Historia Naturalis: Inspiring Ecology

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There have never been people without natural history – the practice of natural history attentiveness is the oldest continuous human tradition. Throughout human history and pre-history, attentiveness to nature was so fully entwined with daily life and survival that it was never considered a practice separate from life itself (Fleischner 2005, 2011).

And there has never been scientific ecology without natural history. Indeed, Charles Elton's *Animal Ecology*, one of the first texts in the new science of the early 20th century, began with a clear statement: "Ecology is a new name for a very old subject. It simply means scientific natural history" (Elton 1927). In recent years, numerous authors have reiterated the crucial importance of natural history as the empirical foundation of ecology, as well as related disciplines such as conservation biology and wildlife management (e.g., Noss 1996, Dayton and Sala 2001, Herman 2002, Hampton and Wheeler 2011, Tewksbury et al. 2014, Barrows et al. 2016).

Historia Naturalis – literally, "the story of nature" – was the title of the first century AD masterwork by the Roman scholar Pliny the Elder, which happened also to be the first written encyclopedia, where everything known about everything important in the world was gathered into one place…. or actually into 37 books in ten volumes. *Historia*, which translates into English as both "story" and "history," was expansive and inclusive, and did not focus solely on the past, as the term is sometimes misinterpreted today.

Thus, "natural history" pre-dated its descendent "ecology" by 1800 years. It remains the crucial foundation of our field, providing the critical empirical basis for all theoretical advances, as well as, for a great many of us, the source of our enduring passion for the field. Natural history is also, fundamentally, the practice of careful attentiveness – the practice, indeed, of falling in love with the world. It is literally what our species evolved to do.

The papers that follow in this special series of the *Journal of Natural History Education and Experience* all derive from a special session at the 2019 annual meeting of the Ecological Society of America, organized by the Society's Natural History Section. "*Historia Naturalis: Inspiring Ecology*" was an "Inspire" session – a format in which each speaker has five minutes and twenty slides, which advance automatically every fifteen seconds. After the presentations, a lively interactive session of question and answer ensued in the crowded conference room. The papers included here will give a sense of the rich dialogue and excitement of that session.

This crucial conversation continues within the realm of scientific ecology, and well beyond. Natural history, as these authors demonstrate, plays a key role in inspiring us as scientists and as humans striving to find our places in an ever-better world.

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Using Natural History to Unlock the Past for the Future of Ecological Inquiry

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One reason why natural history is so important now is that we do not know what questions we will need to ask in the future. Natural history collections and field notes can be extraordinary storehouses of information if we curate them well and handle them with the care and protection we would give ancient artifacts or works of art.

More than a decade ago, I relocated to southern California and took a position at a public wildlife agency, where I was tasked with managing an endangered salamander species. As a result, I soon metamorphosed from a bird and mammal field biologist to a mud-covered, wader-clad, nocturnal herpetologist. Naturalist that I was, I quickly learned the local amphibian community assemblage, and came to know individual species in that familiar way that lends a sense of place and homecoming, just as learning to identify birds in different regions of North America had in the earliest stages of my career.

After two years of southern California residency, I was sure I knew the amphibian diversity and natural history of the region; however, I was stunned to learn that (1) there was a frog species missing from the stream-dwelling amphibian assemblage, (2) this species disappeared suddenly and had been missing for four decades, and (3) nobody knew why. The mystery soon became the motivating force behind the questions that drove my dissertation research for the next six and a half years.

The foothill yellow-legged frog (*Rana boylii*) went extinct in southern California sometime in the early 1970s (Jennings and Hayes 1994). As far as localized amphibian extinctions go, that is breakneck speed. Of the many threats to amphibians, only one is known to cause such rapid extirpations in the absence of habitat loss, and that is chytridiomycosis—caused by the fungal pathogen *Batrachochytrium dendrobatidis* (Bd; Berger et al. 1998; Lips et al. 2006, Gillespie et al. 2015).

I wanted to know—could chytridiomycosis have caused the rapid extirpation of *Rana boylii* from southern California? If it was Bd that caused *Rana boylii* to disappear, we might be able to reintroduce them to areas that are in a post-epizootic (i.e., enzootic) state.

However, understanding whether Bd caused the extirpation in the first place is an essential prerequisite to successful reintroduction planning. What caused the original extinction is just one of the many questions we should ask before carrying out reintroductions (IUCN/SSC 2013). But how can we begin to answer these questions if the species is no longer there for us to study?

Inside jars of formalin-fixed frogs and fumigated feathers is a storehouse of information ecologists need in order to answer important questions about phenomena that are no longer directly observable due to the passage of time. Natural history collections, field notes, and even memories hold data that can give us a glimpse into a different time in which now-extirpated organisms lived, and combining natural history collections with local ecological knowledge can open up powerful avenues of ecological inquiry (Golden et al. 2014).

Natural history information from museums, field notes, and conversations with senior naturalists provided the means to address the *Rana boylii* mystery. I sampled over 1500 museum specimens from before, during, and after *Rana boylii*'s decline to see when in time I could detect the pathogen. Using quantitative polymerase chain reaction (qPCR; Adams et al. 2015), I was able to detect Bd DNA in the museum specimens to examine the number of infected individuals through time.

I also conducted interviews with senior herpetologists to confirm their observations of *Rana boylii* in the field before it was extirpated. They told me their stories about looking for frogs in southern California streams and the changes they saw. Many of them took to their garages and attics, dusted off their old field notes, and sent them to me. Synthesizing all of this information, I found that *Rana boylii*'s extirpation coincided with the proliferation of Bd in the region (Adams et al. 2017), suggesting that the pathogen may have played an important role in the frog's disappearance.

Importantly, the interviews made clear that *Rana boylii* disappeared under the radar. Amphibian populations naturally fluctuate (Pechmann et al. 1991), so it was not considered unusual or worrisome when the species was disappearing. One interviewee described observing the declines in real time:

> *"…I would go to places I had seen them and they wouldn't be there anymore… I didn't think anything of it, of course—you see those patterns—but I saw 2 or 3 frogs at a spot one year and then went back 5 years later and didn't see anything. It didn't mean anything [at the time], but when you don't see them any more times that you're out there…then you realize that they're gone."*

At the time that *Rana boylii* was disappearing from southern California, Bd and chytridiomycosis would not be discovered and described for another 30 years (Longcore et al. 1999). Being able to access the past through specimens, field notes, and memories was essential for addressing the mystery of this rapidly disappearing frog because no other information was available.

Joseph Grinnell, legendary naturalist and founding director of the University of California Museum of Vertebrate Zoology, was among the first in the U.S. West to use natural history information to forewarn of the anthropogenic changes taking place in wildlife populations. He had the foresight to begin collecting specimens for scientific purposes in the early 1900s, prior to which there were no systematic efforts to do so. In addition, his emphasis on taking detailed field notes amplified the value of those collections. He wrote,

> *"Many species of vertebrate animals are disappearing; some are gone already. All that the investigator of the future will have, to indicate the nature of such then-extinct species, will be the remains of these species preserved… "* (Grinnell 1922)

Turning to specimen collections for ecological data amplifies existing research infrastructure by making better use of what is already available, while leveraging technology and applying it to collections enables the information to be shared all over the world (Lips 2011). Natural history collections provide long-term ecological datasets in the absence of systematic long-term monitoring programs (Lister and Climate Change Research Group 2011), and they can provide a window into past environmental conditions that inform models of current and future conditions (DuBay et al. 2017).

Just as Grinnell had the foresight to appreciate the value of collections 100 years ago, it is essential that ecologists, naturalists, and citizen scientists work to document and preserve biodiversity for the ecological questions yet to be asked. What can we do to ensure natural history collections are preserved and maintained for ecological inquiries yet to come?

My answer is four-fold. We can *advocate* for natural history collections at local institutions and support them. We can *use* natural history collections for our research and teaching. Natural history collections are an undervalued resource for undergraduate education that allow for direct observation and wonder of the natural world, and digitization of collections have made their use in classrooms more accessible than ever (Cook et al. 2014). We can *practice* natural history, and record biodiversity information—whether with field notes or a smartphone app. We can *share* our knowledge, expertise, and love for nature.

The steps we take today to honor and preserve natural history will serve to address ecological questions we can't yet comprehend; let's preserve the past to provide more hope for a better future.

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NextGen Natural History: New Technologies for Classical Natural History Questions

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Persistent questions regarding the identities of organisms and their relationships to environments have driven natural history through the millennia. Tools to investigate and record findings have changed, with recent innovations in genetic, tracking, and visualization technologies allowing naturalists new insights into long studied systems. These new approaches to classical questions – "NextGen Natural History" – have changed the content of the naturalist's field bag and enhanced the inherent wonder and appreciation in the discipline.

Figure 1. Larval eels can be connected with adult forms using genetic barcoding. (Image by Danté Fenolio.)

Natural history as a discipline is old, but it is not, and has never been, in stasis. Binoculars first came to be used in the field in the early 1900's (King 1955). SCUBA equipment came later, with popularization in the 1950's, but both are now accepted among the common tools used by field biologists and naturalists. It is our argument in this paper that natural history has always been a discipline of innovation, and that remains true today.

Genetic and Genomic Tools in Natural History

The majority of the world's organisms are challenging to work with. They live in difficult environments, often only coming into human range during a particular season or time of day – or not at all. This has made some basic natural history questions difficult to answer despite the persistence and curiosity of natural historians.

The power of genetic tools, developed over the last 20 years, is changing the questions that can be asked and answered by both professionals and hobbyists. The development of common gene regions as genetic barcodes has facilitated a suite of new tools and techniques. Use of barcoding technology to sample biodiverse environments has revealed the presence of "dark taxa" – abundant species that are not represented in traditional sampling strategies but are likely to be playing important and completely unknown roles in the ecosystem.

Genetic barcoding also provides insights into complex life histories and ecological interactions by serving as a “license plate reader” through which genetic identity can be established even in the absence of taxonomic identity (Barat 2016). This separation means that pelagic larval forms (Figure 1) can be connected with deep ocean adults by relying on sequenced biodiversity collections and large inventory projects (Plaisance et al. 2009, Templado et al. 2010), rapidly sequence gut contents to draw insight into trophic connections (Jakubavičiūtė et al. 2017, Casey et al. 2019), or even search for the presence of specific taxa in environmental samples of water, soil, or air.

Instead of digging into a coral reef matrix, scree slope, or aquifer, scientists can now also use environmental DNA (“eDNA”). For example, the DNA barcodes present in a few drops of well water are being used by the San Antonio Zoo’s Mexican Blindcat Program to locate previously unrecognized populations of deep subterranean fishes, crayfishes, and salamanders and track the population dynamics of challenging species worldwide (Adams et al. 2019).

*Figure 2. The ecological relationship between deep-water anglerfishes (*Limnophryne spp.*) and their bacterial symbionts can best be understood through genetic tools. (Image by Danté Fenolio.)*

Whole genome sequencing, using much more genetic material, is also being used in creative ways to increase understanding of natural phenomena. For example, the DEEPEND Consortium is looking at the evolution of the symbiotic relationship between bioluminescent bacteria and deep-water fishes. With observations limited to trawled specimens, an understanding of the natural history of these taxa is greatly expanded by genetic approaches that allow documentation of the impacts of coevolutionary processes in extreme environments (Figure 2).

Genetic techniques can also be paired with machines that allow reaching environments previously inaccessible to the human body. The use of aerial drones and aquatic ROVs has expanded sampling strategies to include exhaled whale breath (Geoghegan et al. 2018), diverse photographic sampling (Christie et al. 2016), and both deep water and aerial environments (Thatje et al. 2008, Johnston 2019).

Remotely deployed devices (RDDs) have allowed close contact with species that would otherwise be impossible to see in life. For example, the first documentation of a live Giant Squid (*Archyteuthis dux*) in US waters and in the Gulf of Mexico was delivered by the MEDUSA device, developed and deployed by Dr. Edith Widder in the summer of 2019.

Not all “drones” are machines, and creative NextGen naturalists are using the keen senses of organisms to take biological samples. Examples of this are the use of honey produced by bees as a sampler of local flowering plants and phytophagous insects (Utzeri et al. 2018) and blowflies for vertebrate carcasses and scat (Lee et al. 2015). Another ingenious use is to analyze the diets of leeches (ingested DNA) to survey past and present forest communities (Siddall et al. 2019).

Letting the biology of the system reveal itself through these new molecular approaches allows the reconstruction of interaction networks not available to standard observational natural history protocols. In almost every situation, the level of partitioning demonstrated is remarkable (Casey et al. 2019).

Tracking and Motion

If finding and identifying organisms represent primary problems for naturalists, then following organisms through time or landscape is an escalation of this difficulty. These issues have been eased by the recent advancements and shrinking size of tracking technologies.

Approaches to tracking tree frogs vary; bulky radio transmitters or thread spools (Gourevitch and Downie 2018) represented significant challenges to the wellbeing of the animals. Passive integrated transponders (“PIT tags”) and associated antennas allow for the short-range acquisition of location data from a microchip implanted in the body of an animal. Danté Fenolio and the San Antonio Zoo’s Center for Conservation and Research are developing a project that will use PIT tag gate systems to follow cryptic predatory dragon frogs (*Hemiphractus*) in the Peruvian Amazon.

Banding birds gave naturalists a sense as to how huge of an undertaking bird migration is for both the birds and anyone attempting to follow their movements. The data and stories generated by banding hinted at the extremes of migration, which have been further elucidated by the development and miniaturization of new technologies in registering and transmitting data.

Transmitters, once restricted to large mammals and the largest of birds, are now small enough that they can track Arctic Terns (*Sterna paradisaea*) in real time as they migrate from one pole to the other, for multiple seasons (Egevang et al. 2010). Other techniques can be used with even smaller devices, such as light-level geolocators, which provide geographic placement of an individual organism based on light availability at a given latitude (Courmier et al. 2013).

Size-of-device still limits our capacity to study small organisms, but even this barrier may be falling through the development of transmission-and-relay networks specifically targeting animal motion. The "internet of animals" is a term used to describe several systems operating different technologies and different distances, including Motus, ICARUS, and MoveBank.

*Figure 3. Juvenile African Wild Dogs (*Lycaon pictus*) fight over and play with the head of recently killed Impala (*Aepyceros melampus*). (Image by David W. Shaw.)*

These systems share an emergent ability to track even small organisms, relaying complex data to low orbit satellites or another tagged animal, such as a Turkey Vulture (*Cathartes aura*) circling overhead. Perhaps the most exciting element of these networked systems of tags is that they may relay not only geographic location but a host of other parameters such as weather conditions, health, or diet.

As an undergraduate, McKeon (1997) followed New World vultures around thermals of central Mexico in a hang glider trying to understand how they were using thermal energy to maximize available food resources. Dreelin et al. (2018) asked the same question of three swallow species in New York. In the twenty years between the two studies, the question remained largely the same, while technology advanced significantly.

Dreelin et al. (2018) were able to use a barometric pressure logger smaller than a dime (Shipley et al. 2018) attached to the back of the swallows to track how high the birds were going without joining them in the sky. They showed that each swallow species spent proportionally more time at different altitudes, revealing a basic ecological pattern of the aerial insectivore community. Similar technologies, combining geographic locality, altitude, and speed of travel, are being used to examine the movements of American White Pelicans (*Pelecanus erythrorhynchos*), revealing that the birds routinely get up to 30,000 feet and use thermal energy to cover huge distances (Davis 2018).

Optics, Photography, and Lenses

The ability of naturalists to use optical lenses to see and record information about the natural world has had a tremendous influence on the understanding of biodiversity. Starting with early microscopes and the adoption of binoculars by ornithologists, innovation in optical lenses have transformed the fields of ecology and natural history. Lens quality, sensor size, and image stabilization have added to the ability to capture both identity and behavior (Figure 3). Three tools now available to almost all naturalists on this front are trail cameras, "stacked" photographs, and cell phone cameras.

Trail cameras or camera traps were originally designed as security cameras for human habitations and businesses, and hunters quickly co-opted them to census target populations. With such a large group of people supporting the technology, camera traps have become a staple for studies of regional megafauna (cf., resources at eMammal).

Digitally stacked photographs utilize computer software to create images that are not limited by depth of field. This technique allows every curve, spine, and detail of an organism to be viewed simultaneously (Figure 4). The availability of these details changes the speed and effort involved in taxonomic descriptions and census efforts (Mertens et al. 2017).

The quality and availability of cell phone cameras has also changed the number of natural history observations. Operating on the principle that "the best camera is the one you have with you," the power and ubiquity of cell phones has made macro photography of small organisms a reasonable prospect for many casual observers, while pairing this function with the platforms and applications needed to create functional community science projects.

Information Sharing and Community Science

The combination of tremendous computing power, functional cameras, and access to taxonomic keys, field guides, and supportive communities via cell phones has resulted in sharing of natural history information in the last 10 years that is unprecedented and spectacular. eBird, the largest of the natural history community science and information sharing platforms, has over 500,000 contributors who have submitted over 50 million checklists and 700 million observations. Data of this scope and scale applied to natural history questions have never before been available. Direct conservation outcomes have resulted from the application of these data (Sullivan et al. 2017).

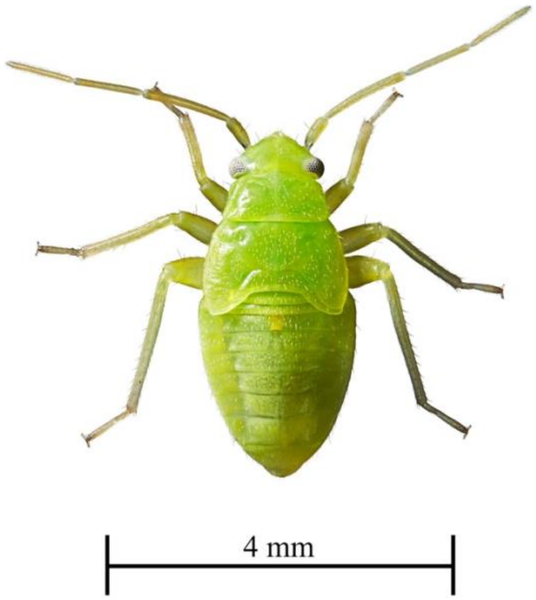

Figure 4. Modern macro photography facilitates identification and description of challenging subjects such as this immature Mirid. (Image by Zachariah Kobrinsky.)

And such tools are not just oriented toward birds. iNaturalist registers observations of all taxa, while many taxa have their own platforms aggregating information and giving voice to communities of enthusiasts who have never before had an opportunity to share their joy for the natural world with a global audience (Appendix 1).

Moreover, both eBird and iNaturalist have leveraged their open-access platforms to broaden the audience for participatory natural history. Machine learning techniques and “computer vision” software, combined with the vast repositories of digital media uploaded by participants to each platform, have enabled apps to capably identify numerous species from images (Barry 2016).

Now, any curious observer around the globe can snap a photo, upload it to Seek (iNaturalist) or to Merlin Bird ID (the sister app to eBird) and receive a suggested identification. In this sense, the digital technology of app-driven community science programs has not only enhanced natural history research and conservation, but it has also made engaging with nature more accessible to a significantly broader audience by lowering a fundamental, skill-based barrier to natural history participation.

The Role of Technology for the Future of Natural History

Who gets access to these new tools? New technologies come with prices that may limit the opportunity of many naturalists to use them. Optical tools such as telescopes and binoculars remained out of reach for all but the wealthiest individuals until “increasing availability of European optics made it easier to see birds” in the early 20th century (Weidensaul 2007).

Modern birding is still associated with wealth, with the average income of American Birding Association members recorded as nearly three times the national average (Wauer 1991). Transition from luxury items to utility for both optical equipment and SCUBA was subsidized by early military adoption and production (King 1955, United States Naval Sea Systems Command 1991), and there are similar signs with the electronic technologies discussed here.

“Computing power available per dollar has increased fairly evenly by a factor of ten roughly every four years (a phenomenon sometimes called ‘price-performance Moore’s Law’)” (AI Timelines 2017). As computer processing is the uniting factor of all of the technologies presented here, Moore’s Law is relevant to our expectations of the adoption of these new tools, as is the ubiquity of computers in children’s toys and home furnishings.

The technical ability to participate in current community science programs hinges largely on access to two things: smartphones to record data and cellular signal/Internet availability to upload data. Their rapid global proliferation in the 21st century has made access relatively feasible for many, even across the global tropics. However, these are still significant barriers to participation for those living in remote regions where these technologies have limited penetration, which are arguably the areas where biodiversity data are most sorely needed (e.g., the interior Amazon Basin), as well as use in marine environments, which constitute the majority of the planet.

While genetic analyses are dependent upon computer processing power, the collection and sequencing of genetic material is still reliant on biochemistry. Yet this barrier is falling as well, with the Centre for Biodiversity Genomics now providing LifeScanner, a free, limited opportunity for any individual to submit samples for genetic barcoding and identification. Jonah Ventures is now making beta-kits available to sample eDNA from local bodies of water. Digitization of museum records has been superseded by observation records from platforms such as iNaturalist and eBird, and these observations may be dwarfed by the power of new environmental sampling efforts like eDNA where one sample leads to hundreds of data points. While currently limited because of costs, the potential is great to monitor natural systems with far greater resolution than ever before in the near future.

The generation of technology presented here, like every generation of natural history tech before, provides useful tools to deepen our shared understanding of the natural world. The tools cannot replace the millennia-old character of natural history. The tools do not take you out to the wild places to sit quietly and watch. They don't ask the questions or find the answers. They extend a person's reach; however, it remains the job of our community to tell the stories, to access and protect the wonder and appreciation for nature that truly defines this discipline.

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Appendix 1. A sample of community science organizations with on-line resources.

Organization/Website	**Taxa/Subject**
eBird	Birds
iNaturalist	All macroscopic taxa
Pl@ntNet	Plants
eButterfly	Lepidoptera
eTick	Ticks
Zooniverse	All taxa
BugGuide	Terrestrial arthropods in North America
USA National Phenological Network	Climate, ecology, and timing
Reef Environmental Education Foundation	Coral reef biota and health

Natural History in the City: Connecting People to the Ecology of their Plant and Animal Neighbors

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The world is becoming increasingly altered in ways that drastically affect habitat quality for wildlife (Seto et al. 2012). Moreover, the majority of people now live in urban and suburban areas (United Nations Population Fund 2007), so this is where primary interactions with nature and wildlife are occurring (Cook et al. 2012). Human society is also facing drastic losses of biodiversity and "extinction of nature experiences" in each generation (Dirzo et al. 2014, Soga and Gaston 2016).

Thus, the grand challenge for ecologists and conservationists is to understand how to share the places we live, work and play with biodiversity while simultaneously supporting the people who live there and inspiring them to care about nature as well. Programs that combine community science with natural history in urban areas can uncover new "stories" about local wildlife and provide valuable new ecological information and benefits for people, and inspire personal conservation action "at home."

There are many opportunities to observe and interact with nature in cities, and often it is right in our own neighborhoods. From new species of leopard frogs in New York City (Feinberg et al. 2014), populations of endangered bumblebees in Minneapolis/St. Paul (e.g., Evans et al. 2019), rare plants in Sydney, Australia (Soanes et al. 2018), and even coyotes that steal newspapers off front porches in San Francisco (Heimbuch 2018), cities are filled with flora and fauna that can be experienced right in our yards without venturing into wilderness.

Yet, the ecological relationships of urban wildlife are surprisingly understudied. To borrow from Callaghan et al. (2018), I encourage ecologists and naturalists to embrace the "*unnatural history*" of urban areas to uncover the new and updated stories of how plants and animals are adapting and reacting to a human-dominated world. For example, recent studies of birds have revealed new diet choices, nesting habitats, opportunistic behaviors, and species interactions (Callaghan et al. 2018). By enlisting the help of students and community scientists who live in urban and suburban areas, present-day ecology is ripe for new discoveries about common species that will advance both science and society's ability to conserve biodiversity in novel environments.

Interacting with urban nature is also important for inspiring and enhancing the lives of people as well. The easiest and most accessible place for people to connect with nature is where they live (Cook et al. 2018). For example, as a child, I grew up in a city where I experienced nature not in any national park or wilderness area but in my own backyard. There, I learned about plants and animals that I could relate to because they lived in the same place as me.

Undoubtedly, that experience and accessibility is part of the passion that drove me to a career in ecology today. Recognizing the importance of access to nature and encouraging natural history observation in urban spaces is critical for reducing the gap of inclusivity in ecology, conservation, nature-based activities, and STEM education (Dunn et al. 2006). Moreover, access and interactions with nature can improve well-being, psychological/physical health, and quality of life, which may be disproportionately low in some urban and underrepresented communities (Miller 2005). By encouraging natural history observation as a means to connect with the natural world, the public may also be more likely to also engage in pro-environmental behaviors as well (Scannell and Gifford 2010, Byerly et al. 2018).

It is important to note that the value of natural history for community-based conservation is not a new idea; it is borrowed from indigenous knowledge, which has long recognized the importance for observing and appreciating nature. For native cultures, giving a living thing a name and story creates a sense of familiarity that encourages intimacy and ultimately empathy (Kimmerer 2003).

It may come as no surprise to hear that empathy is also essential to conservation, because if the public is not inspired to care, how can they be encouraged to do something? It behooves us to learn from the wisdom of indigenous people whose land we occupy and ensure that the names and stories of living things are not restricted to universities and journal articles but are shared with a wider community of people.

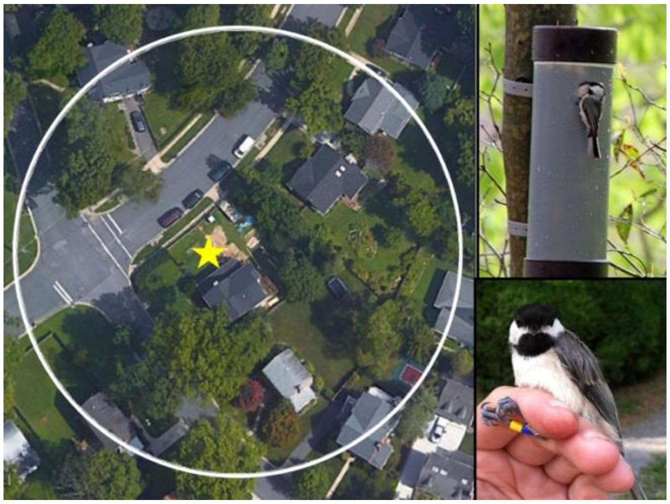

Figure 1. Clockwise from top left: example residential neighborhood study site; Carolina chickadee nest building in a nest box; color-banded chickadee.

Community science (also called "citizen science") is an ideal opportunity to use natural history to learn about urban biodiversity and encourage the public to intimately engage with the natural world (Bonney et al. 2009, Hansen et al. 2018). This became apparent during my dissertation research when I worked on a project called *Neighborhood Nestwatch* (Marra and Reitsma 2001, Evans et al. 2005, https://neighborhoodnestwatch.weebly.com/): a community science program administered through the Smithsonian Migratory Bird Center in Washington D.C.

Through *Neighborhood Nestwatch*, Smithsonian scientists collect data about birds in urban and suburban residential yards with the help of participating householders who also monitor birds on their own properties. This project simultaneously provides an opportunity for householders to learn about ecology and experience the process of science as well (Evans et al. 2005).

During my research, I asked two related questions with separate implications. First, an ecological question: "how do nonnative plants affect food webs?" And second, a practical question for the householders themselves: "How should I garden if I want to create bird habitat?"

To answer these questions, I investigated the story of the Carolina Chickadee (*Poecile carolinensis*), a primarily insectivorous songbird that readily uses urban and suburban areas and is surprisingly understudied. Importantly, they are also charismatic, recognizable, and widely appreciated by the public. Anyone who has given a holiday card or shopped for winter season decorations has probably come across an image of a chickadee. Its widespread familiarity makes it a fantastic ambassador for wildlife, and its specialized diet makes it a great indicator species for the effects of nonnative plants on insectivorous birds.

Using this spritely bird, participants could observe "their chickadees" to learn about complex ecological concepts and evaluate how their decisions affect ecological restoration on privately-managed land. Field coordinators of *Neighborhood Nestwatch* set up nest boxes in yards and color-banded birds so unique individuals could be identified and followed (Figure 1). We asked participants to monitor their nest boxes for breeding activity and re-sight individuals using their yard while I and a team of interns collected additional data. In this way, we gave names to individual chickadees and asked our participants to monitor their stories in real time.

With the help of our participants, we learned about which plants are important for insectivorous birds. In general, we found that when native plants make up the majority of plant biomass in a neighborhood, chickadees have more insect food to eat, they are more likely to nest, and the birds in these neighborhoods produce more young each year (Narango et al. 2018). We were then able to use data that our participants helped collect to give an explicit recommendation that householders and land stewards can use in their management and restoration.

By following individual chickadees, we also learned which native plant species chickadees preferred to forage on (Narango et al. 2017). Using these data, we made maps to illustrate that it really “takes a village” to raise a nest of chickadees and that specific plants could be strategically selected to improve bird habitat (Narango et al. 2017).

During the study, we also documented 51 different species of migratory birds using residential yards on their journeys north (Narango, unpublished data). Most of these species – primarily warblers, vireos, tanagers and thrushes – are not considered “backyard birds” and are typically unknown to the average homeowner.

By engaging in our project, participants learned the name and stories of these transient species and were encouraged to think about the role their yard could play in the full-annual cycle of birds, even if only for a few days out the year. Several participants shared that it was “eye-opening” to learn that a Swainson’s Thrush (*Catharus ustulatus*) that spent the winter in the Amazon rainforest was depending on the trees in their yard in order to make a successful migration to the Boreal forest of Canada to breed.

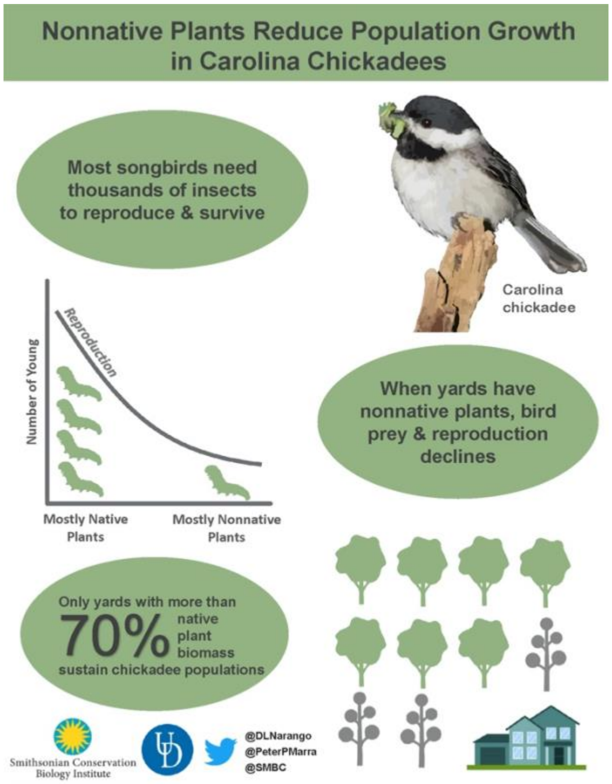

Figure 2. An infographic designed to share the results of our published study (Narango et al. 2018) with participants and on social media.

These conversations opened up new opportunities to talk about how everyone can participate in conservation action in their everyday lives, for example, by purchasing coffee and chocolate grown using sustainable Bird-friendly© agriculture practices (Smithsonian Migratory Bird Center 2019).

This research also shared the stories of caterpillars and other urban arthropods that live in these yards. We invited participants to join us during our arthropod sampling so that we could introduce them to the diversity of amazing species that are overlooked and underappreciated. Insects provide ecosystem services that are globally important ecologically, economically, and agriculturally (Losey and Vaughan 2006), yet they often invoke gut reactions of fear, disgust, or apathy (Shipley and Bixler 2017).

For caterpillars, many participants were aware that monarch butterflies specialize on milkweed plants, but they were surprised to learn that *most* caterpillars are specialist feeders on one or a few plants (Foriester et al. 2015) and that planting host plants, in addition to nectar flowers, could positively affect butterfly and moth populations (Tallamy 2007). Participants were also surprised to learn that insects were critical for the development of baby songbirds (Martin 1987) and that plants included in gardens can be beautiful, colorful “bird feeders.” Using chickadees as a surrogate, we encouraged participants to better understand and appreciate the importance of conserving the “little things that run the world” (Wilson 1987).

Finally, this research shared the story of a scientist. Because we were following the chickadees around their territories, we had the opportunity to meet many inquisitive neighbors. This opened up many spontaneous opportunities to share the project and the plants and animals we were studying. It also gave me an opportunity to share who I am, how I came to be a scientist and what a career in ecology is like.

For many people, I was told that this was their first chance to meet a scientist in person and that learning about our research changed the way they thought about their yard. Having these opportunities to interact with ecologists is critical for improving the public’s relationship with the natural world, as well as trust in science in general (Hansen et al. 2018).

After the conclusion of this study, the feedback I received from participants confirmed that they found the experience to be both enjoyable and informative.

Participants were very excited to learn about the results from this project, which we shared in summaries and infographics after publication (Figure 2). Much of the informal feedback we received indicated that participants were considering birds, and the specific results of our study, in future landscaping decisions (e.g., planting native plants, keeping cats inside). The majority of the participants continue to be involved with *Neighborhood Nestwatch* by helping to collect long-term data collection for the project.

This continued, active interaction between participants, Smithsonian scientists, and involved peers provides encouragement for lasting engagement in natural history and stewardship behaviors (Byerly et al. 2018). There also appears to be a wide interest in more active, “hands-on” ecological projects like these. From the media exposure we received for this project, I regularly receive emails from around the country of people who are looking for similar opportunities or are hoping we could start a research hub in their hometown.

In the end, my project uncovered results that provided a clear answer to my ecological question: nonnative plants used in landscaping negatively impact habitat quality for birds. In addition, I used natural history observations to demonstrate that yards matter and that simple choices made in everyday landscaping can have far reaching implications for ecological interactions.

A community science project that invites householders to engage with the process of science – where the complex nature of food webs was distilled down to an easy-to-recognize story with names for the characters – can be used as a means to help people evaluate and appreciate their “backyard habitat.” With more programs like these that combine natural history, urban/suburban ecology, and community science, these stories can encourage people to care enough to do something about conserving biodiversity at home.

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Drawing Inspiration in the Eastern Sierra Nevada

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Field-based teaching has long been an essential component of natural history education, providing students with spatial, temporal, and sensory context for the study of natural history. The field journal, or nature journal, is used by many natural history educators to augment field-based teaching and help students develop systematic approaches for documenting observations and practicing communication skills (Farnsworth and Beatty 2012, Farnsworth et al. 2014).

The field journal offers students opportunities to use multiple modes of observation, inclusive of writing, diagramming, quantification, and drawing to describe, explore, and gain perspective on natural history subjects (Laws 2016). Whereas college students in natural history courses are generally comfortable with using most of these observational modes to record information in the field, many initially lack confidence with using drawing to do the same. Yet drawing, because it requires students to pay such close visual attention to natural subjects (Keller 2011), is an observational mode particularly *apropos* to teaching natural history as it embodies, like natural history itself, "a practice of intentional, focused attentiveness and receptivity" (Fleischner 2001, 2005, 2011a,b).

In 2013, we began to incorporate an element of field sketching into a natural history field course that we teach in the Eastern Sierra Nevada Mountains of California. Our intention was to offer students an opportunity to develop drawing as part of a larger skillset that would encourage observation, attentiveness, and curiosity.

We were motivated to take this approach through reflection on our own prior experiences as students, in which we spent considerable time observing, learning, and practicing geology in the field as part of our training in the earth and environmental sciences.

Some of our field-based education had involved formal training in mapping techniques. More typically, however, our field experiences consisted of trips involving numerous, brief stops at points of geologic interest – without opportunities to formally study methods of observation or integrate geological observations with other aspects of natural and environmental history.

As we developed our course, we envisioned a field-based experience that would provide students with an observationally focused and holistic approach to learning about natural history, in a place that had long inspired our own love of learning about the natural world: the steep eastern escarpment of the Sierra Nevada, the neighboring White-Inyo Mountains to the east, and the valleys and inland seas cradled by these great ranges.

The geologic bones of the Sierra Nevada and White-Inyo Mountains are sheathed in a living skin that responds to steep climatic, bioregional, and topographic gradients with a blossoming of diverse biotic communities, ranging from sagebrush scrub to juniper-pinyon woodlands to shady subalpine forests to fell-fields sheltering pincushion flowers among frost-heaved blocks of talus. This region is the ancestral home of the Paiute people, and it continues to play center stage in California's enduring conflict over water.

The Eastern Sierra's biological diversity, stunning lithological variety, geologic exposure, palpable human and environmental history, and proximity to the Stanford University campus all made the region a particularly appealing locale in which to offer our course. There is also a numinous current in the big, old mountains that reminds us of a primal, ancient order of which we are a part.

As much as we desired to offer a course that would introduce students to a practical skill, we also desired to share with them a landscape we had come to love for its luminous and dramatic natural beauty. We hoped that such a landscape might help inspire students to slow down and encourage them to practice an attentiveness that could inspire curiosity and foster a sense of place – as it invited them to make independent observations and discoveries about natural history generally, and about this place in particular.

Our course, Natural Perspectives, incorporates four main elements: (1) mini-lectures, taught in the field, that focus on specific aspects of the natural and social-environmental history of the sites we visit, (2) instruction in the use of a field journaling protocol for systematically making and recording field observations, (3) instruction in basic techniques of field sketching with pen and ink and watercolor, and (4) time for students to use drawing to observe and record the natural features of the places we encounter.

The third and fourth elements are of particular importance in that they enable students to build comfort and competence with using drawing tools and techniques over the course's duration.

Figure 1. Photograph of a page from our student Kelly Dunn's field journal illustrating elements of the journaling protocol used in Natural Perspectives.

Our journaling protocol builds on schemes described by Farnsworth et al. (2014) and Laws (2016). Students are asked to use multiple modes of observation, with an emphasis on drawing. They are provided with a template for the kinds of information they should record at each stop, where they are also asked to complete a longer drawing assignment that emphasizes the use of a particular drawing technique or approach. The protocol also emphasizes reflective synthesis, with students prompted at the close of each day to integrate their insights and observations with the themes discussed.

Figure 1 illustrates an exemplar of a page from a student field journal in which several of these elements have been incorporated. Requiring students to adhere to the protocol helps us strike a balance between providing students with structure and encouraging open-ended inquiry with direction and purposiveness. Lastly, students have opportunities to share their journal observations with one another, a practice that helps build community among the student cohort and enables students to learn from and encourage one another.

What exactly do students gain from our time in the Sierra, learning to pay attention through drawing and keeping a field journal? Since we started teaching the course, many students have noted how much they have appreciated the opportunity that the course provides for them to spend time in a beautiful place with a clear intention and purpose.

One student noted, in a comment representative of many we've received in our course evaluations over the years, that "the class really made me stop and take in the world around me." Another student, a talented ecologist and poet – shared with us that using drawing to observe the natural world is "so amazingly different from using words – it enables you to notice details that you wouldn't otherwise."

Another student, also trained as an ecologist, noted that although he'd participated in other field courses in which he'd been encouraged to "look around and notice things," never had he done so in "such a systematic and intentional way" as he had in our course. Although he acknowledged that drawing and keeping a field journal at first "seemed daunting," he also noted that it provided him with an observational tool that led to insights about the ecology of the Sierra Nevada, and in particular aspects of the structure of the range's conifer forest that he had not noticed or appreciated before, even though he'd traveled through the region many times throughout his life.

Another student, reflecting more philosophically, reminded us that "nature journaling affords an opportunity to cultivate a practice of delight and wonder." She noted that the practice of nature journaling situates the practitioner at a "nexus of the scientific and the spiritual" and "enables one to hang on to delight and joy" that for so many students can be easily lost when engaged in the consuming work of scholarship in the natural sciences.

We've found in our course that teaching students how to use drawing to observe the natural world enables them to slow down and pay attention. It is an especially important opportunity for our students at Stanford, who are so frequently overcommitted, overscheduled, and overworked. Despite the busy demands of university life, many of our students have continued to maintain a nature journaling practice using techniques they learned in the course.

Two former students went on to develop their own nature journaling class, which they taught at Stanford's Jasper Ridge Biological Preserve (Chay et al. 2018). This past fall, another former student created a short documentary about the practice of nature journaling that featured several course alumni. In providing instruction to help students use drawing and maintain a field journal in our class, our aim was to offer them a tool to encourage attentiveness and observation as part of a natural history practice. Yet what we did not anticipate was how impactful and enduring this learning would be for so many students.

Using drawing as an observational practice invites us to look carefully – to see a thing as it is – not as we think it is supposed to be (Keller 2011). Drawing invites us, and challenges us, to concentrate our attention on relationships of shape, proportion, color, value, and form. More than just perceiving visual relationships though, drawing trains our powers of observation to notice that, upon close study, things are more nuanced, more interesting, and more complicated than we might have imagined otherwise.

Drawing is a practice that invites students to pause and wonder and ask questions about the world in front of them – why volcanic landforms running south of Mono Lake are arranged in a line, why the species of plants growing in a recently burned area are distinctive from those that preceded them, or why some heaps of glacial moraine have a softer, more rounded appearance than others. Drawing not only leads students to deepen their intellectual inquiry, but it also directs them to channel attention in a way that can serve, as noted by Sewall (1995), as a "first step in ecological seeing" that draws us to beauty "and thus to loving the landscape."

We are drawn to paying attention, as part of a natural history practice, for the way it can help us maintain connection with the beauty, wonder, and mystery of the natural world – and in the case of the Eastern Sierra, with the beauty, wonder, and mystery of a particular place. Students return from their experience in the Eastern Sierra having developed a skill that, if they continue to practice it, can enable them to deepen their relationship with nature.

Teaching students how to cultivate drawing as part of a natural history practice within the context of field journaling provides them with a specific, focused entry point for learning how to practice attentiveness. The value of drawing in a course such as ours is that it leads students to make more acute and insightful observations, just as it offers the potential for providing an engaging way to deepen curiosity, sharpen observational power, and increase students' intellectual ownership of and commitment to their learning about the natural world.

Acknowledgments

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Natural History of a Silent Forest

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Natural history is a "practice of intentional, focused attentiveness and receptivity to the more-than-human world, guided by honesty and accuracy" (Fleischner 2002). Some interpret this as an ability to identify to species every wildflower in a field or to keep a lifetime phenological field journal or to recall life history facts about mammals. I understand it best as a commitment to observing a single place across seasons and years.

In a time when ecology promotes chasing the next big global review, I want to put in a plug for getting to know one place intimately. Commitment to a place provides the opportunity for unanticipated observations and personal connections, which in turn can lead to novel scientific insights and better conservation outcomes (Billick and Price 2010).

For me, this place is the Mariana Island chain, which is south of Japan, north of New Guinea, and east of the Philippines (Figure 1). First populated around 3600 years ago by the CHamoru people, about 219,000 people live in the present-day U.S. territories of Guam and the Commonwealth of the Northern Mariana Islands.

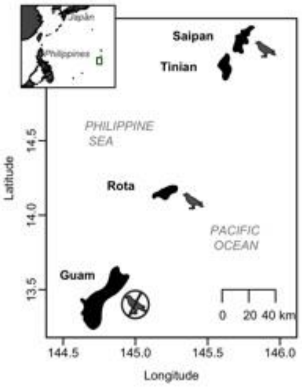

Figure 1. Map of the Mariana Islands.

The Brown Treesnake was introduced to Guam in the mid-1940's and ate its way through the island's birds and bats (Savidge 1987, Wiles et al. 2003).

Motivated by a passion for both understanding how the world works and doing my part to leave it better than I found it, I moved to Guam in 2002 to start the U.S. Geological Survey's Brown Treesnake rapid response team. For three years I traveled between islands in the Western Pacific doing outreach about these invasive, nocturnal snakes and looking for new populations. While slowly scanning the trees for well-camouflaged snakes, I couldn't help but notice differences between Guam and islands that still had birds.

The most obvious difference was the sound. On Saipan, the jungle chatters with birdsong, but on Guam, the forests are silent. I started to wonder what would happen to a forest that doesn't have birds; I noticed more spiders there than on nearby islands, but what else was happening?

I headed off to graduate school to complete a Ph.D. in community ecology, with the intention of then transitioning to a career in the conservation non-profit world where I could make a difference on a global scale. The unanswered questions and welcoming people of the Marianas beckoned me back, so I spent my PhD exploring the impacts of bird loss on the forest.

Towards the end of graduate school, I found myself seeking advice from mentors about whether I could have a bigger impact on conservation by pursuing a career in an NGO as I had planned or staying in academia, continuing my research in the Marianas. Taylor Ricketts, an ecologist who at the time was transitioning from a position as director of the Conservation Science program for the World Wildlife Fund back to academia, asked me whether I wanted to be known as the "Guam Ecologist" 20 years down the road, and my immediate reaction was emphatically "no."

While I loved the Marianas, I hoped to have an impact on a larger scale. Plus, I had the impression that one's academic career would suffer if they focused on a single system. The signs pointed towards leaving Guam behind to pursue other options. But there were still a few big questions I wanted to answer in the Marianas, and I was just starting to have an impact on local conservation. So I accepted a fellowship where I could continue my research on the impacts of bird loss.

And then four years later, when I still wasn’t quite finished asking questions in this system, I accepted a faculty position, and started advising my own graduate students pursuing research in the Marianas. And now, I wholeheartedly embrace my place-based research program. As Billick and Price (2010) wrote in the summary of their edited volume on how place-based research has advanced ecological understanding, “sustained place-based research is a powerful way to gain both general and local ecological understanding.”

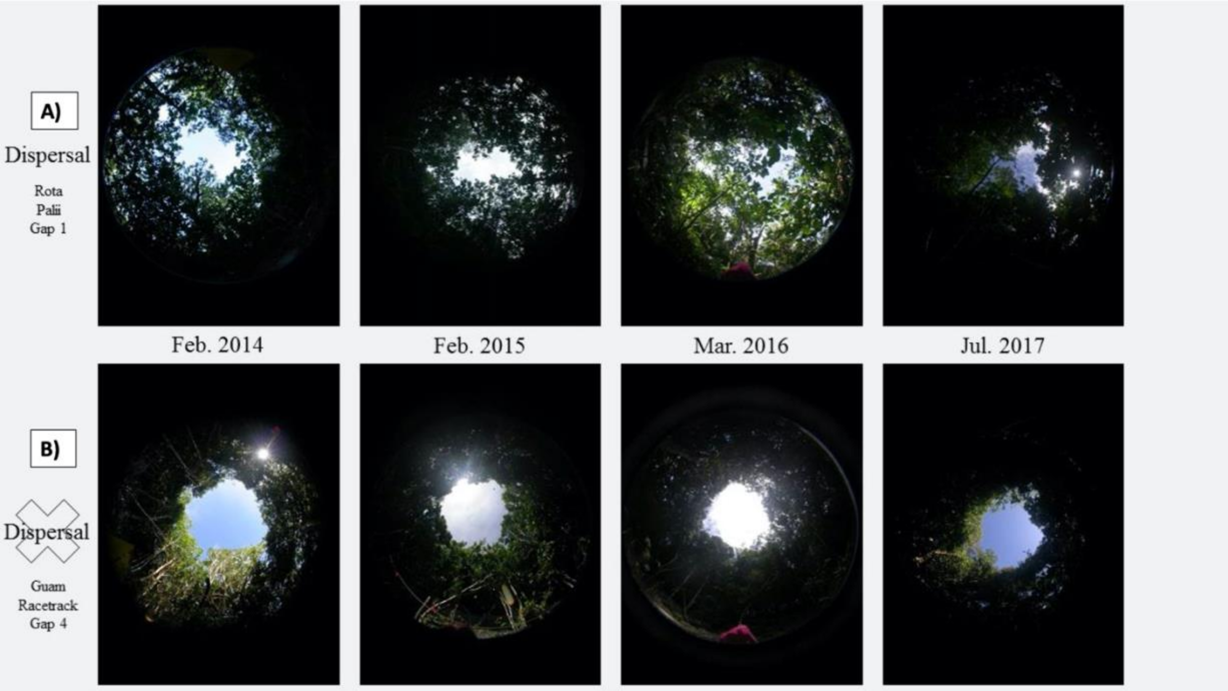

Figure 2. (A) A gap on Rota, with frugivorous birds and bats, demonstrating normal treefall gap closure over 3 years. (B) A gap on Guam, without frugivorous birds and bats, that is still open after 3 years.

Over the last 17 years, a large part of my team’s research has focused on what happens to a forest when it loses all of its frugivores, or fruit-eaters. Because of the Brown Treesnake, four of the native frugivore species are gone, and the other two – the såli (Micronesian starling) and the fanihi (Mariana fruit bat) – remain in tiny populations in one part of the island, leaving Guam’s trees without anyone to disperse their seeds.

My graduate school training guided me to look to the scientific literature for help with making predictions of the impacts of disperser loss, so that’s where I started. The literature told me that frugivory benefits plants by increasing germination after gut passage (Traveset and Verdu 2002), facilitating a seed’s escape from high mortality underneath its parent trees (Janzen 1970) and enabling seeds to colonize new areas (Howe and Smallwood 1982), so I designed field studies to assess those benefits. But two of my favorite projects were inspired not by this secondhand knowledge from the scientific literature but by my primary observations of this “more-than-human world.”

First is a project I call “The Experimental Gap Project,” which explored the importance of seed dispersal for forest structure. In 2008, I noticed a forest gap at one site on Guam and wondered why it was so big. On each subsequent visit, I wondered why the gap wasn’t filling in like gaps do on other islands but instead seemed to be getting larger.

Invasive deer were surely part of the problem, but I hypothesized that bird loss might be another. Without frugivores, I thought, quick-growing pioneer species weren’t reaching the gap, and as a result the gap was staying open longer. So, with a grant to test that, we created experimental treefall gaps on Guam and two nearby islands with birds in 2013 and monitored them every year to see what seedlings were growing and how well the gap was closing (Figure 2).

Postdoc Elizabeth Wandrag showed that gaps without dispersers were missing those pioneer species that grow quickly to fill in the gaps (Wandrag et al. 2017). This link between seed dispersal and forest structure was the result of keeping an eye on the same spot over several years and wondering why it was different.

The second project demonstrates why seed dispersal matters to people. The donne såli, a spicy chili pepper, is a beloved ingredient in local food. People collect and sell donne såli in the markets and celebrate at annual donne såli festivals. Several years after I started studying seed dispersal, a farmer told me that "donne" means pepper and "såli" is the name for the Micronesian Starling, and that the name for the chili pepper is because the "såli plants the pepper."

A light bulb went off: Donne såli seemed more common on Saipan and Tinian than on Guam. Perhaps this was because the birds were gone?

Figure 3. Donne såli, the wild chili pepper in the Marianas, is gathered from the wild (A) and made into hot pepper sauce (B).

Monika Egerer, an undergrad at the time, and I collaborated to figure out just how much the donne såli depends on the såli and whether other birds also "plant the peppers." We interviewed donne såli harvesters on Tinian and Saipan, we talked to people on Guam who remember when birds were still around, we revisited the locations of specimens found in the herbarium on Guam, we did feeding trials with birds on Saipan, and we put cameras on donne såli to see which birds came to visit.

We saw a såli fly away with a donne såli in its mouth, true to its name (Fig 3). As one of our interviewees told us, the såli are the farmers of the forest. We found that while multiple bird species eat donne såli, gut passage by såli increases germination the most (Egerer et al. 2017). And on Guam, the only place that still has wild donne såli is the small area where the såli persist. Seed dispersal, it turns out, affects both plants and people.

Over the years, my team has learned that a silent forest is one that is less diverse, more open, and less likely to recover from disturbance. A silent forest is home to lots of spiders but no donne såli (Rogers et al. 2012).

Thankfully, that future isn't guaranteed. I am working with many others to bring native birds back to Guam. It is now possible to control snakes using aerial drops of acetaminophen glued to a dead mouse (Engeman et al. 2018). This, coupled with snake fences, may allow us to expand the såli population and watch the forests recover. Perhaps that persistent gap in Guam shown in Figure 2 will one day be filled and there will be donne såli across the island again. And by turning this conservation nightmare into a conservation success, we may be able to give hope for ambitious conservation projects in degraded systems worldwide.

I will finish with a few parting thoughts. First, paying attention to local natural history benefits ecology and conservation broadly (Louda and Higley 2010). As Vepsäläinen and Spence (2000) write, "useful generalizations are likely to be built only with knowledge and understanding of biological details." We would not have discovered the link between dispersal and forest structure without careful observation and a comprehensive knowledge of the system.

Second, natural history comes in many forms. For me and many other place-based ecologists, it's about spending a lot of time in the same system, observing the same places year after year (Paine et al. 2010). You can't fast-track this process.

Finally, and most importantly, as scientists and conservationists, we must value and invest in the people living within these places we study and protect. It's worth it. I love to stumble upon my favorite shrub, *Discocaylx megacarpa*, with its emerald green leaves and cherry red fruit, in the jungles of Guam. But this pales in comparison to seeing the grad students from the Marianas in my lab use new techniques to explore their home islands and then present their results at a conference, or introducing high school teachers in the Marianas to field research, or bringing students from Guam to Saipan to hear birds for the first time.

I am grateful to the people of the Marianas for welcoming me to their islands and to the other species for sharing their secrets with me. My life and the field of ecology is richer for it.

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How Natural History Shapes Purpose, Culture, and Identity in Ecology

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Natural history is who we are as ecologists. I understand such a general statement is not quite this simple, but as natural history informs our purpose and identity, it is a big part of the story.

Natural history shaped many of our individual identities as ecologists (McKeon et al. 2019). I remember when I was about six or seven wanting so badly to see the baby robins in our birdhouse that I tipped one out and held it. I still feel a little guilty about that, but the chance to look at it and touch it spurred love of the living world and got me started in this direction.

This identity is also intergenerational, in both formal and informal contexts (e.g., Cristancho and Vining 2009, Zimmerman and McClain 2014). My parents, who immigrated from mountain cultures, centered family time in natural areas when I was little. They did this even though we lived in the city.

Figure 1. Leticia Santillana, a Doris Duke Conservation Scholar at UC Santa Cruz, meets the Pandora moth (Coloradia pandora) in forest lands of the Northern Paiute. (Photo by Diana Martinez.)

My nine-year-old daughter, who wants to be an ecologist too, has grown up chasing and catching animals. Last August, she drove us in a friend's skiff off the California coast to get in the middle of one of the great remaining animal migrations on Earth, of sooty shearwaters traversing the Pacific. These birds come down the California coast each summer on their way to New Zealand.

My husband and I are sharing with our children our lifelong fascination with migratory animals and tying that to a family culture that values understanding how these migrations bind us to other places, cultures, and history.

Place and migration, and my fascination for people's relationships with them, led me to my master's work in the Yukon-Kuskokwim River Delta in the early 1990s. There, Yup'ik communities depend on arriving migratory waterfowl as spring food, when ice melt impedes ground travel (Zavaleta 1999). My time in Alaska revealed not only how inseparable natural and cultural history can be, but also how bodies of intertwined knowledge grow and are transmitted over time and how individuals and families in such communities carry that knowledge on and up in daily life. Working in the Delta taught me that natural history is also, always, cultural history. Nearly every landscape has a peopled history, and its ecology reflects that long human relationship.

Today, teaching natural history in connection to cultural values and shared history can bring it alive for students from a wide range of backgrounds. This happens because students want to integrate natural history with their experience, which for some of them has little nature in it but for all has relationships, place, and history in it.

I have been thinking a lot about identity and belonging over the last five years as I build two programs aimed at inviting broader perspectives and voices into the fields of ecology and conservation through shared field experiences – the Doris Duke Conservation Scholars Program (https://conservationscholars.ucsc.edu/) and the CAMINO (Center to Advance Mentored, Inquiry-based Opportunities, http://camino.ucsc.edu/) at the University of California, Santa Cruz. Identity – who we are – and belonging – how this situates us in community with others – are discussed little in the field of ecology, but they guide whether and how we choose this field. Understanding ecology's roots in natural history, and natural history's roots in wider and deeper knowledges across cultures, connects them to shared human experience.

Today when my students and I learn about the piagi, which is the Pandora moth larva's Paiute name (Fowler and Walter 1985), its relationship to frequently burned Jeffrey pine forests east of the Sierra, and the ways in which logging and fire suppression had made a mess out of them throughout the 20th century, we learn it in the field (Figure 1). We learn it from Paiute elders and Bishop Paiute youth who speak from the lens of accumulated cultural knowledge of the moth as food and relative, tended with care for hundreds of generations. Natural history is cultural history.

And what is culture? Like genes, it can be transmitted vertically to subsequent generations. Unlike most genes – bacteria and viruses notwithstanding – it can also be transmitted horizontally, among unrelated individuals, like we are doing through this journal. Culture also includes a cumulative accretion of knowledge that builds on what came before, like new sediment in a lake core that knows all the layers below it.

The kind of cultural history I am talking about includes other parts, not only indigenous cultures. If we look at the transmitted, collective, cumulative knowledge of ecology as a field and a community, it is natural history. Natural history has fed, responded to, and co-evolved with ecological theory throughout our field's history (Hagenbuch 2006, McKeon et al. 2019). A concept like the Grinnellian niche was born from Joseph Grinnell's careful observation of species like the Gray-crowned Rosy-Finch in the California Sierra Nevada (Grinnell 1917). Now that niche concept underpins how we understand and model all kinds of ecological responses.

As scientists we might think of ourselves as outside of any culture (Forsyth 2011), but we have a cultural story. That cultural story is natural history. Natural history is ecology's cultural foundation (Jardine et al. 1996, Wessels 1997). I want to be clear; I am not saying that natural history is just our past and currently out of style. I am saying that it has driven theory-building and testing throughout the history of our field, and it continues to do so today (Dayton and Sala 2001). Ecological hypotheses still come from observation, and field knowledge is still the only way to ground truth and validate our conclusions (Sagarin and Pauchard 2012).

These days I study the several species of rosy-finches in North America. I use both my lab's present-day observations and those made by Grinnell a century ago to build models of the rosy-finch's niche as it is today and projected to be in the future. In doing this work, I feel as though I am part of something bigger than myself. Some of this feeling comes from knowing the birds and the ecological system of which they are a part, because who would really care about these birds without knowing them? And part of this feeling of belonging comes from being able to build on the intertwined ecological and natural history knowledge of my predecessors in our field – those relationships and history – and being able to share that with others.

To say that ecology requires natural history is true, but it is not the whole point. Natural history defines who we are as ecologists. We depend on it for our work, and we need it for our shared sense of purpose in the body of understanding and relationships that make up ecology.

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