ENVIRONMENTAL HUMANITIES IN PRACTICE

Squished Bugs

Teaching and Learning Reflexivity in Ecology

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Abstract Field guides have been a vital part of biology disciplines for centuries. This article focuses on recent pedagogical innovations in biological fieldwork, in fields such as entomology and ecology—specifically, the creation of informal field guide photographs that depict insects as ecologists-in-training are most likely to encounter them: dead and squished on cards, in nets, and on other types of insect traps. This article examines the training of ecology technicians to identify collected insects in the field and the laboratory. Technicians (whether students or volunteers) are trained to the squished reference images, with the goal of improving their insect identification skills and aid in ecological knowledge production. Using this empirical example, the article argues that squished bugs more importantly represent a pedagogical opportunity to instill an ethical reflexivity in field technicians operating well outside of academic environmental humanities circles. Drawing on multispecies studies' (and its animal studies antecedents') focus on environmental ethics, as well as the scant but growing attention to "unloved others" like invertebrates, squished bugs are used as a way of reckoning with the destruction and deformation of life for the sake of conservation knowledge and, as Donna Haraway has suggested, "staying with the trouble" of killing insects.

Keywords insects, ecology, multispecies studies, ethics

Introduction

Field guides have been a vital part of various field biology disciplines for centuries. In both ornithology and entomology, to take two prominent examples, field guides have been created by and for scientists for a variety of purposes: as art, as educational tools, and to aid both professional and avocational naturalists attempting to identify species and individual animals in the field.[1]

1. Dunlap, *In the Field, among the Feathered*; Crist, *Images of Animals*.

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This article focuses on recent pedagogical innovations in entomological fieldwork in entomology, agro-ecology, and landscape ecology, particularly in so-called "novel ecosystems."[2] Specifically, we describe the creation of informal field guide photographs that depict insects as ecologists-in-training are most likely to encounter them in the working landscapes of highway roadsides: dead and squished on and in various types of insect traps. Using a mixed-methods approach rooted in environmental studies, science and technology studies (STS), and multispecies studies, we recount and reflexively examine the training of ecology technicians to collect and identify insects both in the field and in the laboratory for a road ecology study on which we are the co-PIs.[3] Trapped in the field on devices known as glue-cards, the insects are killed and disfigured before being brought to the lab for identification. The insects on the cards no longer resemble their living counterparts, let alone stylized or idealized representations circulating in traditional field guides or textbooks. To render the crushed insects readable, our laboratory group has created squished bug field guides, with photographs displaying these specimens as they look caught on glue-cards rather than alive and intact. Technicians—scientific collaborators who may be students or avocational volunteers—are trained to this set of reference images to improve their identification skills and aid in ecological knowledge production, with the goal of beneficial insect conservation.

In networks of knowledge production, particularly in insect ecology, the techniques of capturing and identifying insects using traps and improvised squished bug guides have practical, epistemological, and ethical implications. Scholars such as Wolff-Michael Roth and G. Michael Bowen have described the importance of "vision" and "enculturation" of students in ecological fieldwork, while John Law and Michael Lynch have focused on hermeneutic activity in science and species identification as a form of "reading" learned through field guides.[4] Squished bug guides represent a new twist on these practices. They indeed require extensive training with respect to insect identification, but they are neither direct observation of animals in the field nor the comparison of these species to the natural history illustrations or modern photographs common to traditional field guides. Rather, squished bug guides operate as a pragmatic and epistemological middle ground between scientific realism and image manipulation, and they invite comparisons to other, often tacit, practices in the life sciences.

While such novel techniques, environments, and study subjects are ripe for further study and theorization—insects and invertebrates more generally get relatively short shrift in science studies and adjacent humanities disciplines—our primary focus here is pedagogical and ethical. Our study acknowledges the long history of insects in science and the substantial literature on animal experimentation and welfare in the

2. Hobbs, Higgs, and Harris, "Novel Ecosystems."

3. One author is an ecologist with STS training, and the other is an STS scholar with an environmental management background. The project was designed from the beginning to be an ecological study of the effects of human transportation infrastructure on insect habitat, with a strong training component for student technicians.

4. Roth and Bowen, "Digitizing Lizards," 719; Roth and Bowen, "'Creative Solutions' and 'Fibbing Results,'" 533; Law and Lynch, "Lists, Field Guides, and the Descriptive Organization of Seeing," 273.

laboratory, but it extends these studies and ideas to encompass the necessarily organism- and environment-specific ethics of studying bugs in the field.[5] In the sections below, we provide ecological background and empirical examples of lethal insect sampling and identification from the first author's ecological studies in agricultural fields and highway roadsides, and we very briefly discuss the importance of such work in both conservation biology and the history and philosophy of science. For the bulk of the discussion section, however, we take this empirical example a step further to suggest that squished bugs more importantly represent a pedagogical opportunity to instill an ethical reflexivity in field technicians (and their PIs) operating well outside of academic environmental humanities circles.[6] Drawing on multispecies studies and its animal studies antecedents' focus on environmental ethics, as well as the scant but growing attention to "unloved others" like invertebrates, we use squished bugs as a way of wrestling with the destruction and deformation of life for the sake of ecological knowledge and, as Donna Haraway has suggested, "staying with the trouble" of killing insects.[7] For us, squished bug guides are more than just a pragmatic tool in ecology. They are, when brought to student technicians' attention as such, an inescapable reckoning with, and proxy for, inherently violent methodologies in environmental science that too often go unremarked upon by practitioners.

Focusing on squished bug guides as literally graphic reminders of often overlooked insect death in environmental science also provides a corrective to environmental humanities scholarship. As geographer Christopher Bear has recently noted, "Human-invertebrate relations . . . have to date been sidelined in human-animal studies," and scholarship that engages with insects promises to "develop a more holistic and inclusive approach to understandings of animality."[8] Sara Velardi and coauthors similarly point to the dearth of studies on human-insect relations, particularly in the context of farming and pollination.[9] Much recent multispecies ethnography, in fact, mentions insects in passing as examples of the potential to expand human-animal studies beyond the vertebrate, often agricultural, companion, and/or charismatic species that dominate the literature.[10] Similarly, much scholarship has analyzed the ethics of animals in scientific research—but again, mostly vertebrates, and mostly in laboratory

5. For introductions to insects in science and model organisms, see, respectively, Beisel, Kelly, and Tousignant, "Knowing Insects"; Creager, "Model Organisms Unbound." For a starting point in the vast literature on (vertebrate) animal welfare and laboratory experimentation, see Davies et al., "Science, Culture, and Care"; Franco, "Animal Experiments in Biomedical Research."

6. In promoting science-in-action as a pedagogical exercise in ethical reflection, we hope to add to examples of "environmental humanities in practice." Barron, Gruber, and Huffman, "Student Engagement and Environmental Awareness."

7. See, e.g., van Dooren, Kirksey, and Munster, "Multispecies Studies"; Bird Rose and van Dooren, introduction; Haraway, *Staying with the Trouble*.

8. Bear, "Approaching Insect Death."

9. Velardi et al., "'You Treat Them Right.'"

10. For recent examples, see Hamilton and Taylor, *Ethnography after Humanism*; Gillespie, "Unthinkable Politics for Multispecies Flourishing"; Gillespie, "For Multispecies Autoethnography."

science.[11] At the intersections of these literatures, and in the spirit of Nik Taylor and Lindsay Hamilton's call for "closer contact between the social and natural sciences at both a paradigmatic and methodological level,"[12] we offer a novel case study of human-invertebrate relations in science: killing insects in conservation biology.

We take this a step further, however, to envision ways in which this ecological practice may serve a reflexive, pedagogical purpose. As Kathryn A. Gillespie notes in her "pedagogical experiment" with students at a pig sanctuary, "Multispecies ethnography can be a gentler, more care-ful methodology when it more thoroughly considers its relationality, ethical complexities, and transformative potential."[13] We believe that the methodologies of insect ecology can likewise be more care-ful. Gillespie's work is part of a growing literature critically assessing the role—and asymmetrical power dynamics—of animals in both classroom and outdoor environmental education. Like multispecies studies more broadly, however, these pedagogical interventions tend to focus on charismatic vertebrate species and agricultural animals.[14] In a rare and notable exception, Affrica Taylor and Veronica Pacini-Ketchabaw consider the pedagogical and ethical value of "interspecies learning" between young children and ubiquitous invertebrates like ants and worms.[15] In their multispecies, ethnographic project, science serves as a tool for appreciating the biological and ecological complexities of these underappreciated creatures. Here, we consider the practice of entomological field science itself—at times violent and destructive—as its own pedagogical opportunity for students who collect and analyze insect data.

Squished bugs and other lethal insect ecology methods represent an opportunity to expand multispecies studies and sciences studies to more fully acknowledge vast differences across the animal kingdom, and to examine what knowledge production, education, and ethics look like for different species. In this, insects and other invertebrates represent a hard case, in which insight into insect experiences, affective ways of knowing, and relational epistemologies are more difficult to establish. In what follows, we provide background on our study, explain our attempts to infuse novel insect ecology methodologies with pedagogical and ethical value, and reflect on how these pedagogical techniques have, in turn, affected our own views on killing bugs for conservation.

Bees, Butterflies, and Other Beneficial Insects in Working Landscapes

As they are currently understood in field biology, pollinators are any animals that transfer pollen between the reproductive parts of flowers. Pollinating insects are very diverse, including butterflies, beetles, and even mosquitoes. Pollinators are critical to the maintenance of pollination, a regulating ecosystem service that people depend on for food,

11. For a concise, historical introduction, see Guerrini, *Experimenting with Humans and Animals*.

12. N. Taylor and Hamilton, "Investigating the Other," 255.

13. Gillespie, "For a Politicized Multispecies Ethnography."

14. See, for example, Dinker and Pedersen, "Critical Animal Pedagogies"; Lloro-Bidart, "Feminist Posthumanist Political Ecology of Education."

15. A. Taylor and Pacini-Ketchabaw, "Learning with Children, Ants, and Worms."

fiber, and energy. Scientists estimate pollinating insects are declining at global scales, in part due to urbanization and habitat fragmentation.[16] This is widely considered alarming, as the majority of agricultural crops and more than 75 percent of flowers in temperate and tropical regions depend on pollinating animals.[17] Other groups of insects considered beneficial in the sense that they are vital to human interests are predators, insects that eat crop pests. One such group of predators is ladybugs. Also known as ladybird beetles, ladybugs are a family of beetles known in Latin as *Coccinellidae*. It is estimated that there are now over two hundred species of ladybugs in the United States and Canada.[18] Ladybugs are voracious eaters of crop pests—and they are also considered useful to science. They are sometimes employed in field biology studies that have relatively little if anything to do with their taxonomy or entomology per se. Rather, ladybugs are valuable to field ecologists most often for what they represent—a measure of predation. Ladybug abundance can broadly represent the amount and efficacy of pest insect suppression by all insect predators.

Increasingly in ecology, the working landscapes of roadside rights-of-way have been proposed as habitat for these beneficial pollinating and predatory insects. Also known as verges, roadside habitats can provide a broad range of ecosystem services, including habitat and movement corridors for wildlife.[19] Rights-of-way habitats can provide both food resources and potential nesting sites for pollinating insects.[20] The United States is particularly well positioned to attempt interventions in roadside habitats, as it is estimated to have millions of hectares of roadside rights-of-way.[21] Recently, the US Fish and Wildlife Service and rights-of-way managers, including state departments of transportation, entered into a voluntary conservation agreement to use rights-of-way, including roadsides, as habitat to support the monarch butterfly (*Danaus plexippus plexippus*).[22] A similar agreement is being proposed for bumblebee species expected to be listed as endangered in the near future.[23]

Yet roads are also known to negatively impact insects as individuals and populations. Roads can impact insects directly, such as collision with vehicles while crossing, as well as cause indirect sublethal impacts, such as altering movement in the landscape for species unwilling or unable to cross roads.[24] In short, through the lens of conservation biology, understanding the use of roadsides by beneficial insects has tremendous

16. Kluser and Peduzzi, *Global Pollinator Decline*; Cunningham, "Depressed Pollination."

17. Ollerton, Winfree, and Tarrant, "How Many Flowering Plants."

18. Harmon, Stephens, and Losey, "Decline of Native Coccinellids."

19. Phillips et al., "Ecosystem Service Provision"; Stack Whitney, "All the Above."

20. Gardiner et al., "Rights-of-Way."

21. Forman et al., *Road Ecology*.

22. Cardno, *Nationwide Candidate Conservation Agreement*.

23. See, for example, "Rights-of-Way as Habitat Working Group," Energy Resources Center, University of Illinois, https://rightofway.erc.uic.edu/ (accessed November 6, 2023).

24. Coffin, "From Roadkill to Road Ecology"; Forman and Alexander, "Roads and their Major Ecological Effects."

potential value for promoting generally acknowledged ecological goods like species conservation, biodiversity, and ecosystem services.

Surveying Beneficial Insects

Sticky Cards

Field ecology in working landscapes, such as farms and along roads, is generally applied. While plenty of ecology involves more traditional experimentation with controls and manipulated treatments, landscape-scale field ecology uses what are called "natural controls."[25] Ecologists use naturally existing gradients of environmental variables—soil type, rain, land cover, and so on—at a variety of study sites and compare ecological or biological response variables between them. An underlying assumption is that variation in landscapes provides insights into ecological processes happening at the scales of systems humans create and depend on, such as farms and forests, that small-scale (e.g., lab or microcosm) experiments cannot. Beneficial insects have often been that response variable, and it is their ambient abundance that is of interest. Field ecologists want to observe or catch insects in the wild and in their natural habitat and abundance levels. There are several techniques for doing so, which ideally are chosen based on an appropriate match with the study design. Often ecologists want to use techniques that do not require them to stand in a field all day catching insects—they want to passively sample. This is largely due to resource trade-offs in conducting field biology at landscape scales—the larger the sampling area and study length, the more people, time, and energy are needed to make observations across time and space.

This in part has led to the rise in popularity of tools like glue traps. The particular glue traps most used to catch insects in field ecology are known as sticky cards. These are one- or two-sided glue traps and yellow ones are very popular, as the bright yellow color (550–600 nm wavelength) is highly attractive to many insects. The cards are cardboard or plastic; they need to be tough enough to not disintegrate with the glue. Traps can either be homemade, spray-painted with exterior paints and coated with clear polybutene adhesive, or cheaply bought as premade cards. The idea is to catch beneficial insects successfully, but without using hormones or other attractants that will ruin the ecologists' notion of catching ambient levels of insects in the wild—and without the ecologists needing to stand in a field for hours, days, or weeks. Flying insects inadvertently run into the cards, get stuck, and starve to death. The problem, or the reality, is that using glue-card traps is a process that kills the insects and disfigures them. Individuals stuck on cards may struggle in the glue, tearing legs or fraying wings. While the card sits outside in the elements, sun, wind, and rain can dull colors and damage limbs. When the wax paper is applied and cards folded during collection, bodies are flattened

25. Turner, "Landscape Ecology." The idea of landscapes offering "natural experiments" is deeply embedded in the history of ecology and the relationship between "lab" and "field." See Kohler, *Landscapes and Labscapes*.

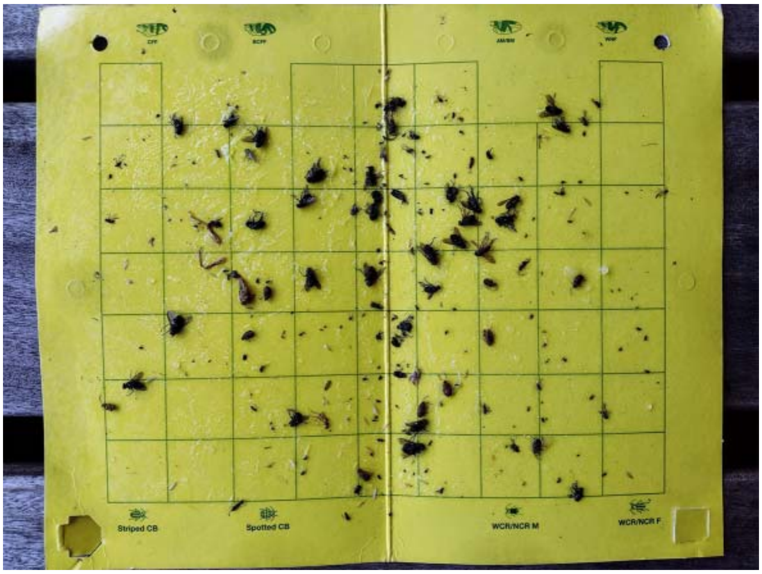

Figure 1. Example of a sticky card covered in dead insects, after deployment and collection from a New York highway roadside in 2021.

into the glue card. Freezing, too, which provides temporal flexibility for researchers, degrades tissue and can contribute to insects breaking when handled for identification in the lab. This efficient collection technique thus results in a bunch of squished, broken bugs (fig. 1).

The Study

We are deeply familiar with killing and collecting insects using sticky cards: our research team has placed and collected hundreds of them over the past several years as part of a landscape study conducted in roadside highway rights-of-way since 2019. In collaboration with highway managers, we established thirty long-term sampling areas across upstate New York, each with multiple sampling locations visited multiple times per year over several years. At each site, beneficial insects, including insect pollinators and predators, are being monitored using a variety of common field biology techniques, to understand if and how roadsides can be enrolled in insect conservation. To date, we have placed 311 sticky cards across a subset of our field sites.

Once collected, the squished bugs on the sticky cards are identified and counted. To render the crushed insects readable as data, we created a squished bug field guide, with photographs displaying insects as they look caught on glue-cards rather than alive and intact. The guide is intentionally created to be full of bad pictures, the kind that would never make it into a published field guide. Insects get stuck on sticky cards in a variety of positions that may be hard, if not nearly impossible, to identify. In the case of ladybugs, that can mean they are upside down, as in their elytra with distinctive markings is stuck on the glue—or that the glue distorts the elytra patterning that is commonly used to distinguish them (fig. 2). The field technicians on this project have been trained to and quizzed on this set of reference images. The goal is to improve their insect identification skills in the laboratory by explicitly training them with insects as

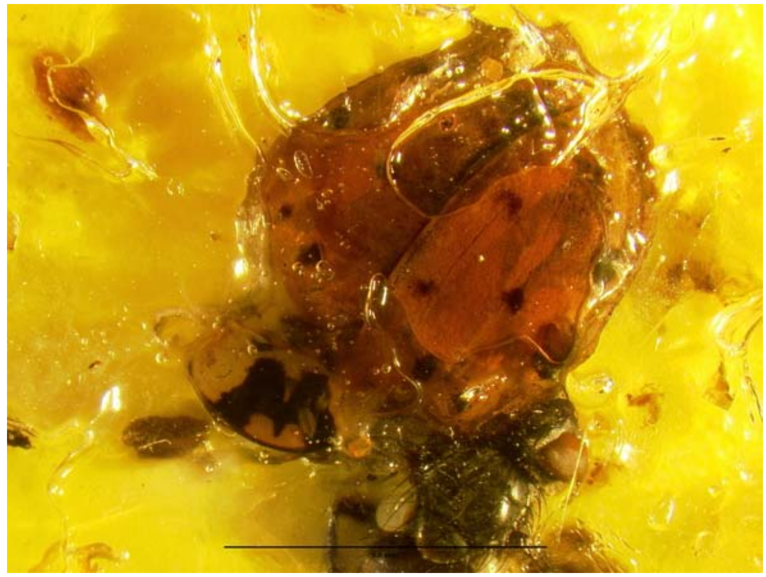

Figure 2. A close-up from our guide to sticky card identification showing what a ladybug looks like after being collected on a glue trap.

they will encounter them, dead and disfigured. Given the wide variety of taxa that the project aims to identify and quantify, the guide is a living document—growing with each field season as more insects and cards are collected. From identifications done on the first three years of observations, we have collected and identified 30,117 insects across seven orders caught on the sticky cards.

The squished bug guide also serves to aid identification for other lethal collection methods we employ. At these same sites, we use canvas nets for indiscriminate sweeping through vegetation along walking transects, knocking insects off plants and into the nets. This is a standard field biology method to compare insect abundance and diversity between sites.[26] After insects are netted, they are transferred into labeled plastic bags and awaiting coolers. Back at the lab, the bags are frozen for later specimen identification. Additionally, our roadside project includes some in-field identification activities when completing nonlethal monitoring protocols. For example, insect identification in "Pollard walks,"[27] timed "focal floral" observations,[28] and Streamlined Bee Monitoring Protocol assessments.[29]

As this description of our roadside pollinator project suggests, a range of nonlethal and lethal collection methods have been employed at a significant scale. And as the images here attest, the glue trap as a sampling and identification technique is a particularly gruesome mainstay of entomological fieldwork—one that can and should be problematized. Our concern therefore is not with squished bug guides per se; rather, it is

26. Prado et al., "Sampling Bees in Tropical Forests and Agroecosystems"; Yi et al., "Comparison of Terrestrial Arthropod Sampling Methods."

27. van Swaay et al., *Guidelines for Standardized Global Butterfly Monitoring*.

28. Roy et al., "Focal Plant Observations."

29. Ward et al., *Streamlined Bee Monitoring Protocol*.

with using these guides as emblems of the inherent violence of some ecological fieldwork and as a means not just to improve identification techniques but to make that violence unavoidable for technicians and investigators.

Killing Bugs and Ethical Reflexivity

Insects and the Environmental Humanities

Much has been written on taxonomy, organismal biology, and field sciences as practices of classification and quantification. Robert Kohler, for example, has written extensively on the history of taxonomy and biological surveys, stressing both the intellectual feat represented by the sciences of classification and change over time in their practice. He notes that contemporary biologists and ecologists have called to pick up where the biological surveys of the turn of the twentieth century left off: cataloging species diversity, especially the world's invertebrates, as a way to quantify biodiversity.[30] Our study also stresses the challenges and work involved in classification, but with a twist: identifying species of invertebrates when the study design itself alters their appearance. For this, classic Linnaean categories and contemporary guidebooks are only partially adequate. Improvised squished bug guides represent tools that fill in the gap between taxonomic ideal and disfigured reality. But however novel squished bug guides might be as a scientific practice, our larger interest here is the ways they serve as a proxy for lethal field biology methods, and force reflexive conversations about killing often less-regarded invertebrate animals. That is, our focus is not on what squished bug images are but rather what they mean—and how they (and other insect collecting techniques) might be imbued with pedagogical and ethical value.

There is a small but important literature in a number of environmental humanities disciplines that centers insects.[31] There has been limited, but influential, attention to insects in the history of science and environmentalism, particularly as pests and the relationships between ecological theory and entomologically informed pest control.[32] In addition, detailing the contributions of ethologists like George and Elizabeth Peckham, Jean-Henri Fabre, and Karl von Frisch, other historical work makes clear that understanding entomological lifeworlds has played an outsized role in natural history and biology.[33] Studies of insects like ants have also been fundamental to competing theories in biology on the evolutionary basis of social behavior.[34] More contemporary

30. Kohler, *All Creatures*.

31. For the most extensive history of human/insect relations, see Melillo, *Butterfly Effect*. For an example of art history related to pollinators specifically, see Greer, "Insect's-Eye View."

32. See, e.g., Russell, *War and Nature*; Palladino, "Ecological Theory and Pest Control Practice"; Nash, *Rights of Nature*.

33. Crist, *Images of Animals*; Parikka, *Insect Media*; Raffles, *Insectopedia*. And of course, the far-reaching influence of Jakob von Uexkull's work drew heavily on the *umwelt* of invertebrates like the tick. See von Uexkull, "Stroll through the Worlds of Animals and Men"; Whitney, "Domesticating Nature?," 84n15.

34. See, e.g., Allee, "Co-operation among Animals"; Mitman, "From the Population to Society."

work, under the banner of multispecies studies, makes space for consideration of human/insect interactions in the humanities as "the awkward, the unloved, or even the loathed."[35] Concepts such as "awkward flourishing" and "estranged companions" are explicit attempts to grapple with the otherness of creatures like insects that we live and work with, may admire, may loathe, and often kill.[36] And work in STS reminds us that collecting and other less euphemistic forms of killing insects are still very much a part of contemporary science, deaths that involve little or no regulatory oversight or guidance due to their status as invertebrates.[37] Compared to other human-animal relations, within and beyond the practices of science, human-insect relationships remain ethically inchoate and protean.

Teaching Ethical Reflexivity

It is precisely these ethical gray areas vis-à-vis insect collection that we set about probing for and with our technicians, despite the fact that these were not students in our classes or completing work for grades. Unlike, for example, Kathryn Gillespie's pedagogical experiments with multispecies ethnography in the classroom and at a pig sanctuary,[38] we were not conducting ethnography per se; we had little to no control of the research space (state highway roadsides), nor could we assign field technicians frequent writing exercises. What we could provide was occasional opportunities for students to reflect on the study design itself, and give them time and space to explicitly reflect on the purposes of this research and the necessity—or not—of lethal collection methods for those purposes.

Our work with student technicians, in addition to data collection in the field and lab, consisted of a mandatory training period (led by an ecologist) and a voluntary exit interview (led by a humanist) that consisted of a combination of in-person conversations and emailed surveys. Of the twenty-two students involved over the course of the project, fourteen responded for a 64 percent response rate. The interviews and surveys ranged from general questions about training, data collection, safety, and ideas for improvements, to pointed questions about lethal sampling methods and their justifications (or lack thereof). These latter questions served a dual purpose: as a pedagogical strategy to give student technicians the opportunity to think and explicitly discuss the project and their effects on insect lives and populations, and as a source of feedback on the study methods that could serve as fodder for our own reflections on squished bugs.

The results of these conversations with students were instructive. Somewhat to our surprise, given the casualness with which many people seem to kill bugs (swatting flies in the home, for example, or mosquitoes around a campfire), the students were

35. van Dooren, Kirksey, and Munster, "Multispecies Studies," 6.

36. Ginn, Beisel, and Barua, "Flourishing with Awkward Creatures"; Hollin and Giraud, "Estranged Companions."

37. Beisel, Kelly, and Tousignant, "Knowing Insects"; Bear, "Approaching Insect Death."

38. Gillespie, "For a Politicized Multispecies Ethnography."

universally uncomfortable with trapping and killing insects. They justified the practice however, with caveats, along a few clear and consistent lines. Student technicians by and large considered lethal insect sampling methods okay as long as there was no other way to get the data and the data had clear conservation value. Representative comments included:

"I think as long as there is no nonlethal way to get the same data (or the same quality data), lethal methods are justified, as the project has the potential to help populations in the long run."

"It's kind of sad to be like, 'Oh here's this beautiful butterfly that I'm going to freeze and possibly ruin.' But it's learning the skill for it, in order to get that knowledge."

"These observations are crucial to making informed decisions and killing insects is the only way to gather all the information needed."

"The knowledge we gain from killing the insects to collect data on biodiversity is significant in addressing issues that hurt insect populations."

Perhaps unsurprisingly, given that the technicians collecting, killing, and identifying insects felt the sacrifice was worth it for the good of populations, the idea that threatened, endangered, or otherwise rare species could also be caught changed their moral calculus:

"If an endangered pollinator that is critical to the local ecosystem is being killed off for research purposes, can we really say that it's for the greater good?"

"One of my concerns killing insects for this project is that there are some endangered species of bees and wasps that we could end up inadvertently killing if we used lethal methods. That would be counterproductive to the goals of the project."

"The only ones that it'd be like, 'Oh that's kind of sad,' is if it's something rare like a hummingbird moth, where I don't know how many of these there are and I've never seen one of these before. . . . Like, I don't know if this is something that maybe would have been better if it was left out there."

The stakes of, and concerns about, our study identified by the student technicians—insect habitat and population health, endangerment, and so on—resonate strongly with other scientists and scholars.[39] Geographer Jamie Lorimer ties "attention to animals' geographies," learning to think "like an elephant, an insect, or even a molecule," to becoming attuned "to the diverse ways in which nonhuman life inhabits the novel ecosystems of an Anthropocene planet."[40] Hugh Raffles, who has written perhaps the

39. The stakes for this kind of study are rising, as volunteers and citizen scientists of various stripes are increasingly called upon to assess the ecological values of working landscapes. See, e.g., Breeden and Estes, *Developing a Plan*. On citizen science more generally from an STS perspective, see Kimura and Kinchy, "Citizen Science."

40. Lorimer, *Wildlife in the Anthropocene*, 176.

only monograph-length account of human/insect relations from an anthropological standpoint, extends this type of attention to killing. Expressing the perspectives of his beetle-collecting informants, he writes, "To find insects, you have to understand them, you have to find a way into their mode of existence. The focused attention that is needed to enter their lives is a form of training, philosophical as well as entomological. It brings a knowledge of nature that is inseparable from an affection for nature and an expansion of the human world. Killing insects is painful, but it is also meaningful."[41] Further, as Kate Rigby writes of the "unloved other" Bogong Moth, a form of killing may actually imbue this largely reviled insect with value it might not otherwise have, as in this case "the best chance for the [conservation of the] bogong is to be honored as food."[42] As Freya Mathews argues with respect to the more charismatic honeybee, beyond the population or species effects of knowing and killing insects, the moral thrust of conserving these animals lies with a concern about the "diminishment of the biosphere."[43]

It is precisely these ethical issues and hoped-for benefits—for the researcher, for insect conservation, and for novel ecosystems like working landscapes—that we encouraged student technicians to think about. But we also wanted to push beyond conversations that could be seen as simply justifying squished bugs, to address ethical concerns that might threaten the status quo of our study. As geographer Jenny R. Isaacs writes, reflecting on study effects involving completely different organisms, "Conservation may be ethically motivated by care and righteous anger for biodiversity loss, but that does not mean it is entirely virtuous and innocent."[44] For example, poet and writer Heather Swan movingly recounts her own experiences of beekeeping, as well as scientists' accounts of their misgivings about lethal experiments with wasps and bees. One researcher in particular recounted for Swan in vivid detail killing wasps for science, the nightmares that ensued, and his ultimate choice to leave the profession—concluding that in lethal experiments, "yes, they suffer."[45]

The student technicians on our project did not all have the same views, and some responses spoke directly to this question of insect suffering and welfare—the experience of the individual rather than the population. One respondent had particularly strong reactions, suggesting that the empathy he gained for trapped insects would not allow him to participate in such a study again:

> "I was surprised by how much I disliked the lethal identification techniques. I know that insects have a short lifespan, but the sticky cards seemed almost like torture."

41. Raffles, *Insectopedia*, 381.
42. Rigby, "Getting a Taste for the Bogong Moth," 91.
43. Mathews, "Planet Beehive," 174.
44. Isaacs, " 'Bander's Grip,'" 17.
45. Swan, "Sorrow of Bees." For a more scientistic approach to the question of whether insects experience pain and suffering see, for example, Tiffin, "Do Insects Feel Pain?"

"The amount of empathy that I grew to have for insects still has an impact on me to this day. Before this work, I would always kill any bug that I found indoors and think nothing of it, but now I capture them and release them outside."

"I do feel as though killing insects for this project is justified. However, I personally wouldn't do it again—I felt too bad killing the bugs."

Scientific and scholarly attention to insect welfare and suffering in entomology and ecology is scant, to say the least. However, a useful analog is the nascent literature on animal welfare in industrial insect farming, and farmers' ideas about humane killing. As Nora Delvendahl, Birgit A. Rumpold, and Nina Langen point out, "Brambell's Five Freedoms" generally applied to livestock and other questions of animal welfare can potentially be modified to apply to raising insects for food, focusing on rearing conditions, killing methods, and precautionary approaches to whether or not insect species can experience pain and stress.[46] While rearing would be beyond the scope of field studies of insects, "killing methods" is highly salient here and invites comparisons across the various methods we employ in this study. Bear highlights similar ethical issues among farmers raising insects for food: potential insect sentience and experience of pain; the lack of guidance and policy related to invertebrates (unlike vertebrate livestock); and the farmers' own views of humane killing—whether their own or their perceived customers'.[47] Interestingly, most farmers freeze their insects, considering it—with some ambivalence—a humane and almost natural death.

Taken collectively, the concerns and commitments of our technicians and literatures such as that on insect farming would suggest a sort of ethical hierarchy in field collection methods. Nonlethal insect observation methods could be considered the most precautionary ethically, followed by sweep netting (involving death by cooling and freezing), with leaving sticky cards—and the starved and squished bugs they produce—as a last resort. In the final subsection below, we describe our own student-inspired deliberations over this hierarchy as an attempt to "stay with the trouble" of insect death in ecology.

Learning Ethical Reflexivity

The pedagogical value of squished bugs has proven multivalent: they are techniques and tools in ecological knowledge production, an entrée into purposeful discussions about environmental ethics with students and, reflexively, a call to reevaluate our own study design. As Donna Haraway writes:

> We—all of us on Terra—live in disturbing times, mixed-up times, troubling and turbid times. The task is to become capable, with each other in all of our bumptious kinds, of response. Mixed-up times are overflowing with both pain and joy—with vastly unjust

46. Delvendahl et al., "Edible Insects as Food-Insect Welfare."
47. Bear, "Approaching Insect Death," 758–59.

> patterns of pain and joy, with unnecessary killing of ongoingness but also with necessary resurgence. The task is to make kin in lines of inventive connection as a practice of learning to live and die well with each other in a thick present.[48]

Our way of staying with the trouble of squished bugs has been to take the responses from our pedagogical interventions with technicians, as well as the growing humanities literature on human-insect relations, and reassess the data collection methods of our roadside study. It is worth stating here that although ethnographic studies of humans and domesticated insects—as pollinators or food sources—offer useful ethical insights, studying bugs in order to conserve them is not the same thing (farming insects is, after all, always and intentionally 100 percent fatal). We tend to agree with our students, that lethal sampling methods can be justified in terms of the greater good of insect population health—while acknowledging that vague gestures toward biodiversity and anthropocentric concepts like beneficial insects and ecosystem services are not themselves ethically neutral, unambiguous goods.[49] Nevertheless, considering the general—at times intense—discomfort our technicians experienced with lethal sampling techniques, and the ways in which environmental humanities scholars have discussed living with and killing insects, we set about to question our own practices.

In a series of back-and-forth questions between the PI (an ecologist) and the co-PI (a humanist) on this project, we tried to home in on what components of the roadside study might be the most ethically dubious or potentially unnecessary, and whether or not certain methodologies might be removed or modified. Could glue traps and squished bugs be eliminated from the study, for example, relying on data from the better death of capturing insects in sweep nets and freezing them? Could we stop using lethal methods altogether, in favor of carefully prescribed observational techniques?

We considered the question of whether lethal methods obtain data that nonlethal methods cannot. These methods, putting out glue traps for weeklong spans of time and using sweep nets that stir up grasses and brush, are tailored to the distinct natural history—one might even say agency—of different species of insects. As such, relatively short observational methods would not capture insects that may not be flying at the time of a technician's site visit, nor insects that prefer to hide beneath grasses, leaves, and so on. Our logical follow-up question was whether or not that kind of data could be collected in some other, preferably nonlethal way. The answer, provisionally, was no, for a number of interrelated reasons. Roadsides as novel ecosystems are unlike other environments and relatively unstudied, particularly at the scale of this project, so the presence or absence of particular families and species of insects cannot be deduced in combination with other studies—they need to be collected. Roadsides are also relatively dangerous for the humans doing the collecting, so using glue traps was a way to maximize sample diversity while minimizing (human) risk. And finally, for many insects the

48. Haraway, *Staying with the Trouble*, 1.
49. Sepkoski, *Catastrophic Thinking*.

ability to accurately identify them requires killing them and examining them under a microscope, particularly if they have been disfigured in the process of collecting them. Observational studies do not provide the same level of accuracy for determining the presence and quantities of insects.

The obvious next question for us to ask was "So what?" Are lethal collection techniques just collecting more and higher quality data for their own sake, or do they help answer a research question—vis-à-vis roadside management and insect diversity—with real conservation value? The answer, again, seems for the time being to be yes. The quantity of data, accounting for a broad geographic and temporal scope, helps to find the signal (best roadside management practices for insect habitat) in the noise (seasonality, weather, adjacent landscapes, and so on). And the quality of data—identification to family, genus, or species—made possible by lethal collection (particularly sticky cards, which maximize quantity and quality), allows us to see if very specific groups of insects that may be lumped together in observational methods are responding differently to various roadside management regimes. In essence, we are substituting physical violence (killing bugs) for epistemological violence (conflating life histories of different kinds of potentially threatened insects) in the hopes that as many species and families as possible can be managed to flourish in a liminal habitat. In this, our project resonates with Vincent J. Del Casino Jr.'s "social geography" of bugs: "Bugs manage to move, thrive, and survive partially because of the worlds humans create," and "bugs are acting upon our networks and forcing humans to interact with their sociocultural and environmental worlds in different ways."[50] Acknowledging that studying insects deemed beneficial to human agriculture is deeply anthropocentric, the ability to disaggregate families and species through multimethod analysis creates space for multispecies flourishing regardless of direct benefits to humans.

While there has been scientific interest in analyzing how to minimize "bycatch" in pest and collection traps, the potential impacts of lethal collection, and tensions between insect welfare and conservation,[51] to our knowledge none takes the practice of science itself as an opportunity for teachable moments and ethical reflection. Pedagogically, our conversations with students help them understand the reasons for lethal collection and that these reasons are not a given—they must be questioned and worked through. These reflections are also a way to foster respect for students' study subjects while acknowledging their own discomfort as well as the power imbalance inherent in such studies—different sampling methodologies rely on the agency and different ways of being of species, but the insects are presumably not choosing to be trapped, squished, and killed for a larger good. These are subjects most ecology and environmental science

50. Del Casino, "Bugs," 289.

51. See, e.g., Spears et al., "Review of Bee Captures"; Spears and Ramirez, "Learning to Love Leftovers"; Montero-Castaño et al., "Pursuing Best Practices for Minimizing Wild Bee Captures"; Barrett, Fischer, and Buchmann, "Informing Policy and Practice on Insect Pollinator Declines."

students are unlikely to encounter in a classroom, particularly with regard to invertebrates, and so such discussions embedded in the practice of science itself offer a novel and important teaching opportunity.

Critically, these conversations highlight the value and importance of centering environmental humanities and humanists when building reflexivity into ecological practices. Training future technicians in observational methods—like those of classical ethology and contemporary multispecies ethnography—can help to foster empathy for creatures like roadside insects and inform discussion of whether or not the death of collected insects is necessary or humane. In turn, such discussions serve to inform our larger ecological experiment, providing a way now and in the future to continue questioning and justifying lethal insect collection. We will continue to foster collaborative conversations about why and how lethal methods are part of ecological inquiry, looking to the growing scholarship in both humanities and entomological disciplines for new ways to reduce killing in the name of conservation. And while, for the moment, we are likely to continue to use glue traps and squished bug guides, "staying with the trouble" and research group reflexivity is now ingrained in this project and others moving forward.

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