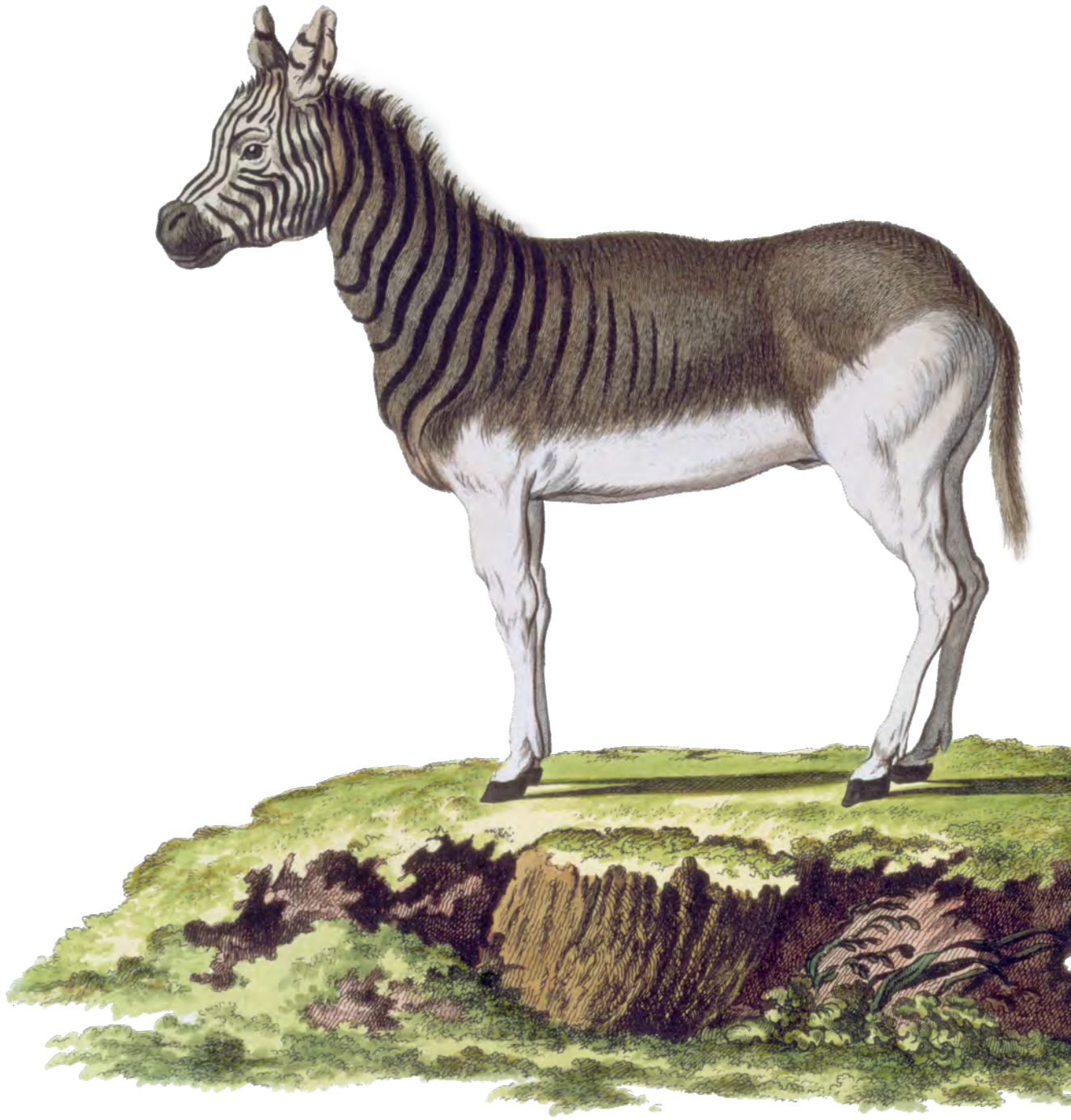
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APPENDIX 1. QUALITATIVE RUBRIC

Assigned Task	Assessment		
	Thorough	Partial	Limited
Pre-class Content Reflection			
Describes student's learning	Clear and focused statement of learning, evidence of thoughtful engagement	Some attempt is made to describe learning but neither thorough nor very thoughtful	Unclear or vague, little evidence of thoughtful engagement
Connects to reading and video content	References specific aspects of the reading and/or video content	General topic of content is referenced but not specific aspects	Does not connect to or highlight aspects of the content provided
Connects to own life experience	Describes feelings, thoughts, or connections between content and student's own life	Minimal connection of content to student's own life	Does not describe any connection between content and student's own life
Applies insights to recommended allyship actions	Student provides their ideas or concrete suggestions for allyship or inclusion relative to content	Student has generalized statements regarding allyship actions or improved inclusion	Student does not reflect on or consider allyship actions or inclusion
Participation in the In-class Activity *(Include community guideline part, only if relevant)*			
	Actively participated through sharing and/or active listening in group discussions. Adhered to community guidelines for constructive conversations	Present but only partially engaged in group discussions, did not appear to be listening or participating actively	Absent from in-class discussion and/or was disruptive or disrespectful of community guidelines for constructive conversations
Post-class Reflection			
Important ideas from discussion were identified	Clear and focused statement of important ideas shared in class	Some attempt to describe ideas shared but not thorough or thoughtful	Unclear or vague, little evidence of attentiveness to ideas discussed in class
Relevance of class discussion to student's life is described	Describes relevance of specific ideas to student's own life or potential future work	Minimal attempt is made to connect ideas to student's own life or potential future work	Does not connect ideas to student's own life or potential future work
Questions from whole class discussion are thoughtfully addressed	Demonstrates meaningful effort to address all questions posed in the whole class discussion	Demonstrates engagement with some but not all questions posed or is overly vague	Demonstrates little to no effort to address the questions posed in the whole class discussion

The Network of Conservation Educators and Practitioners kindly thanks the authors and reviewers for their time, effort, and dedication to the materials provided in this issue of *Lessons in Conservation*.



We welcome your comments and feedback. To write to NCEP or for more information, contact the Network of Conservation Educators and Practitioners at:

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