FROM STANDING APART TO STANDING TOGETHER: THE SOCIAL (RE)ORGANIZATION OF BIOLOGICAL FIELD STATIONS THROUGH COMPUTER-SUPPORTED COOPERATIVE WORK

by

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A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirement for the degree of

Doctor of Philosophy

Department of Information Science

2025

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Abstract

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From Standing Apart to Standing Together: The Social (Re)Organization Of Biological Field Stations through Computer-Supported Cooperative Work

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Biological field stations—scientific facilities adjacent to natural environments—are a resource for many researchers across scientific domains. These facilities provide essential support to researchers (e.g., housing, equipment, laboratory space, and staff expertise) that is necessary to facilitate science. Scientific research, including field research, is increasingly digital and data-intensive. However, despite advances in data-intensive environmental research, digital connections between field stations and the research they support, as well as the connections between field stations as a global network, are often missing. Station directors argue that these missing connections obscure their value in our ever-growing digital world. Thus, this dissertation addresses the question: How could field stations, individually and collectively, address these problems of disconnection from the larger scientific enterprise?

To answer this question, I conducted a three-year qualitative and ethnographic study across 20 field stations examining the social organization of field station-supported research. I found that the research project is central to how science is conducted, and only portions of projects eventually become shared through downstream research outputs, like journal articles or datasets. This makes projects problematically and pervasively inaccessible to other researchers and to the broader scientific enterprise. I conceptualize this condition as “dark projects.” Interestingly, while projects are dark to the scientific enterprise, field stations are aware of projects, since they facilitate access, but lack visibility of the project’s important downstream outputs.

In response to the empirical findings, a final phase of research alternates between ethnography and infrastructuring to co-design infrastructure interventions with a field station director. These interventions illuminate dark projects using metadata that is standardly available but rarely employed.

Through these interventions, field stations can attach their role to the larger research trajectory of projects by shifting the reporting of science from something researchers solely control post-fieldwork to something the field stations can also report by publishing projects at the point of station access. I argue that this shift redistributes power towards the station and research locations, providing an example of infrastructure intentionally designed to resist extractive colonial harms and to demonstrate field stations' value by standing together, individually and collectively.

Acknowledgments

Getting a Ph.D. has been a journey with stops, starts, and even a few wrecks. Looking back on the journey, it is not lost on me what an incredible privilege it is to even attempt a doctorate, to pause mid-career and mid-life to try again, and to have the support to try. I also know that I am lucky that life aligned, allowing me to accomplish this goal. As part of a popular proverb says, 'if you want to go far, go together'. While writing the dissertation was a solo activity, I was able to go further, and my life is more full because of an amazing constellation of mentors, colleagues, collaborators, friends, and family.

I am grateful to my advisor, Leysia Palen, for her encouragement to apply to graduate school, her willingness to accept me as a student, and for the time and care she has taken over these last five years in helping me become a scholar. I looked for a long time to find an advisor and a doctoral program that resonated with me. It turned out to be right here in Boulder. Leysia is not only my advisor, but also the founder of the University of Colorado Boulder's Department of Information Science. Like field stations in this dissertation, the scientific care work to found a department is often unacknowledged. For me, as someone who has benefited immensely from this work, I am forever grateful that Leysia had the strength and vision to found this department, attract so many strong faculty, and sustain this intellectual community. I could not have asked for a more generative, supportive academic home to do this doctoral work.

I am grateful to my committee, both locally at the University of Colorado Boulder: Ricarose Roque, Bryan Semaan, Scott Taylor, as well as externally: Matt Bietz (University of California, Irvine), Andrea Thomer (University of Arizona). Each of you provided perspectives and insights that helped shape my work along this research journey. Collectively, you are exactly the right composition of expertise. It has been a privilege to have your support. I hope that you see our conversations and your ideas woven through this text.

There is a third set of mentors who supported my Ph.D. goal: Karl Benedict, Bruce Caron, Peter Fox, Yolanda Gil, Rebecca Koskela, Kerstin Lehnert, Bill Michener, Barbara Moore, and Lesley Wyborn. They have all encouraged my curiosity and provided advice and mentorship across my career. I am grateful for their steady, encouraging counsel and willingness to champion me. I am also grateful to all of my teachers, especially those in my own family, who cultivated my deep love of learning.

My research has focused on data and information sharing at biological field stations for the last five years. The FAIR Island project provided my introduction to field stations and helped shape the questions I continue to explore. I am grateful to colleagues at the California Digital Library, DataCite, and the University of California, Berkeley for their collaboration and discussions during this period.

Field stations are a valuable scientific asset run by dedicated, talented teams. Over the course of this dissertation, I had the good fortune to visit four field stations and meet many field station directors and staff. I am grateful to the Organization of Biological Field Stations, which generously provided opportunities to connect with the field station community about my work. They were welcoming at their meetings, providing opportunities to share my dissertation work in progress, and offering feedback that shaped this research. To the field station directors, staff, and researchers who participated in interviews, I am grateful for your willingness to share your experiences and practices. I am also grateful for your thoughtful review of my work. This dissertation would not have been possible without you.

While this dissertation was technically self-funded, meaning the time I spent on research was unpaid, parts of the work overlapped with and were supported through research projects I contributed to through my company, Metadata Game Changers, LLC. I acknowledge funding from: the National Science Foundation (NSF Award #2132549) through subaward RP20705-01, administered by the University of California Office of the President (California Digital Library); the SEEKCommons Fellowship (NSF Award #2226425); and the University of California, Berkeley, Island Sustainability Program. The views expressed in this dissertation are solely my own and do not necessarily reflect those of the NSF, the University of California, the California Digital Library, or SEEKCommons RCN partners. I am also grateful to the University of Colorado Boulder for the scholarships that directly supported this work over the last five years.

I am privileged to have kind, funny, smart collaborators and colleagues with whom I can laugh and cry (about all emotions, happy, sad, stressed…) during this work. I am grateful to my lab mates, past and present, including Madelyn Zander, Deepika Rama Subramanian, Tajanee Harris, Lindsay Diamond, Jim Dykes, and Hande Batan. I have enjoyed engaging with the talented CU INFO graduate student community. I am grateful to Shamika Klassen for her generosity in sharing templates to stay organized and to Shiva Darian, Blakeley Hoffman, Divyanshu Kumar Singh, Matt Nicholson, and so many others for rich conversations about overlapping ethnography and infrastructure interests. It has been a privilege learning from you and with you. I am also grateful to my collaborators and dear friends across projects, including Jane Anderson, Adrienne Correa, Neil Davies, Maheata White Davies, Julia Lowndes, and Hannah Stewart. Just five years ago, I could not imagine the interesting places our work would take us, and I am looking forward to what is next.

During my dissertation work, I have been so lucky to collaborate with Pat Chapman, artist extraordinaire and wonderful friend. Pat opened her studio to me every week over the last five years. She listened to me talk about my research, and together those conversations morphed into the art you see in the coda. Through ‘arting’—making art—I gained new research insights. I learned to trust the unfolding of the research process and that it is ok to not know how it will end up. I am also grateful to Pat’s sister, Kay, for her generous offer to proofread my dissertation. Mistakes are all mine, but Kay’s attention to detail made this dissertation better.

CU has skillful support services to make navigating graduate school easier. I am grateful for the CU Writing Center, the Graduate Writing Support program, and Scott Holman, specifically. Scott provided feedback and helped me see the issues in my writing without ever seeming judgmental or harsh. I am also grateful for additional CU support from Crissy Bowen, Sarah Mandos, the INFO Department staff, and Jorge Garza, the Graduate Program Manager in the College of Communication, Media, Information, and Design.

To my friends and family, I love you. Pat Chapman, Lindsay Powers, Arika Virapongse, Marilyn Walker, and Lynn Yarmey, you all provided balance and ensured this was not all work. My immediate family—Ben, Jean, and Wylie Robinson — and my extended family have been steadfast in supporting me as a person. Ellen and Margot, you both bring so much joy to my life.

Finally, to my husband, Ted, thank you for ‘lifeing’ for both of us, at times, and for your enduring belief that I could do this. This dissertation would not exist at all if not for a daily walk five years ago with Xoe, where you said, “Maybe this is a dissertation project?” Since that spark, you have been instrumental, helping me test connections between the global research infrastructure and field stations and pushing

that infrastructure forward. Thank you for making project DataCite metadata records and experimenting with rich metadata. I am incredibly fortunate that you are my partner, and I love you fiercely.

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Chapter 1

1. Introduction

There have been moments across the history of science that have profoundly changed its practice. The introduction of the laboratory as a form of technology is one example (Kohler, 2002). It allowed science to be done on demand and in controlled environments that removed location as a variable (Kohler, 2002). Science is undergoing another such transformation today, sometimes referred to as the ‘Fourth Paradigm’ or data-intensive science (Hey et al., 2009). This transformation is built on the advancement in and accessibility of computing, including the recent acceleration of artificial intelligence (AI) and increased digital connectivity through the Internet (Hey et al., 2009). This transformation allows science to be done from anywhere, to simulate or model reality *in silico*[1] before conducting experiments, and to share results and other artifacts more quickly through the Web. Collectively, these technologies have fundamentally re-shaped scientific work—both the doing of science and its reporting—across many domains.

For field scientists, a term used broadly to describe researchers from many disciplines who study the environment, this reshaping has been slower. These researchers have developed diverse approaches to study different facets of the environment in situ. They have historically hand-collected data, such as species observations, measurements, or physical samples, and, by necessity, the natural environment has been a place they must physically visit (Kohler, 2002). This research is sometimes referred to as ‘little science’ because of its diversity in approaches and outputs (Borgman et al., 2007). The diversity results in fragmented research referred to as ‘little’ because it cannot be aggregated through shared, standard information systems (Borgman et al., 2007). Little science requires many considerations to change field research practice.

Handheld sensors, drones, and new cellular technology are new tools that make environmental data collection faster, easier, and digital from its inception. These attributes can enable the transformation

[1] *In silico* is new Latin which refers to computer simulation and is a nod to Silicon Valley and the computer chip (*IN SILICO Definition & Meaning - Merriam-Webster*, n.d.).

of little science into big science because the data are in standard forms and can be analyzed and shared through common information systems. Further, projects like the National Science Foundation (NSF)-funded Long-Term Ecological Research (LTER) network and the National Ecological Observatory Network (NEON) have standardized environmental data management for some types of measurements (Baker & Millerand, 2024; Jackson & Barbrow, 2015). These examples show how data, like journal articles before, are becoming important outputs for field research projects. Yet, even with these advancements, there is significant friction in sharing data, both low-level challenges with incompatible formats and high-level challenges in translating its meaning across disciplines (Edwards et al., 2011). Thus, the imagined possibilities of data-intensive field-based science have not been fully realized, nor have the implications been interrogated because of both technical and social challenges. However, what unites these researchers are common locations and sometimes shared physical facilities.

Biological field stations, scientific facilities located adjacent to natural environments, facilitate a wide range of scientific research projects in a single location. Field stations often support visiting researchers with a combination of logistical support, including housing, access to the field, and laboratory infrastructure. These facilities were established as early as the 1870s, not long after traditional laboratories were established (Kohler, 2002). Since then, they have expanded the types of field-adjacent science that could be done (Kohler, 2002). With their popularity among researchers, field stations have been established in many locations. Today, there are over 1000 stations worldwide[2] (Tydecks et al., 2016). Despite their scientific facilitation, field stations find it difficult to find research results produced with their support. These results occur months to years after fieldwork is completed, making it unpredictable to know when results will be provided. Further, stations lack a standard form of acknowledgment, so they are either omitted or mentioned in non-standard ways in the scientific record. This variability makes searching for outputs labor-intensive.

With the current transformations in scientific practice toward data-intensive science, this dissertation examines the possibilities now available for establishing connections between downstream outputs, field stations, and the researchers that produce them. Taking a Computer-Supported

[2] Two confederations of field stations maintain maps: https://www.obfs.org/#Stations; https://worldmarinestations.com/the-world-marine-stations-atlas/,

Cooperative Work (CSCW) perspective, I examined the cooperative work practices between two primary actors: researchers and field station directors. I focused specifically on the work needed to conduct biological field station-supported research projects. With this understanding, I designed and implemented technical infrastructure interventions in collaboration with a field station director at two field stations that they oversee. The goal of these interventions is to establish digital connections between the field stations, the researchers, their projects, and outputs. Throughout this research, I tacked back and forth between examining practice and developing interventions, deepening my understanding as I learned from both parts of this process.

In the following sections, I provide a field station primer for those unfamiliar with this type of facility and situate this dissertation within CSCW. Following this orientation, the rest of this introduction provides a guide to the dissertation. The guide includes an overview of my research approach and questions, a brief description of the chapters, an overview of the dissertation data, and a summary of the dissertation contributions.

2. A Primer on Biological Field Stations[3]

A note to the reader: This dissertation aims to contribute to the fields of computer-supported cooperative work, research data management, and environmental science, particularly to those who direct and work at biological field stations. Therefore, I am including this section to introduce biological field stations[4] as a specific type of scientific facility for those unfamiliar.

Biological field stations are an innovation that resulted from a scholarly turn toward new natural history in the late 19th century (Kohler, 2002). This turn sought to unite laboratory technology with the natural environment. In addition to the physical instantiation of stations, new subdisciplines of biology, such as ecology— the study of the relationships between living organisms and their environments and how those relationships can be sustained—also came about (Billick et al., 2011; Kohler, 2002, 25).

[3] This section was submitted to the Journal of Computer-Supported Cooperative Work (JCSCW) as part of Chapter 3. It was written and has been extended here by me. It was edited by my advisor and co-author, Leysia Palen, and is included here with her permission.
[4] Biological field stations will be referred to as field stations or just stations

Though stations are expanding to support more types of scientific work, biology was the initial discipline of study at field stations.

Field stations are formed either by land in need of science or science in need of land. Land in need of science generally comes by a donation from a landowner with the intent that the donation is for science. Science in search of land occurs when scientists identify a research need, like an extremely biodiverse habitat, and raise the support required to establish a station. When stations form, they need a fiscal management arrangement. The two most common arrangements are that stations are managed through hosting institutions like universities or government agencies, or they are run independently as nonprofits (Tydecks et al., 2016). Through these arrangements, field stations manage operational budgets anywhere from a few thousand dollars to millions of dollars. Field station income is generated from a mix of grants directly to the station, direct support from hosted institutions, endowments left by wealthy benefactors, donations, and station fees paid by visiting researchers. The U.S. National Science Foundation (NSF) has a rolling call available for field stations and marine laboratories to apply for capacity-building grants. These grants are primarily used to facilitate science. Station fees are generally paid out of visiting researchers' grant funding. These fees can make the station seem like a transactional resource, similar to a hotel, but not a contributor to the production of scientific knowledge. However, field stations are much more than hotels, as I will describe next.

Collectively, the work of field stations has matured to support scientists through two key functions: controlling access to research facilities and natural environments, which can be public or privately held land, and providing essential services for field research activities (Billick et al., 2013; National Research Council, 2014). Access includes more than just the convenient proximity to the environment; it also includes granting permission for research activities, supporting permitting requests, and providing security for research sites near the stations (Billick et al., 2013). Services include maintaining physical facilities, employing staff support, and, more recently, providing bespoke technical and scientific expertise. In addition to supporting research, some stations conduct research, provide public outreach to their local communities, and offer undergraduate and graduate-level field courses. Each station has a unique composition, which depends on the field station users' needs.

In addition to field stations' staff support, physical facilities are often what distinguish them from other types of environmental resources, like national parks. These facilities often include various housing configurations, from dormitories to house student classes to more private accommodations for faculty and other professional researchers (Billick et al., 2013). Many stations have multi-purpose spaces for meals, lectures, classes, community meetings, workshops, conferences, and other functions (Billick et al., 2013). Though most data are collected while immersed in the natural environment, stations often provide laboratory and office workspaces to process and analyze samples before the data are transported back to home institutions. These workspaces have evolved with the demands of the research being conducted there. For instance, a rainforest station will have shade houses and ambient, unairconditioned laboratories to protect fragile samples; a marine station will have tanks and water tables by docks for analyzing samples with access to saltwater.

Stations also often house a wealth of knowledge about the places they steward. They may have directors and staff with scientific training who are aware of past research and deeply knowledgeable about their local environments. Many stations have historical records, photos, and biological collections that may be useful to visiting scientists (Michener et al., 2009). Further, over the last two decades, environmental sensing technologies—such as weather stations, environmental sensors, and drones—have become prevalent (Hey, Tansley, and Tolle, 2009). Some field stations are now providing new data products, like weather data or snowmelt forecasts, to augment researchers' data collection methods.

Field stations support a wide variety of research projects, from student research to individual professional researchers to large-scale environmental monitoring network projects. Research sites from two such networks—the Long-Term Ecological Research Network (LTER) and the National Ecological Observatory Network (NEON)—are often confused with field stations but are not synonymous. They do make important scientific contributions, so I am elaborating on their relationship here. There are 27 LTER sites. These are a loosely networked collection of individual research projects led by principal investigators who use long-term monitoring techniques at particular ecological study areas—experimental forests, lake regions, or rangeland. Some of these LTER project sites have been studied since 1980 through a series of grants from NSF to researchers at universities or nonprofits. NEON sites are managed by a single organization also called NEON and contribute to the NSF grant-funded NEON project. This project deployed highly instrumented towers that collect standard environmental measurements in 81 locations. NEON sites were operational in 2019 and have a planned 30-year lifespan. Where possible, LTER and NEON sites have been co-located, and some utilize field stations' existing facilities. In the analysis for this dissertation, in collaboration with the LTER Network Office, we identified that 15 of 27 LTER sites (research projects) use field station facilities. For the 20 field stations in this study, two hosted LTER sites, and one hosted a NEON site. The key difference between projects and the stations that support them is that projects are funded to do science, and stations are generally funded to maintain or improve facilities.

With this confluence of research activity, stations' physical facilities offer serendipitous opportunities for new research. For instance, chance encounters between researchers when together onsite sometimes lead to new projects (Billick et al., 2011). These research connections are an important, science-advancing way that field stations support 'weakly-tied social networks' (Granovetter, 1973) of researchers across various disciplines. Some stations more intentionally mobilize their social networks post-disaster or during other environmental events like disease spread, which can also lead to unforeseen, beneficial research collaborations (Michener et al., 2009). These fortunate accidents are ways that field stations importantly reduce science friction or the difficulties of interdisciplinary collaboration (Edwards et al., 2011). Yet, these connections are very difficult to quantify and are often taken for granted by researchers and not attributed to the field station as a scientific contribution.

While field stations are essential to the scientific enterprise, they face a set of challenges. First, with many changing objectives over the years, biological field stations have not settled on a standard name that makes uniform reference to them all. 'Biological' is still often included when discussing these facilities as a nod to the roots of field stations (and is our choice here), even though a station's focus might be broader than biology or more specific to a subfield of biology. Field stations can also be referred to as research stations, laboratories, centers, or institutions, which are then modified by place names or other proper nouns. Furthermore, stations along the coast are often called marine laboratories or stations. In this dissertation, I assume a broad definition and will use the terms field station or station as shorthand to encompass facilities that are best described generally as 'biological field stations', even if they are differently named. However, because of this naming inconsistency and broad umbrella definition, it is difficult to know how many field stations exist worldwide or to aggregate their contributions in ways that would show their collective value (National Research Council, 2014).

In addition to not having a common name or narrow definition for field stations, the connections to researchers are also ephemeral. While researchers feel a sense of affiliation to the field stations at which they work and benefit from these serendipitous connections described above, field station affiliations are often informal and not recognized on a curriculum vitae, for example. This lack of formal affiliation is part of the problematic disconnection field stations can experience from the larger scientific enterprise. When stations are unacknowledged and or acknowledged in non-standard ways in research outputs, they struggle to find, collate, and articulate their contributions or position themselves as more than *just* scientific service providers. This struggle to provide scientific validation is a vicious cycle. If a station cannot justify its scientific contributions, it is less likely to successfully win grants or internal resources to improve the station, which may lead to fewer researchers visiting over time and fewer station fees.

For decades, stations and some researchers have attempted to raise the visibility and recognized value of field stations. In the 1980s, as researchers forecasted mass extinctions across thousands of species, there was a call for field stations to assume a more active scientific role (Brussard, 1982). Brussard, a scientist, recognized field stations' potential since they were situated in critical environments and facilitated research, education, and outreach necessary for local conservation (1982). Again, a decade later, two field station directors called for field stations to move from their historically independent, isolated positions into a network (Lohr & Stanford, 1996). From the late 2000s through today, there has been a steady stream of publications advocating for field stations to be seen as scientifically important, to confederate into a network, and more recently to invest in digital solutions to solve this problem of being invisible assets (Billick et al., 2011; Eppley et al., 2024; Kimbrough, 2024; McNulty et al., 2017; Michener et al., 2009; National Research Council, 2014; Wyman et al., 2009). However, field stations are physical infrastructure, and when they are working, they are invisible.

At the 2025 Organization of Biological Field Stations (OBFS) conference, which I attended, one of their accomplishments for the year was the requirement that field stations be acknowledged in 30 journals. This is progress, but alone, it may not realize the visibility field stations hope for because it still depends on 'human infrastructure' (C. P. Lee et al., 2006)—the labor required to align field stations, researchers, journals, and publishers. This dissertation examines current field station cooperative work practices to develop infrastructure interventions that establish digital connections between the stations, researchers who work there, their projects, and downstream related outputs.

3. Field Stations and Computer-Supported Cooperative Work

Computer-supported environmental science is often synonymous with data-intensive environmental science or 'environmental informatics' (Frew & Dozier, 2012). Unlike some informatics disciplines, which are social science-focused, environmental informatics has focused on applying large-scale computing capabilities to standard environmental data types, such as satellite or model data, to understand environmental phenomena like air pollution (Frew & Dozier, 2012; Robinson, 2010). Environmental scientists partner with applied computer scientists to extend their model and tool capabilities with 'cyberinfrastructure'. Cyberinfrastructure refers to the computational capabilities, including software, hardware, internet connections, and policies, that enable science (Edwards et al., 2007). However, these cyberinfrastructure partnerships can fall short of complete success when they do not account for the relationships that humans have with technology or with each other through technology.

Star, a sociologist, and Ruhleder, a computer scientist, contrasted the technocentric ideas of cyberinfrastructure with their work on information infrastructure (1996). They foreground information infrastructure, not just as computer support, but emergent in relationship to the people who use it. They gave language to the messy work of 'infrastructuring', labor required to produce and maintain infrastructure (Star & Ruhleder, 1996). They also defined the dimensions of infrastructure: embedded, transparent, reaching in temporal and spatial scope, and learned as part of membership (Star & Ruhleder, 1996). Information infrastructure is now referred to as 'knowledge infrastructure'—' the network of artifacts, institutions, and people that are connected to understand our natural world (Edwards, 2010). In this dissertation, I draw from Infrastructure studies in both my method (Karasti & Blomberg, 2018; Star, 1999) and to describe the ways that field stations and the researchers who work there build infrastructure to support their cooperative work.

Just as infrastructuring can be used as a verb, sciencing can also be used as a verb 'to science' (White, 1938). 'Sciencing' means to take the situated experience and make it universal (White, 1938). This occurs in two parts: doing science and reporting science (Hey et al., 2009). I argue in this dissertation that field stations and researchers perform cooperative work, interdependent work activities, necessary to *do* science (Schmidt & Bannon, 1992). For instance, planning for visiting researchers coming to utilize the field station requires extensive articulation work, the extra work needed to ensure that the primary scientific work can occur (Strauss, 1988). Through the research presented in this dissertation, I contrast the idealized view of field work (the plans) with the actual, situated actions. As Suchman argues, it is only when we observe the situated that we can meaningfully intervene (1987).

The cyberinfrastructure necessary to support environmental science is a rich area of study in CSCW (Bowker, 2000; Mayernik et al., 2013; Ribes & Baker, 2007; Thomer, 2022). This work has primarily focused on the challenges related to data management and data sharing. Field stations are social spaces, akin to laboratories, and part of what makes them productive are the collaborations that form on site (Billick et al., 2011; Michener et al., 2009). Scientific collaboratories combine 'collaboration' and 'laboratory' to describe another type of cyberinfrastructure (Wulf, 1993). A scientific collaboratory is a '[digital] place that supports rich and recurring interaction around a common research focus among researchers who are both known and unknown to each other' (Finholt, 2003). In this dissertation, I explore the potential for field stations to be digitally represented as place-based scientific collaboratories where location is the common research focus.

At the time of writing, CSCW is entering what some call the 4th wave (Semaan et al., In Review). This is a critical examination of CSCW work that surfaces power dynamics and addresses racist, sexist, and classist undercurrents of scientific infrastructure (Bardzell, 2010; D'Ignazio & Klein, 2020; Harrington & Dillahunt, 2021; Irani et al., 2010; Ogbonnaya-Ogburu et al., 2020). Uninvestigated, CSCW can reproduce scientific imperialism by building these values into new systems. Interestingly, environmental science is going through similar reflections and questioning the way fieldwork is conducted (de Vos, 2022). With this collective movement towards a more just scientific practice, this dissertation makes invisible labor visible, examines existing power structures, and describes the care necessary for field station-supported projects to succeed. I also consider these justice-centered, ethical values in the intervention design and implementation. In the next section, I provide an overview of how my approach is shaped by this foundation.

4. Approach and Research Questions

My involvement with field stations started in 2020, about five years ago, as a research data management consultant working on the FAIR Island Project (Robinson et al., 2023), an NSF-funded collaboration with the California Digital Library, DataCite, and a field station director with connections to two field stations that I refer to with a pseudonym in this dissertation, Nic.

Nic expressed the desire that I have since heard from many other field station directors: if only cyberinfrastructure were available for field stations, it would solve the challenges they face in communicating their impact, finding and providing research resources for future visitors, and collectively demonstrating that stations are a global asset. Yet, despite discussing this for many years (Billick et al., 2011, 2013; Brussard, 1982; National Research Council, 2014), there is still no field station cyberinfrastructure solution. This refrain led to the central question of this dissertation and builds on prior computer-supported cooperative work by asking: *How could field stations, individually and collectively, address the problems they feel from being disconnected from the research trajectory and larger scientific enterprise?*

To answer this question, I used a combination of ethnographic and design methods in two parts. First, to understand field station-supported projects and the role stations play in those projects, I conducted a qualitative and ethnographic study of researchers and field station directors from 20 field stations. Using a constructivist grounded theory approach for analysis (Charmaz, 2014), I answer these two research questions:

- **RQ 1:** How are field station-supported research projects organized?
- **RQ 2:** How do field stations support research projects before, during, and after visiting researchers use field station facilities?

With the understanding of field station-supported projects, I turned to design methods. I used a participatory infrastructuring approach to design and build infrastructural interventions to address many of the challenges I uncovered in my empirical work. I document this process through design ethnography, moving from an observation practice to a creative practice, where I evaluated and learned from the interventions and how they accreted on top of each other to evolve the next intervention. I framed this section around a third research question:

- **RQ 3:** How might infrastructuring interventions transform the connections between stations and the research projects they support, as well as connections across stations?

Together, these two parts iteratively examined the real-world practice of field stations and the researchers they support (RQ 1, RQ 2), identifying requirements. With these requirements, Nic and I designed and tested infrastructure interventions that facilitate their cooperative work (RQ 3).

5. Dissertation Structure

This dissertation is organized into five chapters, structured as a 'stapled' dissertation, with each of the three chapters addressing one of the research questions and written in the style of a journal article[5]. This introduction chapter serves as light scaffolding to describe the overall structure. The concluding chapter highlights some of the broader implications for scientific cooperative work and future research areas that could extend this work. Chapters 2, 3, and 4 are self-contained with all expected elements of a journal article (related work, method, analysis, and discussion). While the chapters are self-contained, there is a throughline across that examines how field station-supported research is produced and how it might be connected to the station and the locations it comes from.

In Chapter 2, using a constructivist grounded theory analysis, the core concept of *field station-supported project* emerged. This analysis represents 20 stations with both the field station directors' and

[5] I plan to publish modified versions of these chapters. Chapter 3 is under review at the Journal of Computer-Supported Cooperative Work.

researchers' perspectives. These are the activities that field stations and researchers cooperate on. With this broader data, I describe the four types of contexts that shape the social organization of field station-supported projects. From this analysis, I found that projects are *dark*, or digitally missing, from the scientific enterprise. They are only reported on in pieces after the project work has ended. Without projects being visible, research outputs are distributed and fragmented. I argue that *dark projects* reproduce problematic coloniality practices of scientific extraction. I conclude with recommendations for repairing these connections between the project, the stations, the places the stations steward, and future research outputs.

Chapter 3, included with permission of my co-author[6], centers the perspectives of field station directors from 14 of the 20 field stations. In this chapter, I again took a constructivist grounded theory approach. I identified a set of common types of work field stations do to support projects before, during, and after researchers' visits. This chapter found that field stations and researchers are tightly coupled. This relationship requires field stations to reconfigure their infrastructure to support diverse research projects. This relationship has benefited researchers with custom workspaces. However, with the shift towards digitization, we found that, like projects, field stations are inadequately digitally represented in standard ways in the scientific enterprise. This lack of digital representation and labor-intensive, bespoke infrastructure makes it difficult for researchers to be aware of one another at a single station or for stations to form a global digital network. We conclude this chapter with recommendations to improve field station acknowledgment in research outputs like journal articles.

In Chapter 4, after identifying that field station-supported projects are the one common element that stations support (Chapter 2), that field stations have power when they grant access, and that most stations have some bespoke access system (Chapter 3), I report on interventions to make projects visible at the time field stations grant access. I show how, through the Global Research Infrastructure (GRI), a set of four registries for research objects (DataCite, CrossRef), people (ORCID), and organizations (ROR), we can finally digitally represent field stations and establish these connections between people,

[6] This chapter is included with permission from the second author, Leysia Palen. An authorship statement is included in the chapter to describe my contributions.

organizations, field station-supported projects, and future research outputs through structured, standard metadata.

When I started this research, I only considered the field station's challenge. As I conclude, the implications for this work reach farther. We, as the scientific enterprise, are at the very beginning of understanding the implications of digitally bringing environmental research together for a station-stewarded location. For the local communities that these field stations are part of, this provides visibility to the research being conducted in their backyards. With the implementation of Indigenous data infrastructure, we have the capability to notify the community and begin new ways of working. I conclude the dissertation by describing the potential applications of other types of scientific facilities, research funders, and even researchers themselves.

6. Overview of Dissertation Dataset

This dissertation differs from other stapled dissertations in that all three chapters draw on a single dataset. The dataset contains semi-structured interviews and field notes as the foundation for analysis across chapters 2, 3, and 4. This material was collected between March 2022 and March 2025. In total, I collected data from 20 unique stations through fieldwork and in three phases of semi-structured interviews: August 2022, June 2023, and November 2024. The stations represent a wide range of ages, locations, seasonality, and capacity. To indicate the range of stations, I have included the decade each was established and the type of environment in which they are located.

The chapters are not presented in the order the data was collected. The constructivist grounded theory analysis (Charmaz, 2014) started with six interviews that included both field station directors and researchers. This was presented as a poster at CSCW in 2023 (Robinson & Palen, 2023). Following this initial analysis, it became clear that there were two distinct perspectives—field station directors and researchers. Chapter 3 included four field station directors from phase 1, and I expanded to add seven additional interviews in phase 2. In total, the field station director-only data includes 14 stations. Chapter 2 expanded upon the data presented in Chapter 3, incorporating 60 days of fieldwork and interviews with researchers. Two interviews came from the first phase in 2023, and seven additional interviews were added in the last phase of interviews in 2024. Where possible, for phase 3, I added perspectives to field stations already included in the data gathered for Chapter 3, rather than expanding the number of stations. Chapter 4 draws on ethnographic data described in Chapters 2 and 3, as well as ethnographic notes collected about my design process working with a single field station director who had management responsibilities at two field stations.

As designed in our approved Institutional Review Board human subjects' protocol, stations, any affiliated organizations, and participants are all anonymized with pseudonyms to avoid reputational harm, an approach advocated by Vertesi (2020). I use they/them pronouns for all participants because gender was not the focus in this study. When I describe participants' scientific work, I do not specify details of scientific studies. My focus is on how work is organized, so it does not matter if the species being researched is a fish, bird, or mammal. I also do not maintain consistent participant or station pseudonyms across chapters. I am not describing findings in a way that requires readers of this dissertation to hold some characteristics for DIR_X (some random field station director). The key point I want the reader to recognize is that this quote or vignette is from a director (DIR) or a researcher (RES), and to develop an understanding of the directors' and researchers' perspectives. This inconsistency further anonymizes the people and locations that were studied. Additionally, written consent was obtained from each interview participant, and they had the option to withdraw from the study at any time.

7. Dissertation Contributions

This dissertation provides a qualitative examination of the current social organization of field station-supported projects, and the work field stations do to support these projects before, during, and after researchers visit these locations. This dissertation contributes to the fields of CSCW and research data management. I also hope that this is a contribution to the field station community, both those who direct stations and those who use stations. The dissertation contributions mirror my dual roles as an information scientist and a technologist. It makes both theoretical social science contributions aimed toward CSCW, and practical and technical contributions meant for research data management and field station communities.

Turning to the theoretical contributions, I introduced the concept of *dark projects*, which are not digitally registered in the scientific enterprise. *Dark* is most often used to describe data that are not indexed or registered, and so they cannot be found by others (Heidorn, 2008). However, dark data does not occur in a vacuum. It is one type of trace for *dark projects*. Projects with failed results are often not published or shared in any way, so the data and the project are dark. Adjacent projects at the same station can be *dark* to each other until a project publishes journal articles. Dark projects lack connections to their resulting downstream outputs and upstream creators, funders, and contributors, like field stations.

Turning specifically to field stations, I found that there are at least four types of common work. However, each station in this dissertation has evolved what we call *boundary negotiating infrastructures*—bespoke approaches and knowledge infrastructures—to conduct their work. These infrastructures are labor-intensive to build and maintain and are reconfigured and repaired to support the diversity of research projects at each station. This understanding of unstable, ephemeral infrastructure combines the idea of 'boundary negotiating artifacts' (C. P. Lee, 2007) with the idea that boundary objects could be connected as 'boundary infrastructure (Bowker & Star, 1999). Boundary infrastructure connects multiple communities of practice through stable methods. However, boundary negotiating infrastructure keeps researchers and field stations, who create and maintain it, separated because they lack standard, shared methods. Thus, despite wanting to connect through cyberinfrastructure, researchers at a single station digitally stand apart. They miss out on research connections because they lack digital visibility to one another. Moving to the cross-field station connections, there is a scaling fractal pattern. Like connecting researchers at a single station, cross-station digital connections are difficult and fragile because stations lack shared methods.

To go from the understanding that field stations historically and currently "stand apart" but could benefit by "standing together" digitally, I intervened to develop infrastructure that addresses the challenges of dark projects and unstable boundary negotiating infrastructure using existing global research infrastructure (J. Jones & Habermann, 2025). For CSCW, I argue that the global research infrastructure, the relationships between different types of persistent identifier registries[7], is boundary infrastructure. We demonstrated that using it at field stations provides essential methods standardization, which stabilizes field station infrastructure and creates essential digital connections between a single field

[7] Persistent identifier registries are catalogs of identifier records for people, organizations and digital objects. These are more fully described in Chapter 4.

station and the projects they support. Through these interventions, we registered field station projects with standard metadata for the first time. Further, we demonstrated the first steps towards documenting ethical fieldwork by linking social metadata to these projects. In this dissertation, I focused on these interventions on a retrospective project and a single station. However, it points to the possibility of transferring this stable boundary infrastructure to other field stations. It also shows the potential of confederation if more stations adopt this approach.

Through the development and evaluation of these infrastructure interventions, we also contributed a new understanding to the field of research data management. FAIR Principles[8] (Wilkinson et al., 2016), meant to make research data useful, and CARE Principles (Carroll et al., 2020), meant to provide guardrails for ethical data use, were offered as high-level guidance by the research data management community. They have been adopted as aspirational values by researchers across many scientific domains, including those who work at field stations. In the last part of this dissertation, I document and engage deeply with the experience of one field station director, translating those principles into implementation through infrastructure and practice in a participatory and design ethnographic approach. We expect that this approach may be informative to other types of scientific facilities and funders, who struggle with the same digital connectivity problems and are aligned with the FAIR and CARE values. Further, the Global Research Infrastructure is underutilized, and this dissertation shows how to more fully take advantage of the existing capabilities, such as registering project metadata with a digital object identifier and making connections to other related research, organizations, and people.

Field stations, as infrastructure, have historically been overlooked, and I would argue, this leads to being overburdened. Through the examination of current cooperative work practices, the diversity of field station-supported projects became evident. This diversity requires stations to facilitate science in flexible, configurable ways and showcase their complexity. The contribution of boundary negotiating infrastructure provides a lens to discuss field station practices and identify areas, like facilitating access, that might be points of method standardization across field stations. Building on what we learned from the infrastructural intervention experiments, I created a set of recommendations, the FAIR/CARE Toolkit. This

[8] FAIR and CARE are both acronyms. FAIR: Findable, Accessible, Interoperable and Reusable and CARE: Collective Benefit, Authority to Control, Responsibility, and Ethics

provides step-by-step guidance for other stations to implement the successful interventions. I hope these contributions provide the initial steps for the digital representation of field stations and the projects they support to realize the collective potential they articulated over 10 years ago: ‘to facilitate a unique merger of natural capital, intellectual capital, social fabric, and infrastructure that leads to important scientific research required to understand our rapidly changing natural world’ (National Research Council, 2014, p. 2).

Chapter 2

Abstract

Researchers from natural science domains, such as biology, chemistry, or geology, seek to answer almost endless questions about our environment. Answering these questions forms the basis of bespoke projects tailored to the researcher and the phenomenon that they seek to study. Despite variation in research approaches, many projects are concentrated around biological field stations as a common location. These location-specific, scientific facilities provide custom support for a wide range of researchers' needs. In a three-year qualitative and ethnographic study, I collected data across 20 field stations about how scientific projects are conducted. Through a grounded theory analysis, I examined the social organization of these projects, attending to four contexts: spatial, temporal, material, and relational. I found that while projects may utilize the same location and station, the results, if produced at all, occur a long time after the station visit. Further, sharing these products is limited to the researcher’s domain, and they generally are not returned to the places from which they were derived. Thus, these projects are *dark* or insufficiently represented in the digital record, and *place-based scientific stewardship*—the ongoing collective understanding of a place derived from synthesis across multiple projects—is nearly impossible. I argue that overcoming dark projects is a step towards postcolonial research by fostering relationships between researchers and the local communities where they work. I conclude with recommendations that disrupt projects’ legacy patterns of one-way extraction by making projects visible and connecting them back to the places and stations from which they are derived.

1. Introduction

From identifying new biological species to understanding the chemical reactions that produce acid rain to discovering geologic evidence of a major event that may have wiped out the dinosaurs, the natural environment provides a continuous source of research questions. Researchers from natural science domains, such as biology, chemistry, or geology, often seek to answer questions about our environment. Research questions can be small or large. They may be contested, opening new lines of research, or uncontested, building on prior research. Regardless, researchers tackle these questions by organizing themselves around research projects to take action (Gerson, 1983).

To answer these questions, projects require evidence—data. One technique many researchers use for data collection is in situ, environmental fieldwork[9]. Environmental fieldwork requires a substantial amount of logistical and administrative work. Researchers travel to sites, secure housing, navigate the local scientific research and data collection permitting procedures, and employ guides, porters, cooks, or security. Once on-site, they hope to find the species or phenomena they seek to study, and they hope that the weather or other conditions are favorable. To ease the logistical burden, *biological field stations*—scientific facilities adjacent to natural environments—provide bespoke support for researchers.

Biological field stations, which I will refer to as field stations or stations, provide more than logistics. They have evolved as a reflection of the researchers they support. They enable science that might not be possible without them. Specifically, field stations facilitate research access, extend research capacity, cultivate a hub of connections, and sustain the station for return visits to support a wide variety of projects (Robinson and Palen, in review). Thus, there is a high concentration of field station-supported projects around each of the more than 1000 field stations worldwide.

Through their work with numerous visiting research teams, many field station directors see a possibility of place-based research synthesis in addition to the scientific contributions each team makes individually, through their projects. They envision an ‘ecology of place’ (Billick et al., 2011), where data from various projects could be brought together to provide new insights about a specific location and how that place changes over time. Furthermore, some field station directors also employ the metaphor of field

[9] Social scientists like anthropologists and archeologists also conduct environmental fieldwork, but for this chapter, our focus will be on natural scientists.

station-stewarded locations as a model ecosystem, where, like a model species, the value of what is learned from the model ecosystem may be applicable in other settings that are not so intensely researched (Billick et al., 2013). However, due to the bespoke nature of each project, finding, accessing, and integrating all the diverse project contributions across a single station to realize this interdisciplinary vision is often impossible.

In a three-year qualitative and ethnographic study, I investigated how scientific projects are conducted with support from field stations. These field station-supported projects require cooperation between research teams and field station directors, who help navigate the local terrain. In this chapter, I describe the social organization of field station-supported projects, attending to four contexts: spatial, temporal, material, and relational. I also examine the ways that projects, and the people and artifacts that constitute them, are mobilized (Sheller & Urry, 2006), as journal articles or datasets 'journey' (Bates et al., 2016), from the originating site of production.

2. Related Work

Field station-supported projects provide a rich site for information science research. In the next section, I use the literature to contextualize scientific research projects and the situated contexts that shape their social organization.

2.1 The Organization of Scientific Work through Research Projects

Science, while it can seem static and neatly divided into domains, is an active and ongoing process. The verb 'sciencing' is defined as the way one turns particulars of an experience into universals through certain assumptions and techniques. (White, 1938). This active definition of science further argues that the division of sciences into siloed domains like biology or chemistry is artificial (White, 1938). Scientists use particular techniques based on the problem at hand. In natural science research broadly, this blurriness across domains is common.

The act of situated working, with specific assumptions and techniques, is the basis for arguing that science is socially constructed (Knorr-Cetina, 1983). During the 1980s, there was a turn towards the social studies of science, particularly scientific work. This turn came from a realization that the way work was organized shaped the work that was done (Gerson, 1983). These studies, primarily conducted by sociologists, identified two parts of scientific practice to study: ‘scientific controversies, ’ which focused on researchers’ mechanisms needed to reach consensus about facts, and ‘sites of scientific work,’ which focused on the production of knowledge objects (Knorr-Cetina, 1983). These studies attended to micropractices like how researchers ‘make [things] work’, which illuminated concepts like contingencies and skilled labor to do science (Knorr-Cetina, 1983).

Laboratory studies were some of the first sites of scientific work (Knorr-Cetina, 1983; Latour et al., 1986). This study of work practice was quickly adopted by those studying the social construction of technology (Pinch & Bijker, 2012). The combination of how science shapes technology and how technology shapes science led scholars like Lucy Suchman and Susan Leigh Star to shift the ideas of laboratory studies to information systems (Star & Ruhleder, 1996; Suchman, 1983). Yet, since the inception of the study of scientific work, the focus has shifted from the social organization to the scientific outcomes, like cyberinfrastructure (Vertesi, 2020). This chapter builds on the foundation of the social studies of science and returns the focus from outcomes and artifacts to the organization of scientific work.

While laboratory studies and studying controversies were the primary approaches, an alternate way of segmenting scientific practice developed around research questions and projects. Projects can be defined as a problem-solving process with a series of steps (Gerson, 1983). The ways that projects are organized can be considered as a ‘line of scientific work’ connecting various sites required to solve the problems at hand (Gerson, 1983). In this chapter, the concept of research projects is the site of scientific work that I study, specifically those that interact with field stations. Note that field stations are not centered as the site of study, as in laboratory studies, because the project moves between different physical locations, and the field station is just one part.

2.2 Situated Contexts of Projects: Spatial, Temporal, Material, and Relational

Scientific work is studied through contexts, or points of view. From the earliest reference to ‘sciencing’, experience is understood through a set of contexts that are constructed, including spatial, temporal, and material ways that science is organized (White, 1938). Knorr-Cetina returns to similar organizing contexts in their analysis of six different ethnographic laboratory studies, but highlights the implications these different types of situated contexts have on scientific products (1983). Extending this to the analysis of projects specifically, a subset of these contexts was used to understand the ‘articulation processes’, or ways all the project elements are put together, and held together as a unit (Strauss, 1988). More recently, in the study of laboratories, Wershler and colleagues argue that labs and lab-like spaces are a process, not a static structure, that are informed by spatial, temporal, material, and relational contexts (2022). While these may not be a complete set of situated contexts, they recur frequently enough that I use them as categories in my analysis. Further, none of these contexts act in isolation, and all act socially (Orlikowski, 2007), so my use throughout the remainder of the chapter highlights when one context is dominant in controlling the situatedness of scientific work, but all the others are also present.

Projects, as lines of work, are shaped by their spatial contexts. Laboratory studies repeatedly confirm that the choice of specific laboratory and the local affordances at these labs shape scientific products (Knorr-Cetina, 1983). In this case, the instruments available or the type of staff expertise make it easier or harder to complete a project. These laboratories, like other types of scientific institutions, have amassed distributed materials and expertise into a common location, ‘centers of calculation’ (Latour, 1987). These centers of calculation allow a researcher working at a distance to analyze artifacts across many places all at once without ever traveling there (Latour, 1987). The spatiality of people shapes the work that is possible (Olson & Olson, 2000). People who are together physically at a ‘center of calculation’ share a ‘common ground’, or shared knowledge, but they also share awareness of spatial specificity, like notes on a whiteboard (Olson & Olson, 2000). When teams are remote, the spatiality makes establishing common ground more difficult (Olson & Olson, 2000). More recently, the new mobilities paradigm calls for social science to consider the real and imaginary movement of people, objects, ideas, and information (Sheller & Urry, 2006). It is through the mobilities lens that the spatiality of data or ‘data journeys’ is used as a way to connect data to the physical spaces where data are extracted, analyzed, and stored (Bates et al., 2016). In this way, the power dynamics that Latour refers to as ‘centers of calculation’ are tracked as the data physically moves, gets stuck, or even disappears (Bates et al., 2016). Thus, we see that the spatial context of a project is empowered or disempowered by what is physically present, the distance between collaborators, and the ways that artifacts like data can move.

Projects are also shaped through temporal contexts. Projects occur via events or a sequence of tasks over time (Strauss, 1988). These tasks must align, which requires temporal organization (Strauss, 1988). Groupware calendar artifacts are one way of aligning tasks. Studies on the organization of users around groupware calendars found that clocks and calendars, like the academic calendar, make time visible and something that could be allocated (Palen, 1999). The analysis also found that when there was a high demand for temporal coordination, there was social pressure for collaborators to keep their calendars current (Palen, 1999). This work is an example of attending to the temporal aspect of social organization and the distinction between 'clock time'—the uniform, linear march of time—and 'social time'— problematizing time as a social phenomenon (H. Lee, 2003; Zerubavel, 1979). Building on this problematic view of time, the Millennium Clock, designed to chime every century and cuckoo every millennium, was an example of the 'long now' (Ribes & Finholt, 2009). The clock requires planning on both short-term and long-term time scales. Thus, those who designed it would not be alive to maintain it, so contingencies were required. The 'long now' is an example of the difference between shorter term 'project time' and longer, sustained coordination needed for 'infrastructure time' (Karasti et al., 2010). These temporal organizations are all described as collaborative rhythms (Jackson et al., 2011) or ways that different lines of work are in temporal harmony or dissonance. Temporal rhythms may be controlled by projects, like choosing a short working window, or may control projects, like academic calendars dictating research schedules.

Projects are constituted physically and digitally through material assemblages. In scientific work, events, people, and places need to be brought back to one's home institution. This is done through mobilization (Latour, 1987). Mobilization requires materiality, and often it requires stabilizing or transforming one material into another form for transport (Latour, 1987). A coastline traced as a map mobilizes the coastline, and that information can be brought back to one's home institution (Latour, 1987). Orlikowski argues that materiality is inherently social, and attending to the materiality of work in this way makes visible many aspects of social organizing that are otherwise invisible or taken for granted, like the specifics from the Latour example (2007). The sociomaterial lens provides a vocabulary to consider the parts and their relationships required to do a particular line of work, like the fragility or ephemerality of the bespoke research approaches. The materiality of projects is often boiled down to just the results, but those outcomes rely on a myriad of unseen material choices from inception onward.

Finally, projects are shaped by relational contexts. The social network that a researcher is part of and their position within it, central or marginal, controls a project's access to resources—spatial, temporal, and material (Granovetter, 1973). There are three primary ways that projects relate to each other: (1) they 'segment' or further subdivide their domain to work on a precise set of research questions; (2) they 'intersect' to form new collaborations; (3) they establish legitimacy or the rationale that differentiates boundaries between other projects (Gerson, 1983). As an example, the Cretaceous–Paleogene boundary is a thin clay layer that is rich in iridium, a chemical element found in high abundance in meteors (Alvarez et al., 1980). It was first studied by a physicist, a geologist, and a chemist in collaboration because each contributed specific techniques and assumptions regardless of their named domains (Alvarez et al., 1980). Together, these lines of intersecting work hypothesized that a meteor hitting Earth was the cause of the mass extinction of the dinosaurs (Alvarez et al., 1980). In addition to the remarkable finding and the interesting intersection across domains, the physicist and the chemist were father and son, a notable familial relationship. One could speculate that the initial intersection of these lines of work likely came from an awareness that would not have happened without that father-son relationship. The organizations, or sets of relationships at the micro, meso, and macro levels, shape and are shaped by scientific outcomes (Vertesi, 2020). Science is often portrayed as neutral or objective and devoid of relationships, but the relational context is critical to what work is done, and the work informs the relationships.

As I have examined some of the literature that supports each of these situated contexts, there is a common refrain. Many scholars will note that each context is important, for instance, claiming "distance matters," but they all also note that these contexts are often overlooked. This is similar to the infrastructure studies argument that infrastructure is vital but also invisible (Star & Ruhleder, 1996). The analytical move 'infrastructural inversion' (Bowker, 1994) is a way to make infrastructure visible. Through the inversion, there is a shift from the activities that infrastructures support to the activities that enable the infrastructure to function. In a similar analytical move, this chapter uses these four contexts to examine the activities that enable the projects to function or fail, not just what they produce.

2.3 Towards the Just Social Organization of Field-Based Scientific Projects

The social organization of scientific work came to prominence during what is described as Computer-Supported Cooperative Work's (CSCW) second wave, which shifted from rigid models of human factors to considering the situated work of groups collaborating in the workplace (Bødker, 2015). This chapter fits in many ways into the classic second wave, collaborative workplace studies, using theoretical concepts like 'situated action' and the ethnographic methods, with grounded theory cemented into CSCW during this period (Star, 1999; Suchman, 1983).

Some researchers in the second wave began to highlight the harmful implications that may come from bringing information together (Zuboff, 1989), the power disparities that were reinforced between humans, technology, and the institutions they were part of (Orlikowski, 1992), or the politics of classification systems or databases (Bowker & Star, 1999; Suchman, 1993). Methods like participatory design were introduced as ways to empower workers in the design and deployment of technology that they would have to use (Bødker et al., 2000). This is considered the beginning of the critical turn of CSCW. However, while workers were considered, marginalized populations were not generally considered.

Over the last 25 years, computing fields broadly from CSCW, Science and Technology Studies (STS), and Human-Computer Interactions (HCI) have increasingly called for attention to social justice, with a move towards sustainable computing (Blevis, 2007), feminist HCI (Bardzell, 2010), postcolonial computing (Irani et al., 2010), and race and technology (Benjamin, 2019). For instance, returning to the concept of 'data journeys', the material factors are foregrounded to emphasize the critical ways that data have physicality and consequences (Bates et al., 2016). Recent studies of the materiality of large data centers that attend to the energy and water use and the resulting impacts on the health of the nearby community, as well as global warming, employ this critical approach (Siddik et al., 2021).

Just as CSCW and STS are interwoven, STS and natural science are also interwoven through the subdiscipline of political ecology. Political ecology emerged in scholarship in the late 1980s as a pushback to the apolitical scientific lens applied to the relationship between humans and the environment (Perreault et al., 2015). This lens, political ecology, similarly attends to the feminist circumstances of the everyday, power, identities, and the social and historical context, particularly of the marginalized. More recently, in conjunction with a rise in global Indigenous data sovereignty movements (Carroll et al., 2020), political ecology has become more mainstream in ecology, shedding light on practices that reproduce coloniality. One such practice is 'parachute science', an extractive approach where researchers from wealthier countries conduct fieldwork in lower-income countries but do not consider local research interests or return the data or publications back to the places from which data was taken (Stefanoudis et al., 2021). This lack of returned results can be considered 'dark' or not easily findable by those who work or live in the locations from which data are derived (Heidorn, 2008). Through these investigations, political ecology considers the harms of science as status quo.

This chapter sits at the intersection of these critical turns for both computing and natural science. The scholarship of the social justice-informed movements across the scientific enterprise shapes my research approach. This has led me to critically problematize each context, through questions such as: whose knowing is given preference? How is power distributed? What is dark? What is illuminated? Or who is marginalized?

3. Method

The research design of this study uses a constructivist grounded theory approach (Charmaz, 2014)[10]. My approach draws from the extensive prior ethnographic work in the social studies of scientific work (Knorr-Cetina, 1983; Strauss, 1988; Vertesi, 2020) and data practices in ecology (Millerand, 2020), genomics (Bietz & Lee, 2009), and place-based, scientifically significant sites (Thomer, 2022). These works provided both guidance on executing my research and sensitizing concepts that I used in my analysis.

3.1 Participants

This study combines the perspectives of field station directors and researchers, who both have an active role in location-specific research. Field station directors[11] are administrative leaders. They facilitate

[10] This approach builds on the method described in Chapter 3.
[11] In a few instances, field stations identified other staff members who were more suited to discuss the data management aspects of the field station.

access for a broad range of scientific work and are often best situated to see the connections across research projects at the station. The second perspective is from researchers, who conduct scientific studies using data collected in areas stewarded by the station.

Often, these roles are blended, with a director also conducting research or a researcher taking on some administrative tasks. Director and staff participants have worked at field stations either as part of their data collection tasks or as part of their full-time jobs, maintaining the station facility. The researcher participants included a mix of researchers who worked full-time at the stations and those who visited the stations. Participants spanned various career stages, ranging from early to late career. However, most participants were mid-career and actively involved in their roles associated with the field station.

Field station directors and researchers are just two of the stakeholders involved in scientific stewardship. Publishers, funders, or local community members could have all provided useful perspectives. Still, I focus on these two categories of participants because, without either of them, scientific stewardship would not occur as intensely in these locations.

3.2 Data Collection

I collected data from 20 unique stations[12]. The stations represent a wide range of ages, locations, seasonality, and capacity. To indicate the range of stations, I have included the decade each was established and the type of environment in which they are located. This chapter builds upon the data presented in Chapter 3, incorporating 60 days of fieldwork and nine additional interviews. Where possible, I added perspectives to field stations already included in the data gathered for Chapter 3, rather than expanding the number of stations.

As designed in our approved Institutional Review Board human subjects' protocol, stations and participants are all anonymized with pseudonyms to avoid reputational harm, an approach advocated by Vertesi (2020). I use they/them pronouns for all participants because gender was not the focus in this study. When I describe participants' scientific work, I do not specify details of scientific studies. I am choosing to focus on the similarities within biological projects and how work is organized, so I do not

[12] Eight stations are added in this Chapter to the 12 stations from Chapter 3. Seventeen stations were included in interviews and three additional stations were added for participant observation.

specify the environmental study details. This further anonymizes the people and locations that were studied. Additionally, written consent was obtained from each interview participant, who had the option to withdraw from the study at any time.

3.2.1 Semi-Structured Interviews

Because my analysis follows a grounded theory approach, I collected and analyzed the data iteratively, expanding the types of participants interviewed as the analysis progressed to explore the concepts emerging in the data (Charmaz, 2014). In total, I conducted 20 interviews. These interviews were conducted in three phases, as shown in Table 1: August-September 2022, May-June 2023, and October-November 2024. I used DIR (director), STF (staff), or RES (researcher) to indicate my judgment of the major role for a given participant. Additionally, I have used these role abbreviations as part of the participants’ pseudonyms shown in Table 1.

Field Station Pseudonym	Decade Established	Type of Environment	Interview Participant Details		
			Phase 1	Phase 2	Phase 3
FS1	1930s	Terrestrial	RES_1		
FS2	1930s	Terrestrial	DIR_2		RES_2
FS3	1900s	Terrestrial	STF_3		
FS4	1990s	Terrestrial	DIR_4		
FS5	1920s	Terrestrial	RES_5		
FS6	1960s	Marine	DIR_6		
FS7	1920s	Terrestrial		DIR_7	
FS8	1970s	Terrestrial		DIR_8	
FS9	2020s	Terrestrial		DIR_9	RES_9
FS10	1980s	Terrestrial		STF_10a, STF_10b	
FS11	2000s	Marine		RES_11	
FS12	2020s	Terrestrial		DIR_12	
FS13	1920s	Terrestrial		DIR_13	RES_13a, RES_13b
FS14	1900s	Marine		STF_14	
FS15	1980s (lab), 1960s	Marine			RES_15
FS16a	1930s	Terrestrial			RES_16
FS16b	1940s	Terrestrial			RES_16

Table 1. Field Station Interview Participants. Field Stations (FS) (n=17), Directors (DIR) (n=8), Staff (STF) (n=4), Researchers (RES) (n=9) interviewed[13]

I recruited participants for the first phase through an open call to the Organization for Biological Field Stations (OBFS) community listserv. This first phase was heavily oriented toward field station directors, but it also included two researchers [RES_1, DIR_2, STF_3, DIR_4, RES_5, DIR_6]. In the second phase, I used snowball sampling to grow the dataset to include other field stations mentioned by participants in the first round. I also intentionally solicited interviews from stations with public data management initiatives and stations outside the U.S. This phase added seven additional interviews

[13] Pseudonym numbering uses FS<1-16> for the field stations. Individual participants referenced in the chapter follow the designated number for the field station where they work, and for multiple instances of the same type <a-c> added.

primarily focused on station directors [DIR7, DIR8, DIR9, STF10a, STF10b, RES_11, DIR12, DIR13, DIR14]. This expansion in phase 2 allowed me to explore the range of field station features.

Although the focus of the first two phases was on the field station directors' perspective, I saw from this small sample that researchers and directors seemed to have distinct perspectives. Directors and staff focused on facilitating science and researchers focused on conducting science. Following this observation, a third round of interview recruitment was conducted to intentionally add the researcher's perspective more fully, with six interviews. I recruited participants by searching Google Scholar for the field station names and emailing the corresponding author. Two interviews were added through this approach to existing stations in the study: FS2 [RES_2] and FS9 [RES_9]. Two research perspectives were included from FS13 [RES_13a, RES_13b] after reaching out to contacts for projects publicly listed on the website. FS15 [RES_15] was added to include an additional institution type. I initially classified them as a director, but ultimately decided they were a researcher after examining the overall structure of their station. Finally, a contact via FS13 introduced me to RES_16, who works at two stations denoted with a or b, where the specificity of the station matters [FS16a, FS16b].

The semi-structured interviews were conducted on Zoom and lasted about one hour each. All interviews were recorded and transcribed for analysis. The interview questions were designed to prompt stories and experiences from the participants. This approach allowed the participants to expand on topics most relevant to them. Participants were asked about their experiences working at a field station, including details about their scientific work or work conducted at the station, the collaborative processes between the station and researchers, and the kinds of information artifacts they shared. While the interview guide was essentially the same for both types of participants, questions around artifacts did diverge. For interviews with station directors and staff, I asked about how they found data and other research outputs about the station and the impact those artifacts had. For researchers, I inquired about the station's role and how they acknowledged or did not acknowledge the station in their downstream research outputs, and whether they shared the results with the station in any way.

3.2.2 Fieldwork and Details of Participant Observation

Between March 2022 and March 2025, I conducted about 18 weeks (128 days) of fieldwork at three field stations, with most of the days spent at FS_A (Table 2). This fieldwork included participant observation and interviewing. During each visit, I took detailed field notes and photos to record my observations (Emerson et al., 2011; Geertz, 2008; J. E. Moore & Yager, 2011). In total, the fieldwork data considered for analysis comprises over 800 photos and more than 70 informal interviews with researchers, field station staff, and directors.

Field Station Pseudonym	Decade Established	Type of Environment	Participant Observation Details
FS_A	1980s	Marine	✔ 120 days - Supported data management activities and workshops; Taught two-week courses in 2023, 2024, 2025. Environmental fieldwork participant in 2022 and 2025.
FS_B	1950s	Terrestrial	✔ 5 days - Attended and presented at field station network meeting; ~30 informal interviews
FS_C	2010s	Terrestrial	✔ 3 days - Attended and presented at field station network meeting; ~20 Informal interviews

Table 2. Field Stations (FS) (n=3) where participant observation was conducted by the author.[14]

I gained opportunistic access to the field station, FS_A, for ethnographic work through my ongoing work on data management activities at FS_A. These activities included designing and teaching an undergraduate field course on data management for scientists from 2023 to 2025, and collaborating on grants to support data management activities. As a result of this collaboration, I attended meetings at FS_A, FS_B, and FS_C related to field station operations and cyberinfrastructure development throughout the entire 18-week period. In addition to the data management activities, I also participated in two environmental sampling campaigns in 2022 and 2025. In these two experiences, I worked with ecologists to plan and collect environmental samples. This allowed me to have firsthand experiences like those described by interview participants. Brief descriptions of the participant observation activities are provided in Table 2.

3.3 Data Analysis

Data analysis in this chapter followed a constructivist grounded theory approach, where both sensitizing concepts from the literature and the subjectivity of the researcher inform the analysis

[14] Pseudonym naming uses FS<A, B,C> for the field stations. Individual informal interview participants are not referenced individually.

(Charmaz, 2014; Corbin & Strauss, 2014). I analyzed processes and actions present in the data. For all interviews, I used Atlas.ti and conducted line-by-line coding, staying close to the participants' words (Charmaz, 2014). Examples of open codes included 'clear vision of what data infrastructure should do' (DIR7), 'hard to plan timing of snowmelt' (RES_13a), and 'handing off between generations of data collectors' (DIR6). In total, I created over 3,800 open codes, averaging around 200 codes per interview. During this analysis, I organized data in memos and drew diagrams about my approach, individual interview insights, or scientific stewardship process steps, and connections or common concepts I noticed across fieldwork and interviews.

Throughout the entire period of this study, I alternated between open coding interviews and comparing the new data with existing data through rounds of constant comparison. Due to the large number of open codes, I conducted multiple rounds of reviewing the entire code list to create focused codes, a way to consolidate open codes that seem significant or frequent (Charmaz, 2014). Early rounds of focused codes included 'outcomes of data sharing', 'problems or disruptions', 'capacities required for sciencing', and 'identifying temporal constraints'. In another round, I organized open codes by type of labor: 'sustaining', 'relational', 'analysis', and 'infrastructural'. It was tempting to organize codes around an existing data lifecycle: plan, acquire, process, analyze, preserve, and share (Cox & Tam, 2018). While interview informants described the process in that way, my firsthand observations exposed science that was much more situated than it is recounted after the fact.

Through each of these rounds, I continually tried to define and evolve the grounded theory that fit the empirical data. This led to the central idea that the coordination point for researchers and stations was a *'research project'*. With this central idea, I organized my analysis according to four types of contexts that influence the social organization of projects: spatial, temporal, material, and relational.

3.4 Positionality Statement

I approach this research as a white settler woman based in the United States who does not hold an affiliation with any of the stations in this study. I have experience working with scientific organizations on data management issues, including at one of the field stations in this study, FS_A. I was a paid collaborator with the director of FS_A on two joint research projects throughout this work, and I was paid by FS_A to teach an undergraduate field course from 2023 to 2025. The ethnographic work presented in this chapter was unpaid.

As an ethnographer and one who attends to the constructivist grounded theory's assertion that grounded theory is subjective, I appreciate how my work and relationship with FS_A have provided access, informed, and shaped the analysis. During this research, at particular moments, I felt a tension within myself between the dissertation research direction and the direction of my consulting work with FS_A on data management. In planning my dissertation research design, I had imagined that the director of FS_A might help provide access to researchers, but I never felt that it was appropriate to ask. For this reason, the combination of data collection methods was shaped by these dynamics with FS_A. Reflecting on this tension, I realize that the relationships between field station directors and researchers hold their own tensions and are protected.

Conversely, this design, particularly the recurring fieldwork with FS_A and the broad interview study, provided unforeseen benefits. The initial collaboration with FS_A was my first exposure to the challenges of place-based scientific stewardship. It was tempting to think that FS_A was unique in its challenges. In the first interview with another station, I immediately encountered a researcher who was already solving some of the challenges FS_A was grappling with in their own way. The interview study allowed me to have agency over the dissertation research direction and, when needed, completely separate the research and the consulting work. Finally, the design enabled a productive, constant comparison, a component of grounded theory, between the fieldwork and the interviews. Tacking back and forth between broad and deep allowed me to gain a deeper understanding of place-based scientific stewardship. Finally, to ensure that I remained reflexive and true to the field station and research participants represented in this chapter, I presented and discussed ideas in this chapter with the field station community, both formally and informally, during visits to three field stations [FS_A, FS_B, and FS_C].

4. Analysis: How are field station-supported research projects organized?

Research projects are the central way that field stations and researchers work together. The following is a generalized project progression I synthesized from my data:

> *Teams come up with a research question, develop a proposal, procure funding, plan their fieldwork, come to the station and conduct data collection, and return home for analysis. Some repeat the planning through analysis steps over multiple cycles from days to years. Following data collection and analysis, research teams produce and publish a scientific paper or other academic output, like a dissertation. This is the output that builds their scientific reputation and track record for being able to conduct this type of research. These outputs are necessary to secure future rounds of funding.*

Thus, research projects tend to build on each other, where the outputs of one project inform the next proposal to begin this progression again. In the following analysis, I use short vignettes from my fieldwork and interviews to highlight different contexts that shape research projects. I do not expect the reader to hold the specific actors in mind through this section. I use their pseudonyms to indicate the specific data that backs up my claims. While the specific actor is not important, RES and DIR indicate that the actor is a researcher or a field station director and I will indicate this, when it shows their differing perspectives.

Despite orienting projects as a common practice, projects at field stations are highly variable. Projects vary in size, ranging from very large to small. Projects could be synonymous with a single grant, or they could be funded by multiple grants, or not funded at all. They could be repeated over time in the same location, repeated in different locations, or not at all. They could be student or class projects used for training and fulfilling degree obligations or conducted by professional researchers. Projects could have team members from the same institution or different institutions. Therefore, these projects are not constrained by approach but share the field station as a common platform.

In the following sections, I organize my analysis of the social organization of field station-supported projects around four contexts: spatial, temporal, material, and relational. For each of these contexts, I describe examples from my data that highlight the different ways in which it influences projects. Through this analysis, I illuminate the unseen influences of the projects' social organization on the scientific work and resulting outputs.

4.1 Spatial Contexts

For field research, the research topic or question and the location are intertwined. In this section, I describe the ways that projects make space scientific, are spatially situated, and the ways that both researchers and artifacts like data and samples are mobilized.

4.1.1 Making Field Locations Scientific

Field locations become scientific because of specific characteristics like their topography, proximity to the researcher's home institution, or distance from urban pollution centers [RES_13b, RES_16]. One researcher, RES_13b, described factors for choosing sites for their monitoring network. Their specific field station, FS_13, was chosen because it had physical facilities and was both convenient to access and over 1000 feet above the urban center, meaning that, because of elevation, the site was not influenced by local pollution. The combination of proximity and elevation enabled RES_13b to regularly access the site, ensuring near-continuous data collection. For RES_13b, the station was nice to have, but not a driver of their project. A researcher at FS_A provided another reason for choosing the field station. They told me that they had worked in a remote location for eight years without a field station prior to working at FS_A. That site had no running water or electricity. Eventually, they grew tired of the lack of physical infrastructure and looked for a new field location with more resources. They found FS_A to be a suitable location to move their research projects, and they enjoyed the support that the station brought to their project. In this analysis, all projects described are aided in some way by a station. As laboratory studies have shown previously (Knorr-Cetina 1983), the physical properties of the site shaped the work that both researchers (RES_13b and the researcher at FS_A) could do.

Once the site is chosen, researchers make field locations scientific through all the ways that they collect data. RES_13a described a particular way that they collected data: 'we would set down a PVC frame with strings going across it both ways, making 10-centimeter squares, and then use a pin flag to pinpoint at each intersection and identify what plant is touching.' (RES_13a) In this example, RES_13a is showing how they add physical structure to a field location to collect data. This portable PVC grid allows for standardizing measurements across many different plots.

Some field stations implement more permanent physical environmental modifications, such as managing experimental forests where trees are cut in specific ways (Figure 1). These permanent interventions become part of the suite of tools available to all researchers working at a station. One field station, FS_2, maintained such a modified environment, and a researcher working there, RES_2, was able to utilize that environment in their experimental design. They were able to sample a random selection of points in two different kinds of environmental treatments to understand commercial impacts on the ecosystem (Figure 1 shows an example of such a treatment).

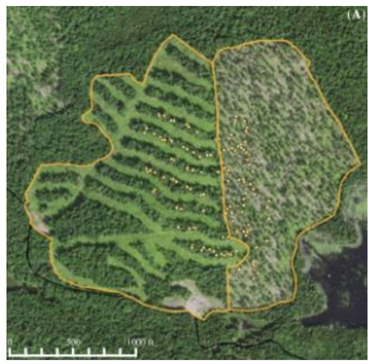

Figure 1. Example of experimental forest interventions (Ames et al., 2023)

In addition to sampling, RES_2 placed humidity sensors in the environment to collect additional contextual weather data correlated with their sampling locations. RES_2 conducted one project, but there are likely many projects that use the same field location and have benefited from making this field location scientific. However, there are no physical traces in the environment that indicate who else is working in the same location. This means that researchers are often unaware of others' work when they are in their study environment.

4.1.2 Spatially Situated

Researchers make the field scientific, but the field also requires the researchers to adapt or spatially situate their work. These adjustments influence their project and the data they can or cannot collect. In my own fieldwork, our team planned a citizen science sampling day as part of a conference at the field station, FS_A. Prior to arriving at FS_A, the collaborators, who were not familiar with the area, used Google Earth to identify a string of points to sample. However, on the day we set out to find the points, we realized the disparity between what we planned and what we found. My sampling team was assigned four sampling sites. We were supposed to collect a water, soil, and sediment sample at each point. We did not make it to any of the exact GPS points planned from Google Earth. Some Google Earth points were not in the stream and needed to be shifted a few meters to collect water. Another point was in a very dense forest with thick brush that we could not access, so we adjusted our plan and collected an extra set of samples at the next site, where the access was easier. These deviations show how spatial plans deviate from the situated action in the field (Suchman, 1987). The Google Earth planning helped to organize teams to go to specific areas on the route and not to overlap, but for each sample collection site, each team had to make decisions about where and how to sample.

Spatial uncertainty can make fieldwork hard to plan. For instance, a researcher visiting a new field station, RES_9, described their planning process when they had a lot of uncertainty because of the unknowns. RES_9 planned several different data sheets and approaches to data collection before their fieldwork:

> 'So the planning, I had still never been to [FS_9] before, going for the research, so I didn't really know exactly what I was going into… I think the most planning was, you know, figuring out a good method that would work, which honestly, I ended up changing in the middle [of fieldwork] because, once you're in the field, you realize there's different things.' (RES_9)

Once RES_9 was in the field they realized that the data collection method they designed assumed the animal would be difficult to find. The animal was easier to find, so they changed their spatial data collection design to transects. They went on to elaborate on how they adjusted both their data collection structures and their method in the field:

> 'In the field, I ended up not even using my data sheets that I printed and just using my little notebook, which I kinda made the same data sheet, but, like, it's smaller, easier to carry, and it's write-in-the-rain. So I ended up using that. And the columns did change a little bit or, yeah… I would say for a transect, they changed quite a lot because, initially, I wasn't gonna do transects…. before coming into the field, I wasn't sure how easy it would be to find the nesting sites of the [species]. I thought it'd be quite hard. And then as we started looking around, we found them easier than I expected. So then I was like, okay, since it's easier to find them, we're gonna actually do structured transects because there's a lot more, you know, power in this analysis than just walking around randomly.' (RES_9)

RES_9 highlights the contrast between planning at a distance and being spatially situated and adjusting to the real world. RES_9 centered the field station and walked 2 kilometers from the station in each direction. As they indicated, being able to conduct transects is a more scientifically robust method, but they only knew this was possible when they were situated in the field. In the examples above, once the researchers arrive in the field, they can make adjustments and correct assumptions made in their plans.

Up to this point, the researchers collecting data in the field were also the researchers conducting analysis and publishing the results. However, with requirements from funders to share data, including in situ environmental data, it is easier than ever for researchers to work at a distance without ever coming to the station. These at-a-distance researchers may not understand the methods used to collect field data they are reusing, or they may make assumptions about the location based entirely on remotely sensed data without ever validating them with in situ data or visits to the location. A field station director, DIR_2, wanted those at-a-distance researchers to come to the station and see the field, and make a connection to the location, arguing that spatial context would augment their work in beneficial ways. This is an important reminder. Publicly shared data, particularly remotely sensed data, are easy to use because of their standard formats and spatial coverage, but, as mentioned at the beginning of this section, what Google Earth can tell a person about a location and what it is like to be on the ground in that location are entirely different. Projects are shaped by how spatially situated they can or cannot be. If the project is distance-only, it can answer different kinds of questions from that vantage point, compared to projects in the field or those that combine field and distance. In the next section, I will elaborate on how both people and data are moving back and forth from at-a-distance to the field and back to distance.

4.1.3 People and Data Mobilization

Projects supported by field stations are almost always mobile, while the stations are not. The term ‘station’ was chosen by Anton Dohrn, the creator of the first marine station, to intentionally evoke railway stations (Groeben, 2013). He envisioned a network of stations that researchers could move between (Groeben, 2013). Mobility studies scholars highlighted that the introduction of rail in the 19th century allowed for new experiences by accessing space that was otherwise difficult to reach (Schivelbusch, 1979; Sheller & Urry, 2006; Urry, 2007). The real-world movement allows for projects to benefit from researchers working at multiple stations looking for a particular species or phenomenon, returning to the same stations to conduct long-term monitoring, or some combination of these approaches. All researchers in the study described these types of engagements. Like railway stations, field stations benefit researchers by providing spatial consistency and continuity across their projects. Stations in the study conducted common types of work, but they did these types of work in bespoke ways, situated in their particular environments and serving the researchers they worked with best (Robinson and Palen, in review). Hence, researchers' movements shape their projects, but they also shape the stations that support them.

Environmental research is not always done alone. It can require collaboration as well as expertise that crosses institutional and domain boundaries. Thus, many research teams have multiple people moving around. These teams spend time working together in a distributed manner. They coordinate synchronously and asynchronously using digital tools like Zoom, Slack, and Google Docs. Yet, "distance matters," meaning that proximity to our collaborators and to the places we work shapes our work (Olson & Olson, 2000). The station provides an added benefit to projects. The station is a real-world common location for researchers to be spatially collocated. The spatial collocation shapes projects by benefiting from different expertise focused on a single location, collecting multiple types of data to provide a deeper understanding, and sharing resources like equipment and materials. Often, teams attempt to temporally collocate, which I will turn to in section 4.2, and the synchronous colocation deepens team relationships and spurs future work (4.4).

When researchers move physical samples, and research artifacts like data sheets or hard drives with digital spreadsheets also physically move from the field. RES_9 mentions capturing data in their write-in-the-rain notebook. This notebook is then taken back to the station lab, where the data is digitized, and both the digital and the physical copies of the data are taken from the field. Several participants mentioned physically deploying instruments spatially during fieldwork, like the weather instruments mentioned by a researcher, RES_2, and collecting them to retrieve the data for analysis with other types of data. A field station director who also conducted research, DIR_8, described bringing external hard drives to the station with them to back up data from laptops and then physically transporting the hard drives back to their home institution. Thus, physical labor is required to mobilize data from its original location to another location for further analysis.

As researchers move back and forth from the field, their home institution becomes a 'center of calculation', accumulating physical artifacts about these locations (Latour, 1987). The more the researcher accumulates from these locations, the more powerful calculations or knowledge production can occur (Latour, 1987). As the researcher builds this center of calculation, there are not necessarily visible traces of this mobilization for others to know that it exists or for the communities surrounding the field locations to know that data was removed. Consequently, the researcher's control of their center of calculation provides a powerful advantage over anyone else wanting to study this same location, but who is unaware of this work. We will return to these relational dynamics in section 4.4.

So far, the spatial contexts have generally acted on projects in the real world. I now move from the real world to online environments. The proliferation of Wi-Fi and cellular networks is reducing the need for human labor to physically gather the data. With these technological advancements, data can be wirelessly transmitted back to home institution servers or stored in public cloud infrastructure, opening up new research possibilities. Considering where and how data will be mobilized digitally also shapes projects. A researcher, RES_11, intentionally considered the final destination for the data during planning. RES_11 explained that this consideration then shapes the structure of data and metadata collected:

> 'We want to share our data and make sure that … we are able to be indexed by other catalogs or the Google search engine or have those metadata records be harvested, for example, by the [international observing network]. That really helps us understand what kind of data, as well as metadata, we need to collect to ensure proper reuse and attribution, making sure that we receive proper accreditation.' (RES_11)

RES_11 is part of a large, international collaboration that is trying to mobilize spatially distributed data into a single network. This planning and conformance to standards help move the data from the field to the digital space.

Mobilization of people, objects, and data can seem like a black box. Yet, from the data shared here, it is evident that mobilization requires significant labor over months and years and requires a lot of effort. The social studies of mobility opens the black box to attend to the social organization of both the people and data moving across physical and virtual space (Büscher & Urry, 2009; Sheller & Urry, 2006). Even with the shift to attend to the mobile, the dominant narrative still describes these movements as 'flows' or 'pipelines.' I use the term 'journey' to describe the ways that projects and the people and data that are part of them move, getting stuck or lost, or end up in unexpected places (Bates et al., 2016; Leonelli, 2020). Journeys are influenced by spatial, as well as temporal, material, and relational contexts, which I turn to in the next sections.

4.2 Temporal Contexts

Field station-supported projects are shaped by time. Time is often taken for granted in projects. However, just as distance matters to spatial organization, "time matters" to temporal organization (Jackson et al., 2011, p. 245). In this section, I approach time as 'social time' or the way that time is problematized (H. Lee, 2003; Zerubavel, 1979). Sociotemporal arrangements are foundational to the social organization of projects. With this lens, I examine how temporal rhythms, alignments, and misalignments influence field station-supported projects.

4.2.1 Rhythms of Scientific Work

Environmental science research is influenced by a variety of temporal patterns or structures that are used to organize work into rhythms (Zerubavel, 1979). For instance, the study subject may have seasonal variations, or the researcher may work at an academic institution with teaching obligations, so the fieldwork is only possible during certain parts of the academic calendar or the environmental life cycle. These rhythms occur at varying intervals from hourly to generational (Zerubavel, 1979). Each rhythm influences the way a project is conducted.

The daily temporal rhythm of a field station, FS_13, shapes how space is used. The director of this station, DIR_13, remarked that many visitors to FS13 are surprised at how empty the station is during the day. One of the researchers who worked there, RES_13a, lived near the station. They described their normal workday during the field season:

> 'I get on the shuttle vehicle in the morning and get a ride up to [FS13] and get there at about 7 AM. And then we go into the [station] lab, [the station headquarters]. But we also have lab spaces, and so we keep our stuff in there and get our stuff together. And we get back in the vehicle by 7:30 and drive up to [the hike in spot]. And then we hike up [to our experiment sites]... Sometimes we stay at the same site all day. Sometimes we go to multiple sites depending on the measurements and how much needs to be done. And then we're back at the vehicle by 3:15 and then drive back down to [FS13]'. (RES_13a)

From RES_13a, we see that they are only at the station itself for about 30 minutes. This daily cycle is repeated during the field season from June to September or October, depending on when it starts to snow. RES_13a can't collect data if there is snow cover, thus the project is limited by seasonal rhythms. Wet and dry seasons are another type of seasonal pattern that research projects may follow. Another station director who also conducted research at another station, DIR6, timed fieldwork around these seasons:

> 'When we were working on the functional trade study, we were trying to catch different seasons. And so it wasn't like every three months, but [we timed visits] to the end of the dry season, in the middle of the wet season, and at different times that seemed to be important functionally to the plants. And we did that for about three years.' (DIR_6)

DIR_6 described how the project responded to seasonal patterns for the research questions of interest, rather than adhering to an artificial rhythm of trips every three months. This dynamic and responsive fieldwork can clash with other rhythms because it is not predictable or easy to plan.

Beyond annual seasonal patterns, projects are shaped by academic calendars or annual reporting cycles for permits or funding. These points provide motivation for information gathering and project documentation. A field station director, DIR7, described preparing the annual report as a reason to reach out to all prior year researchers for any recent research outputs, like datasets. A researcher, RES_1, also used mid-point grant reporting as an opportunity to ensure data contributions were being made and not piling up. Together, the seasonal and annual patterns of field station visits and reporting provide a regular cadence meant to move research forward.

Some environmental projects only require a single visit, like for a few researchers [RES_2, RES_9], but some projects are meant to last longer than a single researcher's career, requiring 'continuous coverage' or persistence through time (Zerubavel, 1979). A director who had their own long-term monitoring project at another station, DIR_6, described how they became the lead on a long-term monitoring project passed down across researcher generations from their advisor to them:

> 'And then we have a long-term forest productivity and tree growth study on the property, too, that was started in 1990, or 91. And so that's 30-some odd years old now. So in my case, I obviously didn't start that dataset [30+] years ago; I guess I would have been [a kid]. …So it turns out my, my PhD advisor, and some of [their] colleagues started it and they were interested in tree growth and productivity in [a particular type of] forests, …, so they measured tree growth, essentially [tree] diameter. [The original research team retired.] So the Forest Service had maintained a lot of the growth measurements until I got down there as an assistant professor, which was in 2005. And then because I had already been part of the project as a grad student, they turned it all over to me.' (DIR_6)

Passing the research project from the original team to the forest service to a student of the original team is an example of the 'long now' (Ribes & Finholt, 2009), or the long-term sustainability of a project that exceeds the career of individuals. Most projects don't outlast a single career, but longevity is fairly common for field station-supported projects in the study focused on environmental monitoring [RES_1, RES_5, DIR_8, RES_13a, RES_15, RES_16]. This continuity is a characteristic that researchers intentionally plan for and design into their project.

The long now requires project continuity over time, which means it needs to transition across people. One-way teams attempt continuity is through staff consistency, employing the same staff for as long as possible. Another way that projects navigate the 'long now' is through documented protocols described by several participants [RES_5, DIR_8, STF_10a, STF_10b, RES_11, RES_13a]. Protocols are detailed descriptions of how to collect and manage the data for a particular project. Protocols are used to onboard new data collectors, connecting past researchers to present researchers. A researcher, RES_11, described the way protocols were used at the beginning of the season:

> '[A]t the start of our field season, we go through our protocol with anybody new that's joining our program. We go through a fairly rigorous, I would say, training week in the sense that we go over safe work practices, we go over the field protocol, we go over [equipment] training, and we physically [deploy monitoring equipment], so there is information available for new people to understand how we collect our data. Of course, doing it in person versus seeing on paper is always, one learns better by doing versus reading, but the information is always there.' (RES_11)

RES_11 emphasizes that a data collector learns best by doing. This is an important note because it emphasizes the highly situated nature of fieldwork, in which researchers make adjustments as they translate their written protocols into real-world actions. Echoing the idea of plans and situated action (Suchman, 1987), where the protocols are the plans, encoding the specific *sciencing* assumptions and techniques (White, 1938), the actual data collection efforts require boundary negotiating or the workarounds necessary to actually complete the tasks. Protocols provide a link between past and future researchers to ensure consistent data collection.

This link across time started with the pre-season review and concludes with post-season updates. Two researchers in this study working at different stations, RES_5 and RES_11, both updated their protocols post-fieldwork for any modifications. RES_11 also versioned these protocols, saving a copy before they made updates for future years. This allowed the data collected in a given year to be linked to the particular protocol for the same year.

While these protocol documents are often for internal use only, this documentation practice turns out to be extremely valuable when the researcher is no longer present. One staff member who supported data practices at a field station, STF_10a, was archiving a legacy dataset, and while that work was ongoing, the researcher who created the dataset died suddenly. However, that researcher had left rich documentation:

> ‘Thankfully, [they] did leave the data in pretty good shape, [they] and [their] field staff and technicians over the years. But what I wanted to say about that is, as I work through that data and make sense of it and put it in a repository, some of the most useful pieces of information are the field and lab protocols. Those have been invaluable to making sense of the data. … They printed everything out and put it in binders, and they were very, very, very, very organized. But it's an enormous job. So it's super useful to see. They wrote exactly what they did and when they did it and how they did it in these protocols that they kept.’ (STF_10a)

The ‘long now’ requires effort, and as STF_10a indicates, the documentation was a lot of work. It’s unclear what drove the researcher and their team to conduct such extensive protocol documentation, but because it was done, future researchers may benefit from their work and be able to use this data in ways that would not be possible otherwise. This legacy data and STF_10a’s work enable future projects that are not known to build on this prior work, persisting the ‘long now’ across artifacts.

4.2.2 Temporal (Mis)alignment

Throughout my data, the interactions between rhythms described in the last section were a recurring topic. Researchers find that working from field stations provides temporal persistence. Many stations in the study are more than 50 years old, with some approaching over 100 years old (Table 1). This means a long history of research experience has accumulated in these locations. This persistence contrasts with researchers’ dynamic temporal patterns. Because of temporal constraints, researchers become extremely proficient at fieldwork and work at stations with an intensity that is not maintained in the same way at their home institution.

Aligning the station and researcher temporal rhythms is one example of where work is required for temporal alignment. Each time a researcher returns, they feel renewed pressure to get as much done as they can. The station staff must inform the researcher about any local changes that could impact their work. This can seem like boring administration, but when this alignment fails and researchers miss details on a new rule, projects suffer from a lack of temporal alignment or dissonance. One example of this dissonance occurs when a researcher’s permit is only valid for a portion of their fieldwork time. A mismatch like this can mean that data collected cannot be used because it wasn’t legally collected in the first place, or that data cannot be collected at all, keeping the team out of the field even when they are at the station.

Often, interview participants would provide the temporal equivalent of a Google Earth 30,000-foot view of the temporal organization of their work, omitting the temporal interactions. However, as I probed for details in these interviews and triangulated through my own ethnographic fieldwork, I saw that there is social negotiation needed to overcome temporal misalignment and work to maintain the alignment required for field station-supported projects.

While I was at a field station, FS_A, in March 2024, I had a set of projects with different temporal rhythms that overlapped. I was teaching an intensive, 3-credit course compressed into two weeks, with about 45 hours of contact time required. During the second week of teaching, my collaborators planned a workshop. It was great news because I happened to be at FS_A, but I experienced temporal dissonance trying to juggle class schedules and workshop time. I felt like I hadn't been able to participate in either project as well as I might have if I were only devoting my time to a single task. However, the workshop in the second week happened to be the window when most participants could attend.

More recently, finding overlapping time between collaborators is difficult. We are at different institutions and do not share calendars. Without group calendars, we are unaware of professional or personal obligations, academic calendars, and other unshared trips planned to FS_A. This lack of awareness means we often just miss each other, sometimes by hours. During fieldwork in February and March 2025, I spent five weeks at FS_A, during which I met with one collaborator in the first week, another in the fourth week, and a third in the fifth week.

From both experiences in 2024 and 2025, our project planning has shifted to communicating all travel plans to FS_A with the group, blocking out visits where being co-located is important much further in advance, and we are very aware of teaching obligations because the work with students makes project work unrealistic. This openness is a first step that indicates our team might be ready for a groupware calendar (Palen, 1999), but we cannot force the team to move their calendars to a new system. The technology to bring multiple calendars from Microsoft and Google together has proved to be a barrier we have not yet overcome.

My experience of stacked obligations while at the station turned out to be common. Fieldwork comes with inherent risk of failure. As a result, the multi-tasking that I found difficult can also serve as a safeguard to ensure research teams accomplish as much as possible in a single visit. One researcher, RES_9, was funded to go to FS_9 for a large, complex project plus a few additional side projects. Ultimately, the primary project failed because of spatially situated complications, but RES_9 was able to pivot to their own project more fully and collect all the data that they needed for that project. So while one project had a loss, another project was completed. This multi-project membership adds complexity to interactions between projects. Another researcher, RES_13a, worked with a set of students who were less adept at multitasking across projects, and the results were error-filled and required RES_13a to do significant post-collection clean-up.

Balancing funding timelines versus data collection timelines is another type of temporal alignment. Funding drives how long a researcher can stay at the station, how many people support the project, the types of analysis they can do, and, more recently, variable requirements to contribute their data to the broader scientific enterprise. A researcher, RES_2, explained this balance:

> ‘I did have a budget [from a funder], … I did have to pay to stay there, technically. So, it came out of my research budget to actually have lodging. So there was not necessarily a time crunch, but the longer I stayed, the more expensive it would be and the less money I would have for the rest of the supplies that I would have needed.’ (RES_2)

For RES_2, this constraint worked to their advantage because a short stay meant that the environmental variability was limited, reducing the complexity of the project. Conversely, DIR_6 prioritized consistent data collection over a long term without requiring alignment to a funding timeline, returning to the idea of prioritizing continuous coverage, which here speaks to the moral obligation those focused on long-term environmental monitoring have (Zerubavel, 1979).

A major misalignment arises from the funder's requirements that researchers agree to manage and share data before collection and the subsequent researcher follow-through to deposit their data. A staff member with a research portfolio, STF_14, describes the very specific instructions they get to publish data:

> ‘So the NSF, my main source of funding, is [NSF Program]. Then they have this policy, this webpage, [domain repository]... we have to put all the data in [domain data repository] and release it two years after analysis…. But in general, for all funded research I do, I need to release all data within two years, due to the legal status.’ (STF_14)

This expectation is set before work occurs, and there are many things that could make this difficult between the start and end of a particular grant. Many participants [RES_1, DIR_4, RES_5, DIR_8, RES_11] talked about embargoing data, particularly to protect early career researchers. Embargoes are agreed on privacy protections for a certain amount of time, which allow the collector exclusive access to the data. This is an example of funder/researcher temporal alignment.

More often, the funder/researcher alignment is out of sync and data is not deposited at all. A researcher, RES_5, described how funding runs out sometimes before the data are even entirely collected: ‘So you get a three-year grant from [a funder], and you don't actually have all the data in even yet, and then you run out of money for a data manager’ (RES_5). Further, researchers prioritize publishing papers over managing data, and this, too, causes temporal dissonance. As researchers move away in time from the initial funding agreement, it can be neglected. This pattern is also seen when researchers are granted permits, and as a field station director, DIR_9, indicated, there is only partial compliance with permit reporting. Funders and government agencies have limited resources, both time and money, so the consequences of neglecting these agreements are minimal, if at all, for projects. These misalignments have material consequences because the artifacts are not visible beyond the research teams.

4.3 Material Contexts

Building on spatial and temporal social organization, the material organization of projects has consequences for what work is done and how it is done. Like the first two contexts, materiality is often downplayed or disregarded (Orlikowski, 2007). Materiality is the central way that projects cross the real-world-digital boundary. In the Spatial Organization section (4.1), I alluded to the materiality of data when I described how researchers used to back up and move data via hard drives or how another researcher [RES_9] reworked their datasheet based on the spatial situatedness required. In this section, I describe the human-artifact relationships necessary to do project work.

4.3.1 Artifacts in Context

Research teams use context as a memory aid and to validate current data with past data, both of which are used to ensure that the data quality is high. Artifacts are produced from prior work to aid future work. A field station director with a research portfolio at another station, DIR_8, described the species count data sheets for the current year used to collect occurrence data. They listed the 50 most common species seen in the last year, and left room to write-in other species. They also printed these on waterproof paper and brought them to the field station. In past years, they printed them onsite at the field station where they worked, but one year the printer broke, causing a lot of stress for DIR_8. They had to devise a work around to continue their project. Another researcher, RES_13a, took their prior year's data with them into the field. They described the information in their field binder as a way they augment current data collection:

> 'I have just one of those thin, like, the skinniest size binder for each site or each experiment. I have dividers in it. And behind one is last year's data, and behind one are blank data sheets, and behind one are pages where we can collect things that we need to identify in the lab. And so we'll have, some of the experiments, we have little maps made of just like the sheet of all the plots and little maps where we've noted, like, this is where we found the [species] because [species] can be hard to find, and we don't wanna spend forever we know things that are present even that we don't hit with the pin flag. And so we wanna be sure and catch everything that's present, but things can be hard to see, so it makes them a little bit easier to find if we have, you know, made a little map.' (RES_13a)

These resources are both examples of a specific type of boundary negotiating artifacts, called a 'compilation artifact' (C. P. Lee, 2007). Compilation artifacts like these support researchers in anticipating their needs in the field and aid in remembering key elements from last year to ease data collection this year. Like all boundary negotiating artifacts, these artifacts are ephemeral. While essential to data collection, they are invisible in the final datasets. They are also not shared. The same researcher, RES_13a, went on to emphasize this:

> 'It's just they're just something I'm using. I do scan them and lump them in with the scanned data for that experiment every year, just in case. … my field assistant and I are really the only ones ever using them.'(RES_13a)

The binder is scanned and archived with the datasheets, but that information is generally just used by the two data collectors, RES_13a and their assistant. This information is preserved, but it is an approach that RES_13a has devised and is not shared across other collectors working at the same station.

Post-fieldwork, DIR_8, in their researcher role, would compare the collected data to the literature and prior data, and anything outside of two standard deviations would be flagged for further review. Another researcher, RES_5, described a similar anomaly detection practice, which was notably collaborative, used to check for outlier data points by situating this year's data temporally, in relationship to their past data, and spatially. The data manager would plot the data, a material transformation, and the project leaders would review for points that seemed out of place.

> ‘And if this year does anything different than we think is, could this be real? Or is there a problem, right? And if there's a problem, we investigate that.…. The longer time you accumulate, the more you know what to expect, which you could say, well, then why are you still measuring if you know what to expect? things happen, you know, like in our [environmental] plots, we had [damage] from a storm in some of the plots and then [the environment changed], right. And then we had a disease come in and kill a bunch of trees. And that shows up in the data. It looks like an anomaly. But if we can explain it, it's like, Oh, those are the [specific type of] trees. And that's when the [pest species] arrived and killed them all, then it's probably real, right? If your [specific type of trees] disappear [from the data], but we'd go out there and they're still there. And then somebody forgot how to or didn't know how to identify [a specific type of] trees. We need to fix that.’ (RES_5)

In this case, the context enables the detection of errors and the explanation of causes in data deviation. In both cases, there is a layering of spatial, temporal, and material context that shapes the project practices and ultimately the resulting data.

4.3.2 Material Transitions

Environmental science relies on the material transitions that turn physical samples and observations into immutable mobiles (Latour, 1987) to be moved from the field to the lab (4.1.3). These are material transitions that could be from observations to jottings in notebooks to digitized data tables that are ready to be combined with other types of information. Samples are packed in ways that can be transported, like one researcher, RES_2, put their specimens in alcohol. These transitions are often dictated by the project's decisions about the particular protocol they will use (4.2.1), which has material implications for what future data could be derived from a sample. Further, what a researcher chooses to write down can allow for future analysis possibilities or foreclose them.

Fieldwork is labor and time intensive. As technology evolves, environmental research teams are adapting their practices, often in ways that accelerate their work. A field station staff member who supported researchers, STF_3, described moving from clunky handheld GPS to phones, which streamlined what needed to be brought into the field. A researcher, RES_5, described the station no longer collecting its own aerial data because satellites and drones provided superior datasets at higher resolution. Another researcher, RES_13b, described transitioning to a new instrument by first running the two instruments in parallel for a few weeks, then calibrating between the old and new instrument, and then switching completely to the new instrument. This material transition provides temporal continuity. This experience was expressed by another researcher, RES_13a, who transitioned from a manual process to a new digital instrument, adopting a similar, albeit longer, multi-year parallel approach similar to the one described by RES_13b. Initially, both were used in parallel, and then, after calibration, RES_13a switched over to just using the new instrument. In the case of RES_13a, the shift resulted in two consequences: (1) the shift to new technology allowed for more reliable data and observing impacts not visible to the naked eye, because the labor was captured through a handheld device and (2) the data generated was much larger so it had its own learning curve, required new ways of processing and storing, which became a project in and of itself. These material transitions fundamentally change the projects that adopt them. In the case of RES_13a, they both needed to incorporate the new instrument into their existing dataset and adapt their practice due to new scientific findings and to larger data files.

The next place that material transitions occur is from the field to analysis. Researchers must digitize handwritten fieldnotes to conduct their analysis. Environmental field data, like biodiversity data, are well known for their bespoke formats, so this process tends to be tedious and lacks tools (Borgman et al., 2007; Bowker, 2000). The temporal rhythm of this transition can vary, some researchers do this as an almost daily practice like one researcher, RES_9, who felt it was important to do this quickly so that if there were anomalies, they might remember what was out of the ordinary, and others do this digitizing work post-field season [RES_1, DIR_6, DIR_8, RES_11, RES_13a, RES_13b].

At one field station, FS_6, the director, DIR_6, described a recent summer intern's work to transcribe decades of data for a long-term monitoring project that was being handed off to a new researcher. This project was maintained by one person since the 1970s, and this person was now in their 80s. A new researcher was hired to take over this project, while the original researcher continued to provide support. In the transition, they needed to transcribe all the original collector's notes. The intern selected to do the transcription was the original project maintainer's grandchild:

> '[This] was pretty sweet because [they] got to work with [their] grand[parent]. The [grandchild] was a little less afraid of calling [them] out on [things that were] totally illegible. … Oh, this was the perfect thing. It really just kind of fell in our lap. Because, because [the grandchild] was a wildlife major. So [they] were already interested in that stuff. And … it's an excuse, just go hang out with, with somebody in your family that you really like, you know, so, and, and honestly, I don't know that anybody else could have done the job that [the grandchild] did on that.' (DIR_6)

This quote highlights the tacit skills needed for transcription and the values encoded in this material transition (Bates et al., 2016). It also allows us to return to the social notion of materiality, where the practice was transformed, and the director, DIR_6, even speculated that the quality of work was better because of the familial relationship. If the transcriber doesn't feel safe asking questions, errors or omissions could be left out of the digitized copy. Thus, the social organization of field station-supported projects is regulated by the material organization required for digitization or other transformations. However, the relational organization that underpinned it was also critical. Without this work, analysis, and the production of research findings cannot occur.

4.4 Relational Contexts

After the interview with the field station director, DIR_6, who shared the anecdote about the grandparent and grandchild, I began to note relationships. I encountered a large number of researchers married to other researchers who worked in the same places. While this is not unique to field station-supported projects, in this particular type of work, you are often far from home for weeks to months. Scientist parents who had children with them during field seasons sometimes saw their children become scientists. Advisor-student relationships are another type of relationship that significantly influences the types of projects a person might work on. It is obvious that the social organization of field station-supported projects would be influenced by relationships. What was surprising was the consistency in the ways relationships influence projects.

4.4.1 Gatekeeping Places and Artifacts

'Gatekeeping'[15] as a term was first used by Kurt Lewin to describe the way material, in his case food, is controlled through social contexts to ultimately end up in a meal (1943). Food enters channels, which have sections, and the sections are controlled by 'gatekeepers' or 'impartial rules' (Lewin, 1943). Lewin also notes that the contexts on either side of a gate are different (1943). Field station-supported projects encounter gates from the funding gate, to the physical access gate, to the publication gate. These gates all shape what work is deemed as research.

Assuming that researchers have funding for their project, the field station is the first gatekeeper that the teams pass through. Most stations have an application process where researchers provide a

[15] Gatekeeping has been more recently used as slang on a social media, as a person who controls access to a certain community or body of knowledge. https://www.urbandictionary.com/define.php?term=Gatekeeping

project description. These applications are reviewed by the stations for scientific validity, alignment with work supported by the station, potential impacts to the environment, or physical materials being taken from the station. One researcher, RES_5, was a reviewer of applications for their field station, FS_5, and they described an application submitted by someone who wanted to test explosives. This application was rejected, and the researcher was redirected to a military base, where that activity might be more appropriate. In my data, this was a rare occasion, but it does highlight the protection of FS_5.

Some stations [FS_A, FS_B, FS_9, FS_12, FS_14] are in areas where biological piracy or poaching occurs. In these areas, applications are reviewed strictly to ensure that it is legitimate research. A field station director, DIR_12, partnered with a government agency to review applications and had a two-step gatekeeping process. Prior to submitting the application, DIR_12 worked with teams about their projects and the details needed, so by the time researchers submit the official station application, it is a formality to approve it. DIR_12 has a working relationship with their government partners and has done all of this preparatory work because the agency doesn’t have time to work with researchers at this intensity. With the application approval, DIR_12 notifies the researchers to next submit a permit request to the agency as a second step. Through all of these steps, DIR_12 is helping research projects justify their research:

> ‘And mostly the [government agency] wants to know why [FS_12]. There is concern that they don't want to provide permits to everyone coming in, especially if it's redundant field work. So that's the other component that has to be addressed. Like, why [FS_12] and why is this unique and demonstrating that it's going to have meaningful results that... or at least some impact that isn't redundant.” (DIR_12)

DIR_12 provided invaluable, invisible support to the research projects working in this area. They struggled with this pressure from the government agency to justify uniqueness in part because it seemed to really be about a second issue, resource management. Researchers responded to the permit with an argument for uniqueness, but DIR_12 thought tracking how many of a particular species for monitoring resources may have been more effective. The government agency also had several staff rotate through the agency review role. DIR_12’s proactive engagement with the agency reduced the gatekeeping threshold for researchers and also provided continuity across agency staff, who would otherwise be forced to reinvent the processes every time someone new stepped in.

Projects also build gates as a competitive advantage. Once researchers have passed through these gates, they feel a sense of ownership in their artifacts and all the derived knowledge they are accumulating. DIR 8, a field station director, exaggerated this sentiment, but it also encapsulates what I have seen across many research teams:

> 'Well, I didn't bust my butt to get a grant [from a funder] and spend three years collecting all this data just to put it on the web so that other people could publish papers. Once I've wrung every last drop of publishable material out of this, I'm happy to share it, but until then, it's mine.' (DIR_8)

This view shows the strong feelings of ownership and the rights that the data collector feels over the data. This quote also demonstrates the relationship between ownership and sharing. Many teams put up significant gates around their data to protect it. One researcher at FS_A described how they did not digitize any of their field notes until they were ready to sit down and write the paper. This allowed them to justify not sharing their data because it was physically impossible. This is a form of 'data siloing' where data are intentionally disconnected to protect it (Darian et al., 2025). However, unlike data siloing for advocacy, this reluctance to share is changing over time and varies across stations and research teams. One station director, DIR_13, emphasized that this type of data siloing does not happen everywhere. They described a counterexample to gatekeeping. The relationships this director has cultivated at their field station, FS_13, are collaborative and sharing data more freely is the norm that was established by prior directors and has persisted through time.

Often this shift starts with research teams beginning to share with each other. One way that this shift occurs is when data acts as a gateway into a community or team (Birnholtz & Bietz, 2003) Collaborators of collectors are often given private access and are aware of data that is not otherwise public. A researcher, RES_9, described this specifically, saying that their team shared data in public cloud storage, but it was only accessible to the team.

> 'When I joined the team … they added me to the [shared team] folder... And so they've got, some of their … data there and I was able to download it [to use in my project]. For my current project now, I'm also still working with them, and I'm using another dataset that they've collected for years, but they've never analyzed... When I finished [my first] project, I reached out to them and I was like, "hey. I'm looking for a new project to finish my [degree]. Do you have any ideas?" And they [said], "we've got this dataset and nobody's used it." It's also in the [cloud] folder. ' (RES_9)

This approach of adding people who join the team to a shared drive was a practice in RES_9's team. They gave and removed access as researchers joined and left the team. The other interesting aspect of this quote is how willing the team was to share an unanalyzed dataset with RES_9 after building a relationship during the first project at the field station, FS_9. This researcher, RES_9, understood the implicit rules of sharing restrictions and only shared what was explicitly under their control.

Despite sharing within the team, this project gate is hidden. The cloud folders or undigitized data are considered ‘dark data’ or data that is not accessible (Heidorn, 2008). RES_9 would never have known about the additional dataset without being part of the team. Finding this data often occurs through relationships. Another researcher, RES_11, described a collaborator reusing a specific dataset that had denoted lesions on the specimens. They said that this collaborator knew about the data because they had been part of the field campaign. Several researchers [RES_5, RES_14, and RES_15] described outside researchers finding their data through papers or conference presentations and then following up to request data access. For instance, one researcher, RES_5, welcomed these requests. It allowed them to have control over the gate. With this control, they had a choice whether to share, to note any idiosyncrasies in the data that might be problematic, and, importantly, depending on the extent of data use, to request co-authorship. This gets back to the station director, DIR8’s, quote, turning data into publications, and the value that data has.

Because of this power dynamic between data collectors and potential reusers, where data are invisible or inaccessible, many funders are attempting to force a change of these project gatekeeping rules. Since 2011, the National Science Foundation, as a funder example, requires that all grant proposals follow its data policy:

> ‘NSF-funded investigators are expected to share with other researchers, at no more than incremental cost and within a reasonable time, the primary data, samples, physical collections, and other supporting materials created or gathered in the course of work under NSF awards.’ (National Science Foundation, n.d.)

This policy requires researchers to submit a data management plan with their proposal, a document that describes the types of research outputs that may be produced, where they will be stored, and what metadata will accompany them. It also requires that they make their primary data, samples, and supporting material for the funded work available “within a reasonable time” (described in section 4.2.2). This requirement comes ahead of any data collection at all, and given the high value of data to produce downstream outputs, it has been met with considerable resistance, like that described by a researcher, RES_1:

> 'In the past, when there was a need for something like that, it was a phone call, or an email message and you developed a relationship with [the sharee] as they were reaching out to you. And the [senior researcher's] frustration was, in essence people are doing this [accessing their data] on the sly, whether it's another scientist, a graduate student looking to latch on onto a project. And it felt icky to them in that they weren't being asked or contacted sort of thing…. If instead of being more direct or forthright, it was just kind of jumping into the data set, not realizing that people could have spent years collecting data, doing the data cleaning and the analysis and the organization and posting it online, and then never receiving any recognition for that over time. So that was the I'll call it a senior [researcher] frustration.' (RES_1)

This example from RES_1, both the icky feeling of someone using data without their knowledge and the removal of the opportunity to negotiate for credit, are two important breakdowns in relationality in the funder requirements for sharing. Both of these revolve around credit. When the data user must ask the data provider for permission, the provider has the power to say no, to share contextual details to be aware of for reuse, and importantly, it's at this point that the provider might negotiate for authorship credit. Contrasting that high bandwidth interaction to a user going to a data repository and easily downloading the data without the relational interaction, there may or may not be credit given, and the data provider researcher may or may not ever benefit from this reuse.

4.4.2 Scientific Care

The other side of the gatekeeping coin is 'scientific care', the enabling work required to do field station-supported projects (Robinson & Palen, 2023). This builds on the foundation of the feminist definition of care, which includes the "interweaving" relationships between ourselves, each other, and our environment to live well (Fisher & Tronto, 1990). Care can be explored as four elements: caring about, taking care of, caregiving, and care-receiving (Fisher & Tronto, 1990; Tronto, 1993). I argue that field station staff and research teams move across these four elements to respond to the spatial, temporal, and material situatedness required to conduct their project work.

All data in this study point to the deep care that participants have about the environment, generally, the specific locations they study, the field stations, their research subjects, and each other. There is very little that connects researchers across diverse station-supported projects, but this 'care about' is one link. Across participants, the amount of care they have for these different elements varies, but the work of maintaining the station and conducting fieldwork is difficult, and without the intrinsic motivation or care, people do not continue in these roles.

Field stations take care of all stages of researchers across the course of their fieldwork, from preparation to exiting the field, and are ‘scientific caregivers’ (Robinson and Palen 2023, Robinson and Palen, in review). As described in 4.4.1, DIR_12, a field station director, takes care of researchers by smoothing the process to gain access to the field. A staff researcher, STF_14, described how they both take care of the researcher and the location by rescuing samples that did not clear customs. They took care of the researcher, preserving samples that took extensive resources to procure, but they also take care of the location, ensuring that laws are followed. During intermediate check-ins with field stations about this emerging category, station directors agreed that they did this work but resisted being called scientific caregivers. It evoked a power dynamic and a gendered role that they did not actually articulate but talked around as not being valued by their institution's leadership.

Stations needed to justify their work and the value they provided. They do this by searching for and collating a list of research outputs generated by research teams across the station. Stations do ask for researchers to proactively send these outputs back before researchers start field work and during reporting periods, as described in section 4.2.1, but the researchers do not notice the need to care for the station in this way. A field station director, DIR_2, described not feeling empowered to ask researchers to change their practice because the researchers view the station as a service provider and have their own funding:

> ‘we don't have a lot of, frankly, clout to be able to require that, although field stations are getting more explicit about doing that. And I think certainly with like NSF now coming out with new regulations at the US federal level, that say if you're going to take federal money you're going to need to make data public.’ (DIR_2)

Through the analysis of station work (Robinson and Palen, in review), stations have the most power when they are the gatekeepers controlling access to the field, and then their power diminishes, and their caregiving work for the researchers increases. However, researchers as care receivers do not often acknowledge this care.

This discrepancy does not mean that researchers do not care. Turning to researchers, there are different ways of taking care of each other and the location. During fieldwork, I observed care through small acts like transporting supplies to others or offering to shuttle another researcher back to the station. One critical way that researchers take care of each other and provide caregiving is through mentorship. One researcher, RES_9, described how a field course they attended as an undergraduate also prepared them for professional fieldwork:

> ‘[The undergraduate field course] prepared me a lot. It showed me how intense field work is when you get somewhere, especially internationally, and you have to collect your data [quickly]. You've got a set time frame of when you'll be in the field. It definitely prepared me in the sense that I know to wake up early, eat breakfast, and then directly go into the field until dinner. And then after dinner, we'd still go in the lab and, like, input data and even start on writing and analyzing data, just like a field quarter.‘ (RES_9)

In addition to formal training, mentorship often looks like informal training. Researchers conducting fieldwork often learn from another more senior member of their research group how to conduct the particular techniques:

> ‘[They] were a PhD student at the time, and then defended before I graduated. [They] had a lot of experience doing work, especially with invertebrates and [my class of organisms], particularly, for some reason, even though [they were] working on [another class of organisms] at the time. My adviser put us in contact with each other so that we could work out the methods [for my project]. So it was definitely [them], for the most part, kind of just teaching me what to do and how to do it, and we kind of went out to the forest near the school and practiced a little bit to see if that was an okay method in general.’ (RES_2)

This method practice and development was not only training them to be a researcher, but part of the planning necessary for a researcher, RES_2, to go to a field station, FS2, to conduct the fieldwork necessary for their academic goals. A staff member at a different station, STF_3, provided similar mentorship for undergraduates over the summer, working with them to design and conduct their first field station-supported project. STF_3 mentioned the extensive research that has been conducted, which indicates that these first experiences with fieldwork are formative, sparking care about the environment and the field, and growing the next generation of field researchers.

Another type of scientific care is related to the care of artifacts like protocols and datasets. In earlier sections, I have described how research teams often take great care to preserve these artifacts for future use. Programs like NEON and LTER both require information managers, who preserve and care for the scientific data being produced (Baker & Karasti, 2018). One researcher, RES_11, showed great care when they used the data management plan with their local community partners to agree on terms of future data release up front. This demonstrates that RES_11 noticed the need for care of those partners, actively provided caregiving through the planning process, and followed through with the agreed-on approach to data release once the data were collected. The care receivers, in this case, the local community, are more willing to engage in future work because of the trust built through this work.

Despite the importance of these project parts and the addition of funder requirements, researchers struggle with doing this data management work. A staff scientist, STF_10b, talked about their own progression across the arc of their career. Early in their career, they felt like publishing papers was essential, but now, as they enter their late career, they see the value of documenting protocols. However, as they convey the importance, researchers say to them, ‘I don't have time. I have to get the experiment done. I have to get out in the field and collect the data’. Or as a researcher, RES_11, described, ‘I can just almost see people kind of zone out because they think, “Oh, this is going to cost so much time. This is going to cost so much effort.”’ The cost of care—time and effort—is being paid by a researcher who may not benefit from that work.

Finally, the field and field stations have not always been safe work environments (Yarincik et al., 2023). This culture is shifting with the current generation of researchers speaking up and pushing back against the historic norms. This is in the context of broader calls for anti-harassment measures across many universities. The movement toward safer fieldwork is collective care work done by everyone at the station. During the station director meeting at a field station, FS_B, a field station director described their anonymous field readiness monitoring program. Their station required one person appointed for each field team to conduct regular comfort checks. This appointed person had all other team members turn around or close their eyes. Everyone then held out fingers, five for feeling good to keep going, and one or two fingers indicating that the person needed to go back to the station. If anyone held up one or two fingers, no questions were asked, and the team went back to the station. Importantly, the person who needed to go in was not identified. This is a major shift that overcomes the power discrepancy between more senior researchers and junior researchers who feel they do not have the power to speak up.

4.4.3 The Role of Coloniality in Science

Fieldwork has a colonial past. However, while colonialism has ended, field station-supported projects still reproduce coloniality, or ‘positional superiority’ (Smith, 2021). Practices described throughout this chapter, such as going to faraway places to work, working on academic calendars, taking materials away, and growing centers of calculation that do not benefit the places, are all ways that scientific knowing is privileged over the knowledge within the communities that are being studied. This disparity shapes the relationships among researchers, field stations, and the local communities that the stations are part of.

While those practices are still the norm, the conversations about gatekeeping, scientific care, and power dynamics at field stations during fieldwork at all three field stations I visited and throughout interviews, preview this idea of a shift away from the dominant practices of scientific imperialism. Latour's centers of calculation are giving way to new ways of working and caring for the places and the communities that the researchers work with. One director, DIR_9, called out the way that station was pushing this shift:

> 'We [FS_9] exist in a very interesting space. So we all live in a neo-colonial world. And we come from [the United States] and from an institution that has very significant resources compared to any of our collaborators in [FS_9 country]. Even though field stations as a whole do not have large budgets by US standards and researchers constantly feel like they don't have enough money to get anything done, we operate in a land of wealth that is incomprehensible to most of our [local] colleagues. [B]ut we don't have the resources to give money directly to our [local] colleagues. …But our model is to basically try to pull some of the scientific resources that exist in the [wealthier countries] and bring them to [the local community]. And in the process, push those [researchers from wealthier countries] to support [local] researchers and local communities when they do their work. So our business model at present is about resource capture and transfer to [local community] and conducting research on [local community issues]. (DIR_9)

DIR_9 went on to say that while this was their vision, the power dynamics again among the researchers, the station, and the local community were heavily weighted toward the researcher:

> ' So … we try to push [visiting researchers] to buy into our model of sharing their resources with [local] researchers and local populations. But there's only so much control we have over what attitudes those people have towards that approach. And so we have people that come in and do the absolute bare minimum engagement with locals that's necessary. And then we have some groups, we have [a group] right now that is a fantastic example of this…. That's the vision of what we want to see. But not everybody does that and we don't have the power to force them to do it.' (DIR_9)

These remarks from DIR_9 imply that field stations are becoming a bridge between researchers and the local community. However, even more than not having the power to change researcher behavior, these shifts lack the knowledge infrastructure to support or enforce such changes. Over and over, the refrain from participants and during field work was that the policy requiring data contributions or research output sharing was in place, but there was no way to track whether the researchers complied. Thus, coloniality persists in field station-supported projects because there is a lack of feedback mechanisms back to the places where the research was done.

5. Discussion

The natural environment of our planet is a rich research subject, from the top of its atmosphere to the depths of the ocean and from its equator to the poles. Research questions about the environment are tackled by researchers across disciplines through projects. Through this analysis which foregrounded field station-supported projects, I demonstrated the cooperative work and bespoke infrastructure assemblages required to do science. Up to this point, both the work and the infrastructures have been invisible.

In this discussion, I describe the implications of this invisible, situated cooperative work and the missing digital representation of projects as *dark projects*. I then extend that discussion to the ways that science projects-as-usual reproduce coloniality and conclude with recommendations to make dark field station-supported projects visible through postcolonial interventions.

5.1 Dark Field Station-Supported Projects

Field station-supported projects are both highly situated and innately mobile. Through this mobilization, field station-supported projects form networks among their home institutions, the location, the field station, and their scientific domains. While field stations are often the nexus for a high concentration of research projects, location can be the only common node in these project networks. Prior research documented the scientific efficiency and benefits that occur through field stations. Researchers serendipitously identify intersecting lines of work that would not be possible without the station as a temporally aligned, common node of shared work and living spaces (Michener et al., 2009). For instance, when disparate researchers spark a conversation over a shared meal at the field station and that results in a funded grant to pursue a new line of work together.

Through this analysis and my prior work, it is clear that stations are not just passive substrates for the research projects that take place there, but active participants. The station network functions like a hub and spokes, where the spokes are research teams' segmented lines of work (Gerson, 1983). Station directors actively foster intersecting lines of work by creating connections to disparate researchers and by attempting to provide location-specific research artifacts as part of their role in place-based scientific stewardship (Robinson & Palen, in review). These connections are possible because of the depth of knowledge about many projects that a director internalizes from reviewing applications and conversations, combined with the intentional cooperative work by the director to write an email or make an in-person introduction, when there are dozens of other to-do items that also need attention. Yet, while these connections are intentional, they are only obvious from the field station perspective.

Many stations have application processes, so they have an internal project description list, and a few stations have begun to provide summary lists of current projects publicly. I did not see the public projects list as a common practice across the field stations included in this study. Thus, many stations have an inaccessible directory of projects. These project descriptions and lists are just one facet of field station-supported projects and could be considered boundary negotiating artifacts because they are effortful to maintain and there is not an agreed on standard method for application processes. Like the station project directory, the analysis in this chapter illustrates many facets of these projects that are *dark.*

I define *dark projects* by drawing from four uses of dark - data, matter, patterns and as protection. Drawing first on the concept of 'dark data' where data is not findable by others in the scientific enterprise (Heidorn, 2008). Like dark data, the existence of a project is often not visible to others, broadly across the scientific enterprise and specifically working at the station. However, unlike dark data, where the data exists, *dark projects* are only sensed by fragments. So, I turn to the metaphor of 'dark matter' drawn from physics, where dark matter is undetectable except in relationship to perceptible things it produces (Hill, 2012). Like dark matter, *dark projects* make up most science, but they are imperceptible except for their partial manifestations like grants, data or journal articles. For each of those objects, there is a digital representation to perceive them directly. There has not been a parallel representation of a project (i.e. project metadata) until fairly recently with the addition of 'project' in the accepted list of DataCite resource types[16] (Stathis et al., 2024). Third, while not intentionally malicious or manipulative, like the 'dark patterns' (Mathur et al., 2021), as Semaan argued, invisible patterns in infrastructure reproduce problematic behavior (2019), in this case dark projects reproduce extractive science.

[16] DataCite is a global registry of digital object identifiers (DOIs). It began to create and register identifiers for datasets, but has expanded to include identifiers for many types of objects (i.e. software, physical samples, text) and now includes 'project'. This will be discussed in detail in Chapter 4.

These uses of dark thus far can have a negative connotation, but dark can also be used in a protective sense. Darian et al. describe ‘data siloing’ as a form of protection and activism through disconnection (2025). If projects are dark, researchers protect their work up until they make it visible through publications. Taken together, dark projects, are not findable because they are only perceptible in relationship to something else like a research output. They potentially benefit from being dark as a competitive advantage or for knowledge protection to the researchers, but this same protection perpetuates the science extraction status-quo.

I argue that we need this new term *dark project*, because without being able to perceive projects, there is a void where connections should be made. For instance, lacking the ability to perceive projects has resulted in researchers struggling to share data because the tacit contexts required to use the data, like the reason it was collected or the social contexts of the team, are not available (Birnholtz & Bietz, 2003). These tacit contexts could be considered part of a *dark project*. Because dark projects only are perceived in relationship to other observable outputs, there are unstable connections between fragmented project parts such as awards, datasets, papers and a huge host of unseen fragments like protocols and internal notes. For instance, grants that support projects are published on funder websites. However, a project may be funded by multiple grants at a single time, or it may be funded by a sequence of grants. Hence, grant databases only provide at best a partial view of potential projects. Likewise, journal articles and dissertations report on a subset of project findings, and again only provide a limited view of the project. Project work that fails may not be reported on at all. Further, the scholarly publication process is delayed behind the project, so publications may only be public near the end or after the funding has ended.

In this analysis, it is evident that all of this situated cooperative work by the station and researcher is done in support of a successful research project outcome and future funding. Field station-supported projects are a type of multi-user application. Like other multiuser applications (Grudin, 1987), the benefits of science are not shared equally across all those who do the work to make science possible. The necessary situated cooperative work, like infrastructuring, is invisible because ‘sciencing’ aims to take the specific and situated experience and make it universal (White, 1938). The consequence of driving towards the universal is that the research becomes desituated, with few contexts (Haraway, 1988). For instance, information about contexts is stripped away, like the support of field stations or other contextual information, as research moves towards reporting. These choices point to the ways that the lack of project documentation practices in the existing knowledge infrastructure have politics (Bowker & Star, 1999). The results of these 'sciencing' choices are that publications are the valued parts of science that count—and, as I have shown, reflect just a small portion of all that goes into making those products possible. Thus, dark projects, they are missing connections to people, the institutions, like field stations that facilitate them and locations that made them possible.

Field stations want to know about the results and currently are all required to individually search for these outputs (Robinson & Palen, in review). These connections are done through repair work and human infrastructure rather than digital infrastructure, making them especially fragile: if staffing changes, connections can break (Robinson & Palen, 2023, in review). Additionally, like other infrastructuring (Karasti & Blomberg, 2018), this project-specific infrastructuring remains generally unseen and unvalued in the scientific enterprise.

5.2 Making Dark Projects Visible: Recommendations for Postcolonial Interventions

These severed connections between downstream project outputs and field stations may not be intentional, but they are not benign oversight either. This disconnection is an example of the coloniality of present-day science that systemically reproduces colonial practices of domination, control, and othering (Quijano, 2000). Natural sciences were slower to adopt data-intensification, due to their low-tech data collection methods, like observing occurrences or physical specimen collection. However, the '4th paradigm' (Hey et al., 2009) of data-intensive science has arrived with the new mobile paradigm (Sheller & Urry, 2006). Hence, the disparity between those who do the work and those who benefit has sped up and is growing with technological advances. Left unexamined, this is rapidly increasing the speed at which extractive practices are reproduced both physically and digitally, and the harms to marginalized communities and those historically excluded are perpetuated by *dark projects*.

Across CSCW and natural sciences, there is a postcolonial disruption to the embedded scientific coloniality by expanding the possible perspectives. Haraway argues for 'situated knowledges', which bring together many partial perspectives and are about collectives, not 'isolated individuals' (1988). This evolution is moving field stations from scientific imperialist outposts (Dumoulin Kervran et al., 2024) into 'boundary spanner' organizations (Hatch et al., 2023) that are actively bridging between researchers and local, often Indigenous communities. Yet, while the practices are shifting, the boundary negotiating infrastructure is not able to adequately support these changes.

Interventions in scientific practice need to be made reflexively. It is easy for systemic coloniality to implicitly reproduce patterns through changes meant to disrupt those same systems. As Audre Lorde famously wrote, 'the master's tools will never dismantle the master's house' (1983, p. 1691). By examining the social organization of field station-supported projects through this critical, postcolonial lens, it becomes possible to identify potential intervention points and consider new tools.

In the examination of field station-supported projects, relational contexts emerged. Relationality, a form of care, shapes how we interact with our world and is critical to disrupting coloniality (Wilson, 2008). Indigenous scholars have compared Western knowledge organization to Indigenous knowledge organization, and one key differentiating concept is relationality (Littletree et al., 2020). Further, relationality resists suppressing the relationships and contexts required to produce place-based knowledge (Littletree et al., 2020; Wildcat & Voth, 2023). This list is an initial set of intervention recommendations for field station-supported projects to work in postcolonial ways:

1. **Make project traces visible early and often.** When the first notice of a project comes at a journal publication, long after fieldwork, it is too late for building relationships. All field stations in this study have project application processes. Making these applications visible is a first step that could shape projects' spatial and temporal contexts, increasing the likelihood of intentionally intersecting lines of work or lines of community contributions. This also creates an artifact to discuss, leading to the second recommendation.
2. **Create opportunities and supporting infrastructure for negotiation.** These first project traces are not a declaration. Community partners and collaborators, sometimes through permitting agencies or community meetings, need opportunities to discuss the data collection process and its sharing before it happens. This is a way to build trust.
3. **Add friction to maintain situated contexts.** New information systems prioritize frictionless access for the user to another's data, but to data providers, this 'feels icky' when they don't have a chance to

connect with the user. These systems break the relational aspect of sharing and obfuscate the person (and the project) behind the data. This needs to ripple past the data collector as well, who historically has suppressed essential contexts about the locations and communities essential to the science produced. An example of friction, might be a review step for the data request, where the creator gets to provide contexts and have agency on how the data might be reused.

4. **Establish bi-directional mechanisms for mobilization of people, objects, and information.** An ongoing complaint from field station directors and the communities they serve is that the researchers do not connect their research outputs back to the places the research is derived from. Existing information systems lack these connections. Future interventions should attend to bidirectional mobilization and incorporate feedback mechanisms.
5. **Speculate about the potential benefits and harms.** Interventions are never neutral. For instance, adding friction might enable the current dark data to persist, with researchers not sharing their data collaboratively. Or by making the projects visible, there may be some AI processes that 'informates' (Zuboff, 1989) or allow for new insights to be gained when fragmented project parts come together in ways that make it easier to identify ideal locations for poaching valuable species or industrializing environmentally pristine areas. Approaches like speculative design, diverse perspectives, and mechanisms for feedback allow for iterating and mitigating as harms are identified.

While these are not technologically interesting interventions, socially, they could be transformative. Considering these intervention elements in future infrastructure design would make projects visible earlier in their progression, increasing the opportunity to influence or intersect and allowing projects to establish their own validity. There is also a potential that, if put into practice, these interventions could enable persistent place-based scientific stewardship by illuminating the significant scientific project work facilitated by field stations.

6. Conclusion

Field station-supported projects are essential to our understanding of the planet. These projects are shaped by spatial, temporal, material, and relational contexts, each requiring bespoke boundary negotiating infrastructures to actively engage in doing science. Presently, the social organization of these projects only produces visible traces, like journal articles or dissertations, long after the fieldwork is completed. These outputs are the social credit researchers need to advance their segmented lines of work, but at the same time, they are stripped of the highly situated contexts needed to do this work. The desituated outputs of 'sciencing' reproduce coloniality practices of extracting resources from one location to amass power in another 'center of calculation' (Latour, 1987).

Across the scientific enterprise, we are entering a new wave of postcolonial research where these choices and practices are questioned. Many field stations are evolving towards boundary spanner organizations, and they are encouraging the researchers to actively connect with the communities where they do the work. These behavioral changes only go so far, however, when the knowledge infrastructure still reproduces these problematic, historic practices, such as severing connections between the research and the locations it comes from. More work is needed to expand the implications of examining the social organization of field station-supported projects. Future scientific infrastructure interventions should increase project traces and make those traces visible much sooner in the project's progression, to consider relationality and to maintain the situated partial knowing contributed by each project, and finally, to intentionally speculate to consider who has power and who is harmed in such interventions.

Chapter 3

Authorship and Contribution Statement: This chapter is based on a co-authored paper under review in the Journal of Computer Supported Cooperative Work. I served as first author, conducted interviews and fieldwork, led analysis, and wrote the manuscript in coordination with my advisor, Leysia Palen. We have agreed that this text can and should be included in the dissertation.

Abstract

Around the world, over 1000 biological field stations—scientific facilities adjacent to natural environments— provide support for environmental research. However, because stations are sometimes remote and can be seen as service providers, the important role they play in the scientific enterprise in many cases is overlooked. In a two-year qualitative and ethnographic study, we examined the role of field stations by considering the ways field stations support researchers before, during and after environmental fieldwork. Through a grounded theory analysis, we identified four types of work that field stations share: facilitating research access, extending research capability, cultivating a hub of research connections, and sustaining themselves to support future research. However, though these activities are shared in common, field stations have independently evolved bespoke knowledge infrastructures to support them—what we call *boundary negotiating infrastructures*. These infrastructures are labor intensive to build and maintain, and are regularly reconfigured and repaired to support a diversity of research projects. While this highly customized coordination work benefits visiting researchers and supports important scientific knowledge production, the autonomy with which field stations operate can unintentionally cause them to be disconnected from the larger scientific enterprise. We argue that overcoming these challenges requires merging cyberinfrastructure solutions with implementation of new policy and practice in cooperation with the scientific community. We conclude with recommendations for future interventions to persist durable recognition for field stations, and to enable new possibilities for scientific work supported by field stations, independently and collectively.

1. Introduction

Researchers worldwide use biological field stations as an essential data collection platform to answer diverse scientific questions, train the next generation of researchers, and conserve natural environments through research and public engagement (Brussard, 1982). There are over 1000 field stations worldwide, and though there are important differences between them, including how they are funded and staffed, collectively they are a set of scientific facilities adjacent to natural environments—from coastal to high alpine regions— that are essential to the conduct of environmental science (National Research Council, 2014; Tydecks et al., 2016). Critically, field stations provide physical facilities and logistical support for visiting researchers—often in the form of housing, board, staff support, research permitting services, liaising with local communities, and deep, situated scientific expertise—which distinguishes them from other designated sites located in natural environments that enable data collection but do not facilitate research beyond this (Billick et al., 2013; Tydecks et al., 2016; Wyman, Wallensky, and Baine, 2009).

Field stations are valuable to science as well as to their adjacent local environments (McNulty et al., 2017; Michener et al., 2009; Wyman, Wallensky, and Baine, 2009). For instance, field stations in the tropics provide a significant return on investment in conservation when compared to areas without stations. Field stations help protect against illegal poaching and other extractive activities (Eppley et al., 2024). In addition, field stations support conservation benefits by supporting knowledge production and training the next generation to conduct environmental research about the area (Eppley et al., 2024). There are dozens, if not hundreds, of accounts about how research findings were only possible through the support of field stations (Billick et al., 2011; McNulty et al., 2017; Michener et al., 2009; Wyman, Wallensky, and Baine, 2009).

Though field stations around the world have much in common regarding their missions, the ways in which individual field stations execute the multiple roles they play are highly localized and idiosyncratic. Each field station situates its practices and facilities to its circumstances, including with respect to the needs of the visiting researchers who frequent them, the natural environments, governments, nearby local communities, and more. Thus, working with researchers, government agencies, and local communities requires that field stations engage in a great deal of cooperative work within and across those populations. This cooperative work must further adapt to the rhythms of visiting researchers, the particularities of the range of scientific disciplines attracted to a field station, and the demands associated with a mission to support not just place-based research but also education and environmental conservation.

Despite the many benefits field stations offer and the significant work they do, they, like all working infrastructure, are often rendered invisible even to the researchers who frequent them (Bowker, 1994). For many stations, their invisibility is exacerbated by their distant locations from the home institutions of those researchers who use them, putting the stations out of sight and, therefore, out of mind when they leave (National Research Council, 2014). In addition, the ‘scientific caregiving’ they perform (Robinson and Palen, 2023)—the work to maintain and care for the physical facilities, the environment, and the researchers who use them— is far too often overlooked despite the criticality of those services. This invisibility results in a lack of recognition of field stations’ roles in the scientific enterprise, which in turn and in time, adversely affect their ability to sustain themselves (Billick et al., 2013; National Research Council, 2014).

As new forms of digitization become available, solutions centered on cyberinfrastructure and data management are often seen as the way forward for making the role of field stations more visible (Billick et al., 2013; National Research Council, 2014). Field station directors themselves have argued that investing in field station cyberinfrastructure may provide a way to overcome some of the challenges of invisibility (Billick et al. 2013; National Research Council, 2014). It is important to note that, for them, ‘cyberinfrastructure’ refers to computational capabilities like the software, hardware, internet connections, and policies of infrastructure that enable science, but none of the relationships that humans have with technology—the latter matter is what the term ‘information infrastructure’ addresses (Edwards et al., 2007). If only, the thinking goes, results like publications and datasets based on work supported by stations could be brought together and visualized as digital collections, this would make the value of field stations more obvious: New scientific projects would be possible and funding not so hard to justify (National Research Council, 2014).

However, as a result of the research presented here, we find that the dreams of cyberinfrastructure are built on reductive ideations about how field stations operate and the range of roles they fill, each adapted to their highly localized circumstances. Even the digitization solutions already in place tend to be 'homebrewed' assemblages of tools (Voida, Harmon, and Al-Ani, 2011) uniquely pieced together to do the necessary internal management work of a station. The research we present here shows that, long before we might dream of digital connectivity, data sharing, and process interoperability within and, more ambitiously, across field stations, we must first appreciate the cooperative and often invisible work conducted by stations—an appreciation that is crucial to inform future digital interventions before they are thrust upon resilient but nevertheless overburdened field stations.

We ethnographically investigated the role of field stations and, specifically, the work of station directors. Field station directors are bridges between the station resources and the research happening on site; they are in positions to see the potential of bringing multidisciplinary research together to describe the 'ecology of place'—the knowledge gained by studying a single environment in depth, from many perspectives, repeatedly over time (Billick et al., 2011). In this paper, we describe how field stations support science before, during, and after visiting researchers use field station facilities. We also examine how field stations bridge boundaries between researchers, the communities they are part of, and the environment.

2. Related Work

By casting field stations as nexuses of artifacts, people, and institutions, we can unravel how they conduct the complex and highly particularized coordination work they face. In the next sections, we look to the literature to ground what we see as the boundary-spanning work field stations perform using available infrastructure that they have built. Finally, we consider the CSCW idea of the 'collaboratory,' which allows for repositioning field stations as more digitally visible elements that contribute to the larger scientific enterprise.

2.1 Field Stations as Boundary (Negotiating) Objects

Star and Griesemer (1989) first used the formation of the Museum of Vertebrate Zoology at the University of California, Berkeley during the early 1900s to understand scientific cooperation across diverse social worlds (specifically, 'communities of practice'[17]). This natural history collection work was the precursor to present biological fieldwork. It also represents the final link of the natural history value chain, whereas field stations today are at the originating end to support the collectors as they head into the field. Star and Griesemer developed the analytical concept of the 'boundary object' (1989): *Objects* could be either material objects or work arrangements that sit at the *boundary* of shared spaces at which different actors do their work (Star, 2010).

The idea of the boundary object is widely invoked to signal the 'interpretive flexibility' of the meaning of what is represented by an object. However, there are two other features that describe boundary objects that are helpful to this research. Boundary objects rely on 'methods standardization' (Star and Griesemer, 1989), or the ways that multiple communities of practice create persistent, stable arrangements for information to be shared (Star, 2016). Star also argued that the concept was most useful analytically when the scope was specific and the scale was organizational (Star, 2010). Boundary objects have come to be understood as stable objects that allow for collaboration across intersecting communities of practice without the need for consensus (Bowker and Star, 1999; Star, 2010).

For example, Star and Griesemer (1989) identified standardized forms as a type of boundary object because they structured incoming information to enable coordination across different communities of practice. Additionally, Star and Griesemer's (1989) museum could be viewed as a type of boundary object called a 'repository'—a collection of heterogeneous objects that are indexed in a standardized way. Repositories allow for people across communities of practice to use objects for their own purposes without the repository degrading (Star, 2010). In a similar fashion, field stations index their shared physical resources—such as boats, trucks, laboratory space, and scientific instruments—into a repository for their visiting researchers to access. However, not all cooperative artifacts can be considered boundary objects.

[17] Communities of practice are a group that work together around a shared common interest or domain with shared methods or tools (Lave and Wenger 1991)

Realizing that the boundary object concept was being overloaded, Lee introduced the idea of 'boundary negotiating artifacts' (2007) to remedy shortcomings and expand upon the power of the core idea. She viewed collaboration processes on a spectrum: Whereas boundary objects support stable processes, boundary negotiating artifacts support non-routine activities that lack convergence around methodological standardization (Lee, 2007). Such artifacts are governed by processes that might not be agreed upon by all; they often appear effortful instead of effortless (Lee, 2007). Lee's perspective analytically expanded how we think about the nuances and types of coordinating objects at work in cooperative settings.

Field stations' efforts to coordinate across a revolving cast of researchers from multiple communities of practice in non-routine ways might be better described as depending upon boundary negotiating artifacts. This positioning becomes important to our analysis to capture the adaptive ways field stations manage their roles and how artifacts are assembled into localized infrastructures.

2.2 Field Stations as Infrastructure

The infrastructure literature offers a second lens with which to understand the role field stations play in environmental science. Over the last 40 years, environmental science has become more data-driven and reliant on 'cyberinfrastructure,' defined as the layer above the base hardware that includes high-performance computing and cloud services as well as data management services, repositories, instruments, collaborative coordinating services (Atkins et al., 2003, pp. 5). This definition tends to view cyberinfrastructure as a generic substrate that different kinds of science build on top of. Since this introduction, cyberinfrastructure is sometimes called e-infrastructure in Europe and Australia and is now equated with computing capabilities (Ribes and Finholt, 2009). This view frames cyberinfrastructure as a purely technical solution that aims to work for anyone and does not examine the sociotechnical relationship between the scientific users and the cyberinfrastructure.

The social studies of cyberinfrastructure arose from this gap, drawing from the study of large technical systems— like electricity and railroads—to articulate its remit in an age of informatics (Borgman et al. 2020; Edwards et al., 2007; 2013; Hughes, 1993). This work led to foregrounding what is assembled and required when an infrastructure is activated, eliciting the famous question, '*When* is infrastructure?'

(Star and Ruhleder, 1996). For instance, Bowker examined the heterogeneous ways that biodiversity databases were maintained, noting the limitations that a lack of convergence around common design caused (Bowker, 2000). As a result of this work, the concepts of 'information infrastructure' and 'knowledge infrastructure' arose which are 'robust networks of people, artifacts, and institutions that generate, share, and maintain specific knowledge about human and natural worlds' (Edwards, 2010, pp. 51). Thus, we see that knowledge infrastructure with its addition of a social science perspective addresses the limits of the earlier cyberinfrastructure definition to foreground what is assembled and required when an infrastructure is activated. Here, we will use *cyberinfrastructure* when discussing the technical-only infrastructure, and *knowledge infrastructure* or *infrastructure* when we holistically reference all-digital, physical and human contributing elements as well as the dynamic relationships between them.

Most prior work at the intersection of CSCW, infrastructure studies, and environmental science focused on the researcher practices and cyberinfrastructure of the *projects at* field stations like LTER sites, but notably did not expand to include field stations themselves as elements of infrastructure (Bowker, 2000; Edwards, 2010; Jackson and Barbrow, 2015; Karasti and Baker, 2004; Mayernik, Wallis, and Borgman, 2013; Michener, 2015; Ribes and Baker, 2007; Thomer et al., 2018; Yeh et al., 2006). These existing studies highlight the challenges of sharing data, the efforts of environmental science communities to settle upon data and metadata standards, and the difficulties in designing and implementing cyberinfrastructure *solutions*.

These environmental cyberinfrastructure CSCW studies have also been instrumental in refining the understanding of knowledge infrastructure and collaborative work environments (Jirotka, Lee, and Olson, 2013). Building on the original eight dimensions that Star and Ruhleder (1996) identified, Karasti and Blomberg (2018) describe five dimensions of information infrastructure: the first four describe how it is (1) relational, (2) often invisible, (3) connected, and (4) emerging and accreting. 'Infrastructuring' brings Karasti and Blomberg's first four dimensions together to describe how infrastructure is modified, with degrees of *intention* and *intervention* as characteristics of the fifth dimension. Infrastructuring is often described by a list of verbs like *developing*, *stewarding*, *sustaining*, *facilitating*, *repairing*, and *caring* for infrastructure, all of which describes the participatory work undertaken to 'grow' infrastructure (Bødker, Dindler, and Iversen, 2017; Jackson, 2014; Karasti and Baker, 2004; Karasti and Blomberg, 2018;

Semaan 2019). Through our research, we aim to be more specific about the ways field stations infrastructure.

Field stations exhibit all these dimensions of infrastructure. They are embedded into the existing infrastructure of the area, such as in the repurposing of an old country club or former plantation. Field station infrastructure is transparent when it works; in addition, because stations are remotely located from their host institutions or researcher home institutions, infrastructure can be further rendered invisible. Field stations as knowledge infrastructure connect past and future research together as physical nexuses of scientific activity and keepers of scientific and local knowledge. With the oldest stations in this study just passing their 100th anniversaries, these stations have survived staff turnover and are examples of the ‘long now,’ where infrastructure is maintained by multiple generations of stewards (Ribes and Finholt 2009). As knowledge infrastructure, field stations have relied heavily on physical and human infrastructure needed to support knowledge production but have had access to limited cyberinfrastructure support.

2.3 Field Stations and the Potential of the Collaboratory

Like traditional laboratories, field stations offer value to the limited number of researchers who can work from these nexuses of local concern and global interest. Field stations host diverse research from across disciplines and universities that center on a common environmental site. As such, they are ‘scientifically significant sites’ (Thomer, 2022) that have attracted large amounts of research attention. Yet the researchers working from a station are often unaware of each other because, while its environment is shared among them, the objects of study, timing of trips, disciplines, and home institutions may all be different.

There has long been a vision to bring computing together with domain-specific scientific practice to connect disparate researchers. Collaboratories encompassed the idea of a technology-aided virtual laboratory that could support collaboration at a distance (Finholt, 2003; Wulf, 1993). In environmental science and biology, there were several early attempts to deploy such systems (Finholt, 2003). In the 1980s, SCIENCEnet provided a platform for oceanographers who collected data in remote areas to share their data, creating a more global map (Finholt, 2003). Some researchers working inland tried to use this platform for similar terrestrial efforts, but they found that it was too tailored to the oceanography community (Finholt, 2003). In the 1990s, one of the most famous collaboratory experiments, the Worm Community System (WCS) (Finholt, 2003; Star and Ruhleder, 1996), was designed to connect researchers working on *c. elegans*. A factor that led to WCS ultimately failing was the widespread success of the Internet and the adoption of email, which replaced the WCS's specific capabilities with more general ones (Star and Ruhleder, 1996). Since then, there have been other environmental collaboratory attempts like the Upper Atmospheric Research Collaboratory and the Environmental Molecular Sciences Laboratory Collaboratory, neither of which persisted (Finholt, 2003). These early examples strove to show the power of connecting separated researchers from a common scientific domain into global networks for research and data sharing.

Today, through the legacy of this collaboratory research, the benefit of bringing together the laboratory, environmental data (like large global satellite datasets or standard sensor networks) together with computational capability is ever clearer. The impact of these newly configured forms of science is felt through the emergence of new fields, including environmental informatics and environmental data science (Hey, Tansley, and Tolle, 2009; Frew and Dozier, 2012). However, these new fields have yet to meaningfully include the variable contributions of in situ field research that field stations could offer, which ushered the need for the research reported here.

3. Method

Our research approach draws from the rich history of ethnographic studies of workplaces in CSCW (Blomberg and Karasti, 2013; Randall, Rouncefield, and Tolmie, 2021; Vertesi, 2020) and specifically, laboratory studies (Knorr-Cetina, 1983; Latour, 1987) to examine how field stations support science, with a focus in this paper on the work of field station directors who are in leadership positions with the authority to manage local resources, a commitment to the local community, and a responsibility to steward the connection between the station and the larger scientific enterprise. Our approach also draws on the ethnographic studies of information and knowledge infrastructure (Karasti and Blomberg, 2018; Star, 1999) to pay attention to the 'boring' (Star, 1999) and invisible parts of field station infrastructure that might otherwise be overlooked.

This research was conducted as primarily an ethnographic study complemented by additional interviewing outside the phases of fieldwork. Between September 2022 and November 2024, the first author conducted a total of 14 weeks of fieldwork at three stations which included participant observation and interviewing. In addition, she supplemented the field work with a semi-structured interview study with field station directors and staff from another 11 stations conducted over video conference calls (see Table 1 and 2).

We used a constructivist grounded theory approach to analyze the data. Grounded theory generally is well-suited to exploring social processes, especially invisible work (Bryant and Charmaz, 2007). Evolving from the original grounded theory, our choice of *constructivist* grounded theory explicitly acknowledges 'the subjectivity and the researcher's involvement in the construction and interpretation of data' (Charmaz, 2014, pp. 14)[18].

3.1 Field Station Directors as Primary Participants

Field station staff members consist of the station director or manager and, depending on the station's size, may include operational staff in maintenance, administration, or housekeeping. More recently, some stations have added technical and scientific staff. Many but not all field station directors and staff have environmental science backgrounds, and most have advanced degrees. Before being employed by field stations, many directors conducted research at field stations. The participants in this study were currently employed or had been employed by field stations. Most participants were field station directors, but we also interviewed four staff members who were determined to be best suited for describing the activities of their field stations.

3.2 Data Collection

Across the methods of data collection, we have collected data from 14 field stations. The facilities represent a diverse range of characteristics. To preserve anonymity, we have chosen to only include

[18] During the time covered by this study, the first author was a co-investigator on a grant with the director of FS_B to explore data management improvements at FS_B.

station age and type of environment, as described in Table 1 for the three fieldwork locations and in Table 2 to describe the stations for which semi-structured interviews were conducted.

Field Station Pseudonym	**Decade Established**	**Type of Environment**	**Participant Observation Details**
FS_A	1950s	Terrestrial	✓ 5 days - Attended and presented at field station network meeting; ~30 informal interviews
FS_B	1980s	Marine	✓ 60 days - Supported data management activities and workshops; Taught two week course in 2023, 2024.
FS_C	2010s	Terrestrial	✓ 3 days - Attended and presented at field station network meeting; ~20 Informal interviews

Table 1. Field Stations (FS) (n=3) where participant observation was conducted by the first author. [19]

Field Station Pseudonym	**Decade Established**	**Type of Environment**	**Interview (Director/Staff)**
FS1	1970s	Terrestrial	✓ DIR1
FS2	1900s	Terrestrial	✓ STF2
FS3	1990s	Terrestrial	✓ DIR3
FS4	1960s	Terrestrial	✓ DIR4
FS5	1920s	Terrestrial	✓ DIR5
FS6	1970s	Marine	✓ DIR6
FS7	1990s, re-start 2020s	Terrestrial	✓ DIR7
FS8	1980s	Terrestrial	✓ STF8a, STF8b
FS9	2020s	Terrestrial	✓ DIR9
FS10	1920s	Terrestrial	✓ DIR10
FS11	1900s	Marine	✓ STF11

Table 2. Field Stations (FS) (n=11), Directors (DIR) interviewed (n=7), Staff (STF) interviewed (n=4).[20]

As designed in our approved Institutional Review Board human subjects' protocol, all stations and participants are anonymized and referred to by generalized characteristics like approximate age (of the station) or their professional role (of participants) to avoid any potential reputational harms, an approach advocated for by Vertesi (2020). In addition, written consent was obtained for each interview, with an option given to participants to withdraw from the study at any time.

[19] Pseudonym naming uses FS<A,B,C> for the field stations. Individual informal interview participants are not referenced individually.
[20] Pseudonym numbering uses FS<1-11> for the field stations. Individual participants referenced in the paper follow the designated number for the field station at which they work.

3.2.1 Fieldwork and Details of Participant Observation

The first author conducted 14 weeks of ethnographic fieldwork across three stations (FS_A, FS_B, FS_C) to understand how field stations support science. She spent 12 weeks at FS_B across five visits from 2022 to 2024, with visits varying from one to three weeks. She also visited two additional field stations (FS_A, FS_C) in 2022 and 2023 for one week each. During each visit, she took detailed field notes, conducted over 50 informal interviews with field station directors and technical staff, and took 550 photos (Emerson, Fretz, and Shaw, 2011; Geertz, 2008; Moore and Yager, 2011). In addition, she was invited to design and teach a two-week course on field data management for early career researchers at FS_B in 2023 and 2024.

Field station directors are responsible for managing their station and staff; many work on-site. They have the autonomy to manage the stations as necessary. Data collection at FS_B permitted observation of this day-to-day work. However, some directors and staff coordinate across stations in annual meetings of field station networks. We followed field station directors to two such meetings hosted at FS_A and FS_C. This provided the opportunity to see station directors interact with each other and discuss common problems and solutions. Brief descriptions of the participant observation activities are described in Table 1.

3.2.2 Semi-structured Interviews

We recruited participants for semi-structured interviews through the Organization for Biological Field Stations (OBFS) community listserv. After the initial wave of volunteers (DIR1, STF2, DIR3, DIR4), a snowball sampling of directors at other field stations mentioned by the initial participants added seven additional interviews (DIR5, DIR6, DIR7, STF8a, STF8b, DIR9, DIR10, STF11) to explore the range of field station features. The semi-structured interviews were conducted on Zoom and lasted about one hour each. All interviews were recorded and transcribed for analysis.

The interview questions were designed to prompt stories and experiences from the participants. This approach allowed the participants to expand on topics most relevant to them. Interviews generally focused on understanding how field stations supported researchers and, by extension, how they supported science. Participants were asked how they came to work at a field station, the station's history, how stations work with researchers, the kinds of information artifacts a station manages, and how a station demonstrates impact.

3.3 Data Analysis: Constructivist Grounded Theory

Data analysis followed a constructivist grounded theory approach, which maintained the inductive, iterative, and comparative elements of grounded theory but was expanded to include the subjectivity of the researchers (Charmaz, 2014; Corbin and Strauss, 2014). Using Atlas.ti, for each interview we conducted line-by-line coding focused on the actions described by the participants, trying to stay close to the participants' language for code identification (Charmaz, 2014, pp. 116). Focusing on the participants' actions helped us interrogate the data and avoid jumping to conceptual conclusions too early (Charmaz, 2014). Examples of these types of open codes included: ‘Maintaining physical access,’ (DIR3), ‘Quick access to the [environment]’ (STF11), ‘Accessing the site is very difficult,’ (DIR7) and ‘Collecting data in exchange for access’ (DIR6). We created 2400 ‘open codes’ across these interviews. As we coded the interviews, we grouped codes relevant to how field stations support science in Atlas.ti. This reduced the total open codes considered for this paper to about 1600 codes. We further grouped these 1600 codes to develop ‘concepts’ yielding a total of 74. As an example, we grouped the codes above and others like them into a concept of *access* where the participants described their experiences accessing the station. Other concepts included *permit work*, *approval process*, and *facilitating research connections*. Throughout this process we used the ‘constant comparison’ method, to refine the concepts with the addition of new data. We repeated this process for all 11 interviews. We also applied the resulting concepts to field notes and document analyses.

Furthermore, and in keeping with the constructivist grounded theory approach, ‘memos’ were created throughout the analytic process to document and explain emerging connections and themes. For example, we noted through memoing that across all interviews, field stations had a role in controlling and managing access, allowing for risky or extreme work, avoiding conflicts and determining the types of work that could be done. These memos and concepts were used in discussions between the authors to analyze and further synthesize concepts. This example for access led to the formation of one of our core categories, *facilitating research access (4.1).* Through this same approach, we identified *extending* *research capacity (4.2)*, *cultivating a hub of research connections (4.3)* and, *sustaining the station for future research (4.4)* as three other core categories, the total of which the narrative in the next section is structured around.

3.4 Research Positionality Statement

We approach this research as white settler women based in the United States who do not hold affiliations at any of the field stations in this study. The authors have experience working with scientific organizations on computer-supported cooperative work. The first author also has prior experience in environmental data management and owns a consultancy that works in that area. Her work includes a collaboration with FS_B. As ethnographers, we both acknowledge that our backgrounds and identities shape the data collection and analysis reported in this paper. Where possible, we use participants' words as our terminology to ground the accounts with their perspectives. To ensure that we remained reflexive, we have presented and discussed ideas in this paper with the field station community formally and informally during visits to FS_A, FS_B and FS_C.

4. Analysis: How Field Stations Support Scientific Study

In the following sections, we organize our analysis to describe how field stations support research projects before, during, and after researchers visit stations and discuss the cooperative work of doing ecological fieldwork is arranged.

4.1 Facilitating Research Access

To begin, when a researcher is interested in conducting research at a field station, the first step is usually to contact the station, and the first point of contact is often the station director. Prospective researchers and station staff—who are often unfamiliar to each other—use email, forms and phone calls to coordinate. The director points researchers to documentation—often on the website—about characteristics of the local environment, how to apply to conduct research at the station, travel logistics, cultural customs, and necessary permits. If a researcher decides to move forward, the next step is for them to submit a project application which outlines their scientific project. In this section, we examine the specific ways that stations facilitate research access all of which is usually done at a distance.

4.1.1 Reviewing Field Station Applications

Almost all stations have some type of application process. The systems that support application could be simple email requests [FS2, FS7] or custom online forms [FS1, FS3, FS4, FS5, FS6, FS8, FS9, FS10, FS11, FS_A, FS_B, FS_C]. Each of these applications requesting access can be considered a research project. We consider field stations to be ‘project-based organizations’ (Kodama, 2007; Sydow, Lindkvist, and DeFillippi, 2004), a construct used in organizational studies to describe the work of creating temporary structures or many ‘articulation processes’ (Strauss, 1988) all at once. The first of these processes is application review, stations have varying levels of scrutiny.

Applications are reviewed to ensure that the research is ethical and aligned with a station's mission. The research’s impact on the environment must also be assessed. Environmentally intrusive studies are not automatically declined, but stations weigh scientific benefits of studies against implications for future use of the environment. Applications also prevent research in sensitive areas and avoid temporal and spatial conflicts across researchers. DIR4 described reviewing research applications for FS4 and ensuring researchers avoided historic sites. Station FS1 includes an old-growth forest, and its director (DIR1) explained that no manipulation was allowed in that forest. DIR1 highlighted that researcher applications allowed them to coordinate between projects to avoid conflicts in both space and time:

> ‘[The researcher application] alerts us [that] some group is coming; they want to go out and do early morning birding. We also have some researchers periodically that might be coming up to take a shotgun and shoot down branches and leaves to get some stuff from the top of the forest canopy. And that obviously can be noisy. So clearly, if somebody's doing an auditory bird project, we really don't want the people with the shotguns to overlap with the birders in space or time because that will make the birding part really challenging. So part of it is allocating the [projects] in time and allocating them in space so that the researchers get what they need.’ (DIR1)

Station FS5 has between 200-250 researchers visit each summer. Managing this large population in a relatively confined area over a short amount of time requires significant planning, scheduling, and coordination. Further, in some of these environments, specialized equipment has been installed, which may pose an unseen hazard if it is, for example, covered by snow or brush; visitors need to be notified of such things. DIR5 uses a GIS system that tracks research sites across FS5:

> 'We're tracking about 4000 research sites or polygons, so one research program will have multiple polygons. And so the way we do that is to require that we know explicitly spatially where they are, and we're over about a 75-mile north-south gradient.' (DIR5)

This spatial awareness of research sites for multiple projects allows stations to protect them for data collection between visits. DIR10 collaborated with the LTER team based at the station to track the locations of all research sites around FS10. Despite this coordination, they occasionally make mistakes. Many stations do not track research sites at all, leading to potential conflicts like a station allowing a newer researcher to add equipment or conduct an experiment physically on top of an existing research site being monitored for longitudinal changes. Since the researchers may not be present at the station simultaneously, the first researcher's experiment could be disrupted long before it is noticed, resulting in the loss of valuable environmental data.

4.1.2 Navigating Government Permissions

Another required element of pre-fieldwork administration is the matter of permitting. Obtaining a permit is an additional layer of permission requests to conduct research in a particular area. Some stations [FS1, FS7, FS9, FS11, FS_A, FS_B, FS_C] are in areas that require research permits, such as state and, national land, countries that are signatories to the Nagoya Protocol[21] or similar. These lands often have restrictions with respect to accessing biodiversity. Many government agencies, from local to federal, require permits for accessing government-managed land. Some stations provide written guidance to researchers, such as permit agencies' contact information or websites [FS3]. However, several stations provide significant staff support to ease permit applications. FS5 and FS10 have special use blanket permits in place that the stations previously negotiated. DIR5 reviews all research applications to coordinate the work under the blanket special use permit. Such an arrangement makes the station application even more important because it also acts as a mechanism to authorize research. DIR10 was allowed to authorize everything within a specific area. If the research included access to the watershed,

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[21] The Convention on Biological Diversity (CBD), established in 1992, is a part of the UN Environmental Program and has 150 countries that are signatories https://www.cbd.int/.The Nagoya Protocol was established in 2010 and is a supplementary agreement to the CBD. The protocol provides a transparent legal framework where, in exchange for access to a signatory country, benefits that arise from the use of genetic resources are shared back to the country from which they were sampled.

DIR10 would have an extra meeting with the local permitting agency to negotiate those project permits. Both examples show how the stations provide a service to ease the visiting researchers' logistical burden.

DIR9 and STF11 described the work they put into maintaining relationships with their permitting counterparts to reduce the friction for researchers trying to obtain permits. DIR9 reviews applications and flags potential issues with researchers before the applications go to the permitting agency. They may also consult with the permitting agency staff about a project to see if anything else needs to be revised. Once these two informal review steps occur, researchers formally submit their permit applications. STF11 is the point of contact at FS11 for permits. They advise visiting researchers to submit permits at least four weeks in advance of arrival so there is time for review. However, STF11 also sits on the permit review board and can help rush a permit if researchers do not submit with sufficient advanced time.

We observed the complex workflow that station staff went through to submit permits on behalf of researchers. The staff responsible for permitting described the work as stressful because what is at stake if a permit is denied— the research could be delayed or stopped completely. The staff also navigates local pressures from the government to seek justification for the research. The permitting work that happens on the researchers' behalf is invisible work. Despite this significant staff support, the prospective researchers view the permitting process as tedious and frustrating, but if there are any issues, the staff may be blamed so this work must be carefully done.

In these examples of application review and permit negotiation, we see elements of 'articulation work', or how staff navigate contingencies (Strauss, 1988). An example of this is STF11's attempts to accommodate a late permit and DIR9's preemptive reviews to smooth the formal permit process. These negotiations between the stations and the government are 'shadow work'—'expertise hidden from view'—and is another way that stations ensure that work can flow (Star and Strauss, 1999). Collectively, the coordination between the station and researchers around applications and permits is considered 'anticipation work', the often invisible and bureaucratic work required to prepare a productive future for the visiting researchers (Steinhardt and Jackson, 2015).

4.2 Extending Research Capacity

After extensive planning, researchers launch into the field. This often requires travel to distant or hard-to-reach locales and bringing equipment or materials that are essential to fieldwork to combine with materials and facilities in place at the hosting field station. Research consists of long, hard days of work in the field and then processing data and running preliminary analysis at night. For the researchers, launching research starts a fieldwork clock, against which they race to collect the data they need before funding runs out.

Because of the intensity with which researchers need to work, stations strive to make the field experience as productive as possible. Stations often provide environmental data to augment the researchers' data. Stations' on-site support can include significant scientific and, more recently, technical expertise. Stations are also increasingly augmenting their facilities with information and communication technology of various kinds. These components may save researchers days to weeks in the field and create new research possibilities.

4.2.1 Characterizing the Local Environment with Contextual Data

Environmental characterization is helpful to researchers before and after their fieldwork. These types of data are often the result of long-term monitoring and called 'contextual data' (Borgman, Wallis, and Enyedy, 2007) that are not seen as independently valuable and so are more readily shared. Weather data are an example of such contextual data that are not particularly interesting on their own, but when combined for analysis with researchers' experimental data, can yield additional analytical insights. For instance, DIR4 described how one might tie plant growth patterns to weather patterns. Thus, many field stations provide weather data [FS1, FS3, FS5, FS6, FS7, FS9, FS10, FS_A, FS_C] as a service to the researchers who work there.

Weather data can be considered a standard form boundary object (Star and Griesemer 1989), because the collection and reporting instruments follow consistent methods and output a standard format data stream for parameters like temperature or wind speed. This allows stations to provide weather data online, one of the only online data presences many field stations have. Weather data access allows researchers to use weather data to augment their own research data; it also allows researchers who have never been to the station to study the station remotely. Many stations, like FS1, hold an archive of historic weather data, sometimes even predating the institution of the field station itself. This provides a persistent trace of what the place was like along this important dimension.

Weather data not only support the data analysis of researchers who collect data at a station, it allows for stations to work together in a network. For instance, FS2, FS6 and FS11 were part of a network of stations that shared weather data through a single portal. This was possible because of the methods standardization built into the same off-the-shelf weather stations that these field stations agreed to use. They [FS2, FS6 and FS11] could provide their researchers weather data in a standard format through a shared online portal, which connects these stations virtually, and allows for weather data comparison across sites. Convenient off-the-shelf weather station solutions offer standard methods built-in from data collection to data sharing. This example shows the potential for station-supported monitoring and cross-station standardization by choosing the same tool.

Though powerful, the weather station example does not translate to other forms of data sharing. For instance, species occurrence lists or flora and fauna surveys that some stations also maintain [FS1, FS3, FS6, FS7, FS9, FS10, FS_C] are non-standard across stations. They may be stored in different document types, and they may have different associated metadata. Unlike weather data, these datasets are more labor intensive to create and manage.

Some stations have creative partnerships with the community to develop these contextual datasets. DIR6 allows recreational birders to access the station in exchange for the birders tracking and sharing their sightings:

> ‘[Recreational birders] want to be able to bird in the reserve, so I've made a deal with them. You can bird in the reserve, but you have to upload your sightings list to eBird, and I've given them all a copy of the map of the reserve, and they have to indicate on the map where they see every species. They just write a little initial and draw a circle, or put it in the margin and draw a line, or whatever. I have a distribution map now, and some of these people bird weekly.’ (DIR6)

In addition to physical paper maps mentioned in this quote, DIR6 asks the birders to upload their findings to eBird, an online repository of birding data that standardizes the method of bird identifying globally. DIR6 benefits from utilizing eBird and its existing tools and standards, contributing to the broader scientific enterprise while also providing a local bird occurrence list. Digitizing transforms a physical object to a digital object, or an ‘immutable mobile’ (Latour, 1987), which is then accessible to researchers interested in the work of the station from afar. Like weather data, this step of digitizing scientific products with a standard portal expands their usage as boundary objects to more potential communities of practice beyond those the station normally works with.

Even with the support of eBird, maintaining a bird species list is effortful and will fall apart if there is no attention paid to this resource. Lists can fall out of date, or the eBird website could break (Lee, 2007). eBird can also be seen as *one more tool* required for stations to learn. Further, eBird only captures one type of animal among the thousands that environmental scientists would like to understand: even if there were other such tools, how many are stations meant to support? As a result, the practical reality is that many stations maintain simpler lists that are updated as time and attention allow. In addition, we found that versioned copies of the lists are not maintained. DIR6 described this lack of standardization as a missed opportunity to aggregate species lists collectively over time and across stations that may provide broader research value.

Despite the challenges, environmental data that characterize locales provide a foundation for basic research. They contextualize important questions for researchers who are considering the station as a potential research site: Is X species here? How abundant is it? DIR6 described the value of this approach to researchers, saying:

> 'If people can go online and [say], 'Oh, look. There's a really well-developed species list. Oh. I can get [weather] station data. I can get some really basic, fundamental data that now I don't have to spend time, and money, and effort to collect on my own,' [they're] much more likely to go work at that site than …someplace where it's a black hole and [they've] got to start from scratch.' (DIR6)

Collectively, these types of data—if they could be systematically collected over time— would form a shared understanding about the environments where the stations are located, and allow for new, expansive scientific inquiry.

4.2.2 Utilizing Scientific Staff Expertise

Many stations are adding scientific and technical expertise to their staff to augment the purely logistical support such as equipment maintenance, hospitality or administrative support. STF11 described this inclusion of staff scientists as a practice that began in the 1980s. In their role, STF11 helps visiting researchers with successful data collection, describing a particular instance in this way:

> ‘I provided everything that was needed [in the field]— [materials], microscopy …, logistics, contacting the right people to use the instruments, whatever. And [the researcher who was in need of this support] was very successful. So then she was presenting her data in other places and [yet another] researcher saw her data and then contact[ed me] to come here…. then the same thing….[a second research group visited]… So then [the researchers] love both: how much I helped them and what they found [in their research].’ (STF11)

This quote shows the significant expertise that STF11 provided, including logistical advice about when to visit and where to collect data, combined with deep scientific expertise and results specific to this place. Together, these contributions from STF11 were essential to successfully attracting and supporting two sets of research teams to work from FS11. These collaborations also proved useful for STF11’s own scientific work. While STF11 moved to work at FS11, some stations like FS7 and FS_C employed local community members as field guides, often trained as naturalists to support visiting researchers, and at FS_C, they also supported visiting tourists.

A second type of expertise offered by stations is related to data analysis. STF2 described their geospatial expertise and how they supported several undergraduates learning to do research. They ensured that these early career researchers learned to manage their data and had exposure to R, ArcGIS, and other analysis tools. They felt that this role was building the next generation of researchers. DIR5 also saw the power that data science capabilities added to their station and took the initiative to add additional resources ahead of researcher demand:

> ‘So my sense was, we needed to leapfrog the situation. So … what you need is … the data plumbing, which is the support system for archiving the datasets getting the appropriate metadata [and] facilitating access to that. And so [the staff data scientist at FS5] was hired to build the spatial data platform to take advantage of emerging technologies to essentially address these scaling issues and promote collaboration. …it's been super successful, as measured by the number of scientists taking advantage of [their] work and utilizing the data products.’ (DIR5)

The data scientist at FS5 provides scientific and technical expertise to support active research by combining the station’s tracking data with remote sensing data products, another type of environmental characterization dataset. Building on this work, the station staff also collaborate on proposals with FS5 researchers to ask new questions that they could not have asked without this additional support. The concept of ‘data plumbing’ that DIR5 invokes unknowingly makes reference to the infrastructure literature and speaks directly to the technical and human infrastructure that is needed to support data processing (Lee, Dourish, and Mark, 2006).

In addition to data science expertise, some stations have librarians on staff and, increasingly, data managers. One station, which had a librarian-data manager on its staff (STF8a), was aware of the shifting data management landscape and began to build capacity to support researchers. At FS8, STF8a shared how the station adapted to changing government mandates:

> ‘In mid to late 2010, we started hearing about the NSF mandate that would go into effect in January 2011—the data management plan requirement. I started sharing that information, and the conversation became more real. Our director at that time immediately was supportive. They said, ‘Let's create a data management committee’ … we were supposed to start talking about creating a data management plan template for our researchers to use right away, starting in 2011.’ (STF8a)

This case of data management support at the field station is unusual. Generally, field stations are engaged after the data management plan has been submitted with a funding proposal. However, when templates like this are available, they can provide a valuable resource to the researchers and begin building consistency across the different kinds of work being done at the station.

The ways that field station experts like STF11, STF2, DIR5, and STF8a arrange artifacts (supplies, data products) or processes (such as coordinating optimal times and places for researchers to visit) can be considered ‘synergizing’ activities that build and maintain relationships which make the infrastructure function (Bietz, Baumer, and Lee, 2010). Synergizing is particularly important in resource-constrained environments such as field stations.

4.2.3 Evolving Technological Capabilities

Field stations have long served as a platform for data collection. However, as biology has adopted new instruments that produce more data, field stations have had to evolve their services including to meet researcher requests. For example, because the researchers who conduct their work at FS5 visit annually each summer, DIR5 emphasized their evolutionary response to their needs:

> ‘[The field station] is the scientist and so they [the researchers] wouldn't consider themselves visiting. Right, because it's an institution that's their institution and built for them. So now, the way that people interact with the field station has changed and diversified. And so you'll have different types of scientists interacting with the field station in different ways. But there's no one way.’ (DIR5)

Though field stations are usually most characterized by the logistical support and physical facilities they offer, DIR5 highlights how the station infrastructure is shaped around the scientists’ needs. Many additions are made to enable research including through the acquisition of off-the shelf technology as well as experimental technology.

DIR3 described how a group of computer scientists were once interested in using the land around the station, which had a steep terrain for an initial mesh network that was considered a research endeavor in the early 2000s. Using FS3, researchers built an outdoor network of 40 mobile sites that included 12-volt power and Wi-Fi to transmit data. DIR3 then offered this new infrastructure to ecologists. The ecologists' biggest desire was to have a small animal tracking capability, a need the computer scientists responded to in a second round of implementation. However, this time, there were challenges in getting the research technology to work in the way the ecologists needed. In the end, the animal tracking technology that sat upon the mesh network was not widely adopted:

> '[The computer scientists] did a lot of novel things, but they never quite got it fully functional the way we wanted it. The ideal was a system where the ecologists would capture animals, put a transmitter on them, [then] let them go. And then the system would collect those beeps, triangulate [them], put it on a map that's available [online] for researchers. They can go near real-time, and see where their animals are, how they're interacting with other animals that are also tagged and then be able to download the history of all that data. And then you can do whatever you want with that, including a bunch of mapping. So some of those aspects worked. Some of them didn't. Inevitably what got hung up is the computer scientists fought over [decreasing the instrument uncertainty]. [This research focus on precision did not serve] the needs of the [ecologists]… this system didn't continue to develop because it didn't... have a wide enough user base.' (DIR3)

DIR3 described how when the cutting-edge research interests for computer scientists waned, the station became responsible for the mesh network's difficult maintenance. Further, the animal research funding that supported the ecologists' investigation ended, so there was no longer a clear motivation to maintain the animal tracking capability. Finally, in 2020, the area around the station burned and destroyed both the mesh network and the animal tracking system. DIR3 felt confident that adding Wi-Fi and power through existing off-the-shelf technology would be easy enough to do should they need to replace it in the future, but was unsure if they would ever add animal tracking again.

The uncertainty expressed by DIR5 highlights the trouble that stations sometimes have in adding an additional layer of infrastructure to maintain. When these pieces break, the infrastructural inversion (Bowker, 1994) that results highlights that stations do not always have the specialized, technical expertise they need on hand to sustain or maintain the knowledge infrastructure. While ultimately unsuccessful, this example shows the iterative collaboration or tacking back and forth between field stations, the computer scientists, and the ecologists to 'accrete' new layers of infrastructure. It also demonstrates the ways that DIR5 meant that stations act as *reflections of the researchers*. The station would not have added either of these layers without supporting researchers' needs.

Another way that new technology is added is through off-the-shelf products that offer a lower barrier for learning how to maintain. Wi-Fi is one example of such an off-the-shelf addition. Since the point in time when FS3 was among the first to explore Wi-Fi mesh networks in 2007, many stations have added Wi-Fi capacity. All but two stations in the study had reliable Wi-Fi. Wi-Fi changes the work practices at stations. Reference materials are now easily accessed online, so researchers no longer need to bring field guides. Wi-Fi also allowed for transcribed digital data to be easily sent back to a researcher's home institution servers or stored in the cloud, providing additional safety in case local computer hard drives fail (DIR6).

A more recent example of how the stations are built to accommodate researchers is demonstrated by the surge of interest in augmenting traditional survey methods with new analytic capabilities like environmental DNA (eDNA)[22,23] analysis to detect and measure the occurrence of species (Beng and Corlett, 2020; Shea et al., 2023). The demand for eDNA requires new kinds of clean-room laboratory spaces that are removed from spaces that are doing other kinds of DNA work (Goldberg et al., 2016). Clean-room laboratories have features like positive air pressure, separate equipment for use in that room only, and strict rules for researchers to avoid contamination (Goldberg et al., 2016). These new labs in place at FS_C and planned at other stations make it possible to do this analysis closer to where the sample was collected, important for reducing the time for sample degradation. Unlike the animal tracking example, this form of laboratory expansion seems to be easier to manage for the existing station staff because it relies on the skills of the visiting researchers and does not need new skills from the station staff since much of the laboratory equipment is the same.

Expanding research possible at field stations shows how they themselves are experimental spaces to try new ways of working. This experimentation has a cost. In all three of these examples—the collaboration with researchers, the introduction of Wi-Fi, and the new eDNA laboratory capacities—we see that each addition contributes to the overall station overhead that needs to be managed (Grinter et al., 2005). Though STF2, STF8a and DIR3 described picking up these new skills as they were needed, other stations expressed overwhelm at being tasked with yet another part of the system to maintain.

[22] Environmental DNA is genetic material, or partial bits of degraded DNA, originating from a collection of organisms that can be detected in water, soil, or sediment (Beng and Corlett 2020)

[23] Between 2008 and 2019, over 800 eDNA studies were published (Beng and Corlett 2020).

4.3 Cultivating a Hub of Research Connections

Beyond facilitating access and extending research capacity, field stations are hubs to support researcher connections. In the prior sections, we have shown how stations maintain relationships with permitting agencies, and governments. We have also shown ways that the station maintains connections with their local communities. In this section, we will describe two other types of connections that stations foster: those between researchers and those between stations.

4.3.1 Connecting Researchers to Each Other

Field stations support researchers that share a coincident boundary for their research, like an experimental forest [FS1] or protected areas [e.g., FS5, FS10, FS_B, FS_C], but do not share methods or domains. These connections are generally between individual researchers or teams and stations, like spokes to a hub. Stations use the application forms and permits—examples of standard forms—to negotiate the precise location for their data collection activities within the coincident boundary. The station may support many teams that use this same coincident boundary, but there are fewer connections across the researcher teams themselves. One station director explained how their ‘mental map’ of the work that has been happening at the station was developed through application reviews and interactions with researchers on-site. With this big-picture overview of the station, station directors are positioned to see the possibility of connecting across diverse, station-supported projects. DIR1 realized that potential by making introductions between research teams with complementary interests. This type of work is one way to create connections between researchers that can further extend the collective understanding of the place.

Station directors develop station narratives that are often repeated publicly as the ‘story of a station’. They are expanded versions of the mental map to support consumption by others and so include details about important history, the kind of research that is happening, and the vision for where the station is going. These narratives are repeated when new people are introduced to the station formally in presentations and informally across casual exchanges. The narrative about the work of the station over time gives researchers a shared framework in which to situate. This cohesive scientific narrative about the station supports multiple communities of practice and provides points of comparison during cross-station conversations.

Another way that stations support serendipitous researcher connections is through their facilities. Stations offer classrooms and meeting rooms, and some also offer event planning support. While at FS_B, we observed how researcher connections are initiated when there are meetings or workshops at the station and scientific results are presented. Additional visiting researchers are included because they happen to be at the station but otherwise would not have attended such a meeting. The researchers across activities are aware of their shared membership in a station-supported community. When this occurs, from our observations, researchers seem more willing to connect and share research data for unanticipated purposes. As others have reported, conferences and workshops reduce the distractions of normal business and life, which may also increase the researchers' capacity to make interdisciplinary connections and build trust, both essential for data sharing (Sanderson, 2023). The addition of videoconferencing capabilities is now allowing researchers to participate without being physically present at the station, but the impetus of in-person meetings at the station seems important in prompting this behavior.

Finally, some stations use information resources as ways to create researcher-to-researcher awareness. FS10 has a sign posted that lists the current projects with contact information physically at the entrance of the station and on their website. FS5 has a project list on the website that geospatially displays all the research sites (as polygons) for all active research around the station to generate shared awareness. These more passive approaches to communicating how the station is being used mean that the station does not know if they were of benefit or fostered connections. As with other station activities, maintaining these resources is one more thing the stations must do; without attention the project lists can easily fall out of date.

Through these examples, we see the benefits of co-located research to science and the shared understanding of the location. Many of these benefits seem serendipitous (Michener et al., 2009; Billick et al., 2011; National Research Council, 2014), with research opportunities arising when interpersonal connections are made via stations' physical spaces. Though sometimes serendipitous connections between researchers are made because of stations' online materials, this is of course only possible to the extent that stations can maintain and fortify those services—an opportunity that is ripe for expansion and that we will return to later in this paper.

4.3.2 Connecting with Other Stations

Stations are loosely connected through memberships to organizations like OBFS, the National Association of Marine Labs (NAML), or the World Association of Marine Labs (WAML) for example. There are also smaller and often ad hoc regional coordination networks among stations. OBFS, the longest-standing organization, was formed in the 1960s because directors needed a forum to discuss common goals and challenges, and to identify how to evolve the field stations in support of scientific demands (McNulty et al., 2017). These organizations act as a shared voice to advocate for the importance of field stations nationally and internationally. Most of the stations in this study are members of at least one of these networks, and they find these partnerships helpful in their individual and shared missions.

Field station directors serve an important role in making station-to-station connections that exist. They are supported by in-person meetings in addition to email listservs. When the first author participated in two director meetings (held at FS_A and FS_C), the value of learning from other stations was consistently mentioned by directors. Still, one station director commented how surprised they were about how resonant other directors' experiences were. We found that the work of directing stations shares commonalities but is also highly localized: the experience is at once universal but uniquely situated because of their environmental locales, the kinds of communities in which they are embedded, the nature of their relationships with host institutions, and more. Station directors have such demanding roles in managing physical infrastructure, information infrastructure, community partnerships, and researcher agendas—and to ensure that the facilities and partnerships persist indefinitely—that only other directors can easily understand.

These meetings provided opportunities for directors to connect during which they readily established common ground (Olson and Olson, 2000) and develop shared awareness of the unseen intricacies of their responsibilities. In addition, the relationships that result between directors and the staff from these meetings allow for additional station-to-station coordination. Station directors participate in exchange programs or external station reviews, which allow for field station staff to learn from each other. These opportunities are particularly useful for learning how to maintain and sustain field stations. For instance, during the COVID-19 pandemic, stations shared protocols and approaches for running stations safely by email. STF2 was a member of OBFS and described initial efforts to share data analysis and data management expertise with other stations. At one of the station director meetings the first author attended, the idea of sharing a data curation staff person across several stations was also discussed. This type of sharing allows stations to benefit from expertise without having to fully support yet another staff person.

There was also a clear sense from the collected primary and secondary data that if stations could confederate with respect to infrastructure, they would benefit from access to more resources. At FS_C, one participant cautioned that divided resources to individual stations could be less helpful than pooling shared resources for collective use. One small-scale example of cyberinfrastructure confederation was a common application portal to streamline facilitating access to a regional network of stations. This portal had been developed and maintained for about a decade. Because of the collective resource pooling, the cost of the two full-time developers needed to keep the system running was shared across the participating stations. However, with multiple participating stations came conflicting system requirement requests. As with other collaboratory examples, it is difficult to have both local flexibilities to please all and the required standardization. The example also highlights that, while there are benefits to sharing, there are also additional cross-station cooperative work costs and trade-offs to using a shared platform. With these challenges, the platform becomes difficult to sustain, which we turn to in the next section.

4.4 Sustaining the Station for Future Research

For researchers to sustain their research programs, they must publish their results. A successful publication record with contributions to science can lead to more funding, which in turn leads to future environmental fieldwork. In parallel, stations must demonstrate the twin goals of showing how they support research and offer scientific value so that they may generate interest, purpose and revenue to sustain themselves. They need to answer two primary questions: (1) What happened when researchers worked at the station? and (2) What was produced with support from the station? Even though field stations support the necessary stage of data collection, their roles fade as research traverses research toward publication such that, perhaps surprisingly, these questions prove difficult to answer. In addition to justifying the station’s impact, there is also the real and ongoing work of maintaining and repairing the station for future research.

4.4.1 Demonstrating the Station Use (Near-term)

Many stations collect usage statistics [FS3, FS4, FS5, FS6, FS7, FS9, FS10, FS_A, FS_B, FS_C], which are collected by counting 'user days', or the number of days researchers used the station. The user days are often classified as *higher education*, *public outreach*, and *research*. Those classifications may be further subdivided into 'users' who were from the host institution versus outside of it, or users who stayed overnight and used a station's residential facilities versus those who did not. Stations may also report details about users' grants, and information obtained during the application process (5.1.1). DIR3 described the ways the institutional host administrators are interested in the overall use:

> 'just overall use, are we [the station] being used?...., and that's at different levels. How are their faculty researchers using it? But they also want to see the educational uses. That's because that's our other leg of the stool or other pillar [or] other mission is, the instructional use, mostly,...undergraduate, and … they'll pay a little [attention] to any kind of K-12 activities.' (DIR3)

These numbers demonstrate to funders and home institutions the usefulness of the station, but these accountings do not seem to be meaningful to researchers or to local communities. These types of institutions have the power to shut the station down. Researchers tend to be focused on the work at hand that is time sensitive. They are coming to a particular station because it is adjacent to their phenomena of study and of research interest. Local communities, on the other hand, may not be aware of the station and if they do have awareness, they are not in positions of power to influence the station.

When researchers have received a permit from a local permitting agency, the permit acts as a legal contract and is part of a mandated report. STF11 emphasized this: 'the research permit [ultimately] is signed by the researcher and by the official [permitting authority], and it's a binding contract.' They went on to add that part of their role was to ensure that researchers understood the permit and its reporting expectations. Stations and permitting agencies struggle to enforce their reporting requirements to which DIR7 expressed frustration over researcher non-compliance:

> 'So, [researchers] do have an obligation because of their research permits to submit to [the permitting agency] a report on what they found. And we have a staff member who just on a monthly basis sends out I don't know how many emails to all the people that haven't done it. And often it's like once you pass the six-month mark, they're not doing it. We keep sending the emails, but the…compliance on that is not ideal.' (DIR7)

Even without permits as a legal requirement, some stations ask for near-term research results. DIR10 was implementing a new reporting requirement for FS10 researchers this year to document what happened at the station:

> 'So [researchers] are going to get a Google form probably in October that just is very simple, but asks how many people are on your research team? How many hours did you spend in the field approximately? And also please summarize your research in three sentences for the public. And then those research summaries will all go on the website as what happened in 2023, again, as a way to kind of increase visibility on what goes on there.' (DIR10)

There was a sense from directors that stations did not want to burden the researchers. This quote highlights how the simple form was meant to be easy and unburdensome. In addition to the quantitative statistics, requesting the three-sentence public description is a way that FS10 tries to communicate current research projects to future researchers, which connects back to the point about how they facilitate access (4.1).

4.4.2 Documenting the Station's Impact (Long-term)

Publications based on data collected at or supported by field stations are highly valued evidence that the station was used. DIR3 said: 'Publications are the other metric. …. the argument is: this [is the field station] that enabled this high-level research.' Because publications are a way to prove credibility, stations work to find past work done at the station. Without these publications, it is hard for stations to build a scientific reputation [FS1, FS8, FS10, FS_B].

Some stations have reporting policies [FS1, FS5] where they ask for copies of publications. These policies are agreed upon before field access, but all too often are forgotten afterward. Like the near-term reporting attempts, DIR1 highlights the difficulty with researcher compliance. They cited the lag between when a researcher visited the station and when they received notice of follow-up:

> 'We do ask researchers right up front to please make sure that they at minimum share any publications that come out: dissertations, things like that. People are really terrible about doing that. But I think it's because of the time lag that you usually have between … people get[ting] out of the field….and then it takes a while to publish the materials. So I don't think anybody means to be negligent about that. But I can't tell you the number of times I've been tooling around on the internet and typed in some keyword and accidentally found it, "oh, that person's published."' (DIR1)

As DIR1 notes, for researchers, fieldwork is just the beginning of their scientific process. In comparison, the first clock marked the race to collect as much data as possible once fieldwork commences, a second clock starts when translating data into publications, the primary currency of the scientific enterprise. Upon leaving stations, researchers may not be able to take their data with them immediately, which can cause delays in analysis (because it can be difficult to transport or because there needs to be government paperwork filed to allow removal). Furthermore, researchers may need multiple data collection visits before they can publish, which extends the time between initial contact with the field station to publication.

Even more problematically, despite the significant work done by field stations, scientific results often fail to mention field stations in their publications in consistent or standardized ways. Sometimes, the station is not mentioned at all. At a meeting of station directors at FS_C, one conversation was highlighted: 'Someone designed a sensor, did extensive testing at [a station], and published a methods paper without mentioning [the station]. When asked why, they said, "It just didn't occur to me to mention the [station]."' This lack of acknowledgment was recurring and observed across all sites we observed and, in most interviews, [DIR1, DIR3, DIR5, DIR7, DIR9, DIR10].

Despite the difficulty with researcher compliance sharing directly or the inconsistent mentions or acknowledgments, publications are essential for station justification. Stations described their attempts to recover these publications. The end of DIR1's quote above about accidentally finding these publications through a keyword search highlights one of the most common ways research conducted at field stations is found and reclaimed by them. Many directors and staff described the same behavior: conducting an internet search with their station's name and any variations to locate publications whose data originated from their site [FS1, FS4, FS5, FS7, FS8, FS9, FS10, FS_B]. Where the station name was completely absent, some station staff tried to overcome this problem by searching all researcher names and deducing whether the paper was conducted using station resources based on geologic place names or other cues.

Once stations find these publications, some stations create bibliographies or publication databases [FS1, FS3, FS5, FS6, FS9, FS10, FS_A, FS_C]. The detective work to find related publications and share them re-establishes the connection between the researchers, their work, and the station. A bibliography showcases the breadth of research stations have supported and is part of the anticipation work (Steinhardt and Jackson, 2015) they do to inform future researchers of the foundation of scientific work upon which they can build. Finally, this work is an important aspect of sustaining the existence of stations. Scientific publications are evidence of their past and potential future contributions to knowledge advancement, which is the basis for future funding.

Despite these essential functions, maintaining bibliographic databases requires time and patience to search for papers. A lack of conventions about how to acknowledge the station role makes associated publications hard to find. The nonstandard and oblique ways in which authors reference or fail to reference stations altogether make manual data capture difficult and automated data capture impossible. Despite their clear value, bibliographic database efforts are often outdated or abandoned entirely.

This difficulty highlights the combination of the invisibility of stations in research and the temporal dissonance between the 'rhythms' of publication and station reporting (Jackson et al., 2011). The researchers' temporal rhythms around subsequent analysis and publication may be controlled by academic calendars, obligations to professional societies, teaching loads, and other administrative burdens. The publication rhythm, which spans submission, reviews, revisions, and final publication, is often slow and unpredictable. Meanwhile, stations instead tend to operate on more regularized annual reporting rhythms to their host organizations (despite the rest of their responsibilities being non-routine and irregular). Further, because publications that report on research that used station facilities often occur outside the bounds of a station's annual reporting window or long after the visiting researcher left, they are frequently missed. This lack of temporal alignment is yet another reason that stations find bibliographies difficult to maintain and why field stations feel disconnected from the scientific enterprise.

4.4.3 Repairing and Maintaining the Station

Field station infrastructure is in tension with the natural environment. This tension requires constant maintenance and repair to keep the environment from overtaking the infrastructure. One director described stations as 'people-powered', meaning that this work is generally done by resource-constrained field station staff. These staff ensure that every task — from facilitating access (5.1) to documenting impact (5.4.2)— results in stations being operational. Without station effort, all these tasks will go undone, and the artifacts from the physical buildings to the species list or project lists will fall out of date or eventually be discarded. Drawing from Jackson et al., we see the repair and maintenance of stations as sites of difference, sustainability, innovation, and power and dependency (2011).

Station differences are easily recognized. Stations are adapted to the localities of their environment and researcher needs. However, in this adaptation, each station has also established different ways of accomplishing the common types of work described above. For instance, almost all stations had station-specific processes for facilitating access, meaning that many stations developed their own application forms and permit support documents (5.1). Another area where we saw high variation was the different approaches stations took to providing species lists (5.2.1). With variations in how stations approach these shared tasks, there are no shared conventions or standards, placing the burden on each station to maintain these artifacts independently. The burden results in unnecessary redundancy and duplicated work across stations despite technology or practices that might be shared.

Conversely, this same independence also makes the approximately 1000 stations 1000 places of experimentation and, thus, innovation. Specifically, DIR10 repaired the connection between researchers and the station after they left through the proposed near-term reporting (5.3.1). FS10 also shared their project list online and physically at the station's entrance. In these ways, FS10 is a 'site of innovation.' Though simple, FS10 makes visible the unseen work happening at the station. A challenge of sharing innovations is the lack of inter-station shared awareness. If this approach were shared, other stations and researchers could benefit, an idea we will return to in the next section.

In addition, we saw how field stations repaired facilities in ways that moved them towards more environmentally sustainable impacts. FS_A, FS_B, and FS_C all posted signs reminding users of waste rules. Stations proactively upgraded technology like hot water heaters to solar-powered heaters and added other renewable energy where possible to reduce their overall energy demand. These repairs to their infrastructure ensure their impact is environmentally light. As stations begin to consider digital facilities to complement the physical, STF8b worried about the environmental impact of hosting environmental data long-term. Sustaining the station by repair is one way stations take the long view, which ensures persistence for generations of researchers.

While there are many researchers who benefit from the station, the burden of sustaining the station rests with the station director. Sustaining the station requires demonstrating the impacts that the station has on the scientific enterprise (5.4.1, 5.4.2). However, in attempting to document the impact, the power disparity between stations and the researchers becomes evident. Researchers are recognized for the knowledge they produce; with new publications and resulting citations, researchers' reputations increase. Researchers with strong reputations and successful research track records can secure more funding and repeat the cycle of accumulating academic power. Stations depend on researchers to acknowledge their role. When researchers fail to recognize the support that made their work possible, it diminishes stations' contributions. This neglect shifts the onus onto the station to repair the connection between research outputs and the stations.

5. Discussion

Collectively, field stations have contributed to biological science for well over a century. Their aims are now as they were originally, to support place-based scientific research, education, and outreach, and to conserve the areas they steward (National Research Council, 2014). Field stations can be considered model ecosystems (Billick et al., 2013) or instrumented 'islands' that offer unique capabilities and have accrued a significant foundation of research that benefits other similar, but unstudied, ecosystems. As such, station directors argue that they must be valued as strategic scientific assets, like other shared facilities such as satellites or scientific telescopes.

Field stations necessarily stand apart from the surrounding world in the sense of providing well-preserved natural lands that can be studied. They stand apart in other useful ways as we have documented here, including in how their staff must provide multidisciplinary expertise as well as maintain strong relationships with local communities. However, while the contributions of field stations are undeniable, a growing lament from their staff is how incidental their role today seems to the conduct of science as a larger enterprise, and how at-risk this makes their longevity.

5.1 The Paradox of the Field Station

The challenges arise, we believe, in the paradox with respect to how field stations enact their role. As a function of their historical evolution, field stations *evolved in response to the needs of the researchers they support.* Thus, researchers and field stations are closely coupled entities. We have heard refrains from visiting researchers and field stations alike that echo the idea that 'the field station *is* the scientist' and that stations act as 'reflections of the researchers.' Even the notion that researchers are 'visiting researchers' is a qualification we use only in this paper, simply to make clear to the reader when we are talking about those researchers who frequent the station, from those few who are employed by the station —the field station director may also be a researcher, after all. In day-to-day operations, the visiting researchers *are* 'the researchers,' and the shared perception is that stations exist *for* them.

Historically, this tightly coupled relationship served scientific achievement very well. Bespoke solutions tailored to the needs of the research being conducted enable high-quality science. **But what we are finding is that, today, this single focus of tight coupling of the researcher-field station identity is no longer serving the larger enterprise of science. Instead, the relationship is failing science because the contributions of field stations are being lost, even in this networked world—perhaps especially *because* of this networked world.** The recognition from a limited number of visiting researchers that field stations previously possessed by resiliently standing alone for decades does not carry over to digitally encoded archives that we now expect to show how data originates, where funding was secured, and what the qualifications of the scientists are. **Thus, field stations insufficiently exist in the digital record.** Remarkably, we now know they cannot even be accurately counted because no one really knows for sure where they all are or how they might be named. Field stations, as important as they are, are fighting invisibility. They are fighting not to be forgotten because they know that to lose them is to lose a major apparatus of basic science.

The tensions of the paradox—of needing to be highly localized and responsive to researchers and yet needing to be seen collectively as an institution in need of independent recognition—is what needs attention. We argue that for field-based biological science to excel, the tight relationship between field stations and 'their researchers' needs to be loosened at specific points, while the relationship *between* field stations needs to be strengthened. Recall that field station directors are relieved when they can convene to find out how many issues they encounter are felt by all. The very idea of being lone, independent, and even scrappy falsely permeates the perceptions of field station directors that their experiences must also be singular.

5.2 When to Stand Apart, When to Stand Together

The way forward is for field stations to know when to stand apart—as they have always done—and when and how to stand together—which would be mostly new. Directions to take are alluded to by examples of what field stations have already experienced, though in the small.

Standing Apart. The gold standard in biological field science must not be lost in supporting the execution of high-quality original research, field stations will need to continue to 'stand apart' and operate in localized, bespoke ways. The bespoke practices arise from the boundary work that stations do to facilitate science. Boundary work is defined as 'those acts and structures that create, maintain, and break down boundaries between knowledge units' (Fisher, 1988, pp. 160). Stations sit at the lab-field boundary (Kohler, 2002). From this analysis, we unpack that lab-field boundary and see that stations are doing boundary work between research domains working at the station, researchers, and the local communities and environments that the station is part of, and between other institutions, including governments, host institutions like universities, or other stations.

Stations have developed bespoke existing infrastructures that are highly adaptable to do this complex, non-routine boundary work. To extend the theoretical work of this paper, we propose the concept of '*boundary negotiating infrastructure'* to describe this often-overlooked form of organizational coordination. It brings together Star and Bowker's (1999) notion that boundary objects can be linked together as boundary infrastructure with Lee's boundary negotiating artifacts (2007), which support non-routine coordination through labor-intensive artifacts that do not have an agreed-upon process. An example of this infrastructure comes from the work that stations do to find and catalog research outputs. Stations request in advance that researchers share their outputs with the station, but there is no agreed-upon process for that sharing. There is also no agreed-upon process for what to call the station or where to put this acknowledgment in an output, so searching is a non-standard process. Finally, there is no agreed-upon approach for sharing these research outputs. These outputs might be in a spreadsheet or a shared reference management system, but every station is developing their own approach. Each of these is individually a boundary negotiating artifact. At each point, collaborative work is occurring, and stations are coordinating across multiple perspectives, as shown in the database example by Bietz and Lee, these artifacts exist across communities (2009). However, infrastructure emerges through relationships between artifacts over time. The relationship between the stations, the researchers, and the outputs does not have agreed-upon processes and requires stations to maintain these relationships over time in effortful ways. Hence, when we examine the relationships between boundary negotiating artifacts, boundary negotiating infrastructure emerges.

We argue that we need this new concept because, like boundary objects, infrastructure, particularly knowledge infrastructure, is also overloaded and underspecified. Boundary negotiating artifacts provided the other end of a continuum from boundary objects (Lee, 2007). Likewise, boundary negotiating infrastructure provides the other end of the continuum with boundary infrastructure. It allows us to see the nuances of stable and unstable knowledge infrastructure, or the fluid, temporary 'knotworks' (Bødker et. al., 2017). Stable infrastructure has agreed-upon processes within boundary objects and in the relationships across those boundary objects. In contrast, boundary negotiating infrastructure is unstable. By this, we mean that it is fluid and shifts to support non-routine and often complex work, as defined by Strauss (1988). Like the example above, this infrastructure may lack an agreed-upon process internally within boundary negotiating artifacts. Instability can be magnified when the relationships between the components of this infrastructure do not conform to an agreed-upon process. Also, like Lee argues that boundary negotiating artifacts may be a precursor to boundary objects, there may be a similar argument that boundary negotiating infrastructure is a precursor to boundary infrastructure.

In accepting that a good deal of field stations' work requires engaging with such boundary negotiating infrastructures, we also ask where the burdens of beleaguered field station staff could be eased. The answer, based on observations and interviews, seems to be in restricting the bespoke support to the execution of the research itself—temporally, this means to conceptually restrict such support to the period during and immediately before a research project is launched. Does a project conflict with other research going on? Or what special advisories and equipment will researchers need? This also includes evolving station research capabilities to better support location-specific research. Such attention still respects the inherent, necessary coupling of the researcher and station. The mutual dependence and cooperative work of how the research gets done is a specialized—and special—one. We could argue that the cooperation of expertise *is* science itself.

Standing Together. Outside of this active researching period—that we will call the *during* experience of the researchers and field station—we can look for opportunities where relationships need not be so intertwined and as a result could be stabilized through shared processes. This is where standing together in mutually beneficial alliances with other field stations comes into view for innovating the future of the scientific enterprise.

We have instances that demonstrate that this is possible and exciting, while respecting that change is not without its own challenges. Field station directors do make efforts to convene and discuss experiences and have since the 1960s through organizations like OBFS: this suggests a readiness for field stations to not only be researcher-facing, but also station-facing. The example of weather station data sharing demonstrates how agreeing on standard hardware and cross-tabulating environmentally contextual data with software is possible and beneficial, which also means that field stations can be seen more clearly as the independent research-providing entities they also are. The desire for some shared alliance and methods standardization around species list is another indication of the powerful possibility for station confederation. Bolstering this connection with shared software, like in the weather station example, may enrich the station-to-station connections through perhaps more collaboratory (Finholt 2003) opportunities.

We see other opportunities for station-facing alliances that could ease the before and after periods of stations' obligation to research support, and for amplifying more contextual data sharing across stations more enduringly. However, we believe that station-facing cooperation will not happen without a reconceptualization of how stations see themselves. So historically strong is the idea that stations act as 'reflections of the researchers' that we believe a new frame of reference needs to be introduced for a new perspective.

For this frame, we propose reconceptualizing *visiting researchers and their projects* as existing apart from field stations, even though field stations enable the research. Just as funding agencies enable research efforts but exist in a different sphere from them, so too must be the field station relationship to the many research projects they support. Further still, we suggest researchers be recast as the *audiences* to field stations until the point at which both are cooperating to accomplish research projects. Field stations can therefore be not *of* researchers as they are now; they can be aligned *with* researchers in an evolved sense of partnership.

The 'audience' view also means that it could be possible for field stations to imagine that they stand together in fielding this shared audience. It does not mean that the audience needs all field stations in the same way—disciplinarians of terrestrial ecologies may not work in marine ecologies or vice versa.

It rather means that stations can infrastructure themselves as being able to act on an in-common audience with in-common infrastructures.

With this shift in perspective, there are a few areas ripe for infrastructural solutions. In the before-time period, there were many small steps in the form of low-tech practices that could be implemented here that can be found as examples in this ethnographic record. There is also the lesson from a small alliance of stations that share a field station access application platform, with benefits in efficiency and shared resources outweighing new hardships. We note that for stations, this is the period that stations have the most power since it is the point at which they could deny a researcher access to the station.

The other end of the visit—the 'long after' from data collection to publication— is yet another expanse of difficult communications that field stations across the board experience and is ripe for additional infrastructuring, but this is the point that stations have the least power. In repairing this connection, we argue that stations are not just responsible to research teams, the research teams become responsible *to* the field stations—a significant shift in the usual power dynamics. This will require the biological community to shift their worldview: they must recast their conception of field stations not as individual and incidental actors in science, but rather as an *institutional and integral* aspect of the scientific enterprise. In the long-after of data collection, it must become a norm for researchers to recognize field stations in their reports, if they want the stations they utilize to persist. This recognition will create a lasting record of stations' contributions to science and, therefore, build an argument for their continued existence.

It is naive to expect that norms are enough. Stations like funders ask researchers to recognize them at the start of their fieldwork, and this does not consistently happen. Successful solutions should consider the policy, practice, and infrastructure at once (Jackson, Gillespie, and Payette, 2014). Policy solutions could support technical solutions to ensure encoding so that archival activities, including automated search, can locate the elusive research-field station links. Standard, *encoded* acknowledgment turns the social exchange of field station support into accessible information. This link is a way that field stations become visible in the digital record.

None of these solutions is especially ground-breaking: they can all be done now. There is no state-of-the-art tech we are awaiting. The success of infrastructural solutions are political in both the little p and big P senses. In the little p sense, in the short-term, field stations and researchers may have to convert some ways of doing things (such as emailing between the station and teams to set up a visit) that might be lighter-weight in the short run for something that is more infrastructured but beneficial in the longer run. Further, by collectively infrastructuring before and after the researcher visits, there are additional benefits like a shared awareness for visiting researchers of a single station about knowing what other kinds of research are happening in the same field stations they frequent. This would allow researchers to build on prior work and eliminate redundant work.

In the big P sense, a dream of a confederation of all known field stations around the world may be far off. Yet, if stations and researchers reconceptualize their relationships and they both start to standardize around some of these recommendations, they may generate cumulative positive 'network effects', including the broad recognition of stations within the scientific enterprise that directors have called for. The implications of these recommendations would realize the potential of the networked world for field stations, allowing cyberinfrastructure interventions to enhance the bespoke contributions they make around the world.

6. Conclusion

Biological field stations provide integral scientific support for researchers around the world. Individually and collectively, stations are critical scientific assets. They have evolved in a tight relationship with the researchers they support, which has provided enumerable scientific advances. Yet, as we move towards a networked world, stations insufficiently exist in the digital record. Through our analysis, we found that stations do four types of common work in support of research. Despite these commonalities, stations each have largely independently grown bespoke knowledge infrastructures in response to those research support needs—infrastructures that we call *boundary negotiating infrastructures.* The flexibility and reconfigurable properties that make infrastructures so adaptable at the same time make the infrastructure unstable. This adds significant overhead to individual stations to provide labor and repair. These bespoke adaptations at individual stations also makes cooperation across field stations challenging and limit the potential for scientific progress. With this understanding of the ways field stations work, we respond to the field station director community's call for solutions to demonstrate the integral role that stations play in the global scientific enterprise (Billick et al., 2013; National Research Council, 2014). Our recommendations call for shifting the ways that field stations and researchers relate to each other. We seek to unite not only cyberinfrastructure advancement but also innovation around policy and practice, building on the vision of the collaboratory (Finholt, 2003). Such interventions could reduce staff burden and redundant work that is so common across stations. In addition, it could provide visiting researchers associated with a single station with broader awareness of past and concurrent research to spur new scientific questions. Strengthening station-facing connections enables the potential for stable collaboratory infrastructure that spans field stations. Field stations standing together in this new way can more easily reveal their collective and integral impact.

Chapter 4

Abstract

Despite advances in data-intensive environmental research, the digital connections between field stations and the projects they support are often missing in the scholarly record. When connections exist, they tend to be labor-intensive and fall out of date quickly. This chapter builds on the ethnographic findings of the prior chapters, which demonstrated the challenges field stations face when they *digitally stand apart*. From 2022 to 2024, I collaborated with a field station director whose goal was to digitally connect station-supported research outputs back to the stations they managed. Through an iterative, participatory infrastructuring methodological approach, we developed a set of infrastructure interventions reported on in this chapter. Using the standard connections between three global registries that uniquely, persistently identify people, organizations, and digital objects across the scientific enterprise, we successfully demonstrated the field station director's goal by registering field station-supported projects and creating connections between the station and downstream outputs. As we learned from these interventions, our goal evolved to create connections between research outputs and the local community the station is part of. These interventions, taken together, enable postcolonial repair, with the addition of a connection back from visiting researchers towards the places and institutions essential for producing this work. When these connections are established, researchers *digitally stand together* at a single station, and stations can collectively *stand together* as a network and global asset. I conclude with recommendations for other field stations interested in creating digital connections between the projects they support and the places they steward, and ideas for extending this work into field station collaboratories.

1. Introduction

For decades, there has been a steady stream of publications advocating for field stations to be seen as scientifically important, to confederate into a network, and more recently to invest in digital solutions to solve this problem of being unrecognized assets (Billick et al., 2011; Eppley et al., 2024; Kimbrough, 2024; McNulty et al., 2017; Michener et al., 2009; National Research Council, 2014; Robinson & Palen, in review; Wyman et al., 2009). Despite this advocacy and despite limited attempts at some field stations, broadly speaking, field stations still struggle to make their contributions individually and collectively visible to the broader scientific enterprise.

The first part of this dissertation focused on understanding the cooperative work of field stations and the researchers who visit. In Chapter 2, I started by examining field station-supported projects at 20 field stations, which included the perspectives of researchers and field station directors. In Chapter 3, I specifically considered 14 field station directors' perspectives to understand how they support these projects. Both of these chapters describe how field stations *digitally stand apart* —that is, the ways that stations and researchers lack connections when they are not physically together.

In Chapter 2, I found that field station-supported projects are shaped in unique ways by at least four types of contexts—spatial, temporal, material, and relational. The highly situated nature of these projects means that often, the only common element across them is their location. Everything else about the projects, including their research method, is bespoke. Further, I found that the scientific reporting occurred long after researchers were in the field and often represented only a portion of the overall project. I argue that field station-supported projects are problematically *dark*, meaning they are not registered or findable by others, such as the communities who live in the environments they have studied or other researchers working in the same location. Said another way, field station-supported projects are a missing connection between field stations, the researchers, and potentially downstream outputs, like data, that, if made visible, would remedy many problems.

In Chapter 3, I examined the ways that field stations support research projects before, during, and after researchers' visits. I found that field station directors have a unique view across these projects; they see the potential for bringing research together digitally as a station-provided resource whose impact could be documented. I also found that while field stations do common types of work like facilitate access, extend the facilities, create a hub of research connections, or sustain the station, they do this work in bespoke ways that are tightly coupled with the researchers they support. This has served the researchers and their projects well, but as we move into the 'Fourth paradigm' or digital, data-intensive science (Hey et al., 2009), the bespoke approach field stations use to build infrastructure is not working to build digital field station infrastructure. We define this infrastructure as *boundary negotiating infrastructure*—labor-intensive, ephemeral infrastructure without shared or agreed-upon methods. Thus, field stations, like the projects they support, are inadequately represented in the digital scientific enterprise.

In this chapter, I explore how infrastructuring interventions might transform the connections between field stations and the research projects they support, as well as connections across stations. This chapter reports on a collaboration with a field station director to design and evaluate solutions that transformed the station's internal application system required for accessing the station, making field station-supported project metadata visible and connecting that metadata to the station and to research outputs. Through the work reported here, these interventions made dark projects described in Chapter 2 visible and connected the field station to the project in a standard method agreed on widely across the scientific enterprise, a challenge identified in Chapter 3.

2. Related Work

Over the past sixty years, advances in computing and, more recently, the introduction of the Internet, have fundamentally changed the course of environmental research (G. E. Moore, 1965). In the early 2000s, computer scientist Jim Gray named this transformative shift the 'Fourth Paradigm of Scientific Research,' referring to the fundamentally new, data-intensive science that was possible with this technology (Hey et al., 2009). These advances shifted the practice at scientific workplaces, including field stations, making new types of research that were inconceivable just a few decades prior possible.

Gray identified two transformations happening as a result of the shift to the Fourth Paradigm: the first transformation is the development of new tools for researchers to collect, manage, and analyze their data, and the second transformation is the digital representation of the scholarly record, making all scientific literature and data more easily available online (Hey et al., 2009). These transformations digitized the environmental scientific record and enhanced the types of collaborations that were possible.

Many take a triumphalist perspective on the transition to data-intensive science. Yet, as we enter the second decade of the 21st century, the problematic implications of data-intensive science are becoming increasingly apparent. Critical scholars have catalyzed a third transformation towards the ethical and just collection and use of scientific data (D'Ignazio & Klein, 2020; Leonelli, 2015). This transformation illuminates the encoded power imbalances, noting whose knowledge is prioritized and who is rendered invisible, and the potential harms data-intensive science may cause. These transformations are required to disrupt the systemic coloniality inherent in parts of the scientific enterprise.

In the next three sections, I describe how field station-supported projects have developed cyberinfrastructure but are missing digital connections to field stations to establish the need for this work, the pre-existing materials used to build the field station infrastructure interventions, and the ways that infrastructuring is changing with the ethical implications of science and data.

2.1 Missing Digital Connections to Field Stations

Field stations provide critical physical infrastructure to sustain long-term monitoring projects. However, up until the late 1970s, these projects had largely been done in isolation from each other. In the late 1970s, ecologists, a subset of environmental science researchers, began advocating to the United States National Science Foundation (NSF) to invest in coordinated, multi-sited, long-term monitoring projects (Kingsland et al., 2021). In a series of three workshops from 1977-1979, this community defined the core research questions common across sites in 1977, piloted related monitoring approaches in 1978, and planned network management, including the idea of a 'data bank' or repository, in 1979 (National Science Foundation, 1977, 1978, 1979). This was the formation of what is now known as the US NSF Long-Term Ecological Research Network (LTER). In 1980, NSF funded the first six LTER sites, all located at existing field stations. Today, around 15 of 27 LTER sites are hosted by field stations in the United States (M. Downs, personal communication, September 21, 2025). The remaining 12 do not have permanent facilities and use field camps or nearby university campuses like Scripps Institute or UC Santa

Barbara[24]. Thus, field stations[25] have played an instrumental, real-world role in supporting many LTER projects.

One transformative element of the LTER program was that the LTER sites confederate, individual projects at individual stations, into the national LTER Network with shared services, including data management coordination (Karasti et al., 2010). Over the forty years of LTER-funded research, the network has continued to invest in cyberinfrastructure. They have established sophisticated data management practices and information infrastructure (Michener, 2015; Michener et al., 1997). This shared information infrastructure provides many research services and aims to maintain robust links to research data across LTER sites. The LTER information managers provided the LTER projects' data management support, but this funding and support did not necessarily extend more broadly to the rest of the projects at a given field station, so it is still only a *partial* solution to the field station directors' ongoing challenge of connecting research back to the station. Thus, while LTER sites are digitally visible, their connection to field stations has been inadequately digitally represented.

In the early 2000s, the operating LTER data management infrastructure was one of the inspirations for NSF's concept of cyberinfrastructure (CI). NSF defined CI as a "platform in service of research," or the layer above the base hardware that includes not just High-Performance Computing (and now cloud computing services) but data management services, repositories, instruments, collaborative coordinating services, and the humans needed to sustain it (Atkins et al., 2003, p. 5). Additional environmental cyberinfrastructure has come online since then, aided by the proliferation of sensors and tools like drones that create digital data from the outset, skipping the need to transcribe handwritten field notes (Hey et al., 2009). Advancing DNA analysis techniques have also increased the amount of data researchers are working with and mobilized environmental data in new ways (Dumoulin Kervran et al., 2024). The introductions of new tools are changing the kinds of research questions that can be asked and increasing the need for shared tools for collection, curation, and analysis. This growing volume and

[24] The number of LTER sites hosted by field stations is not clear from the LTER website. I examined each LTER site's hosting arrangement and determined if it was hosted at a field stationfederatedn.
[25] While LTER sites and field stations have a mutually beneficial relationship, where the LTER project is supported by the station and the station financially benefits from LTER's grant funding, these two entities are distinct.

variety of digital environmental data furthers the disconnect between field stations and the data they support.

Because LTER, along with other environmental science cyberinfrastructure, was digitally visible, significant work focused on the intersection of CSCW, infrastructure studies, and environmental science (Borgman, 2020; Edwards et al., 2007, 2013; Jackson & Barbrow, 2013; Karasti et al., 2010; Mayernik et al., 2013; Ribes & Baker, 2007). Baker, a CSCW and infrastructure studies scholar, began her career as an LTER information manager from 1990 to 2011 (Baker & Millerand, 2024). Hence, one well-documented CSCW topic was the data practices of the LTER information managers and their experiences developing and using the LTER information infrastructure across the network (Baker et al., 2002; Baker & Karasti, 2018; Baker & Millerand, 2024; Bowker, 2000; Karasti et al., 2010; Karasti & Baker, 2004). These studies highlight the challenges of sharing data, the efforts of a subset of the ecology community to agree on data and metadata standards, and the challenges in designing and implementing cyberinfrastructure "solutions." They also highlight the tension in harmonizing the place-based idiosyncrasies in data and metadata found at each project site with the standardized U.S. national network. However, because field stations were unintentionally missing from the digital record, they were not included as part of the infrastructure examined in these studies.

Field stations and the environments they are part of are highly significant to the researchers, yet the research and stations can be practically invisible to the scientific enterprise. Recent work has examined data curation practices at 'scientifically significant sites', defined as sites that have attracted a large amount of research attention, often in legally protected areas (Thomer, 2022). A key difference between scientifically significant sites and field stations is that those sites have curatorial control over the data. Field stations do not control researchers' data and are left out of the curatorial loop, meaning they do not have awareness of or connection to the data (Robinson & Palen, in review). This omission makes it difficult to demonstrate the scientific significance of field stations.

Additionally, while this might not be a conscious omission, it may be a result of the norm, where researchers working on field station-supported projects do not consider two-way connections between themselves, their projects, and the field stations (Robinson & Palen, in review). Furthermore, there are no standard digital mechanisms for connecting field stations to this cyberinfrastructure. In this chapter, I report on our interventions that aim to create connections between the field stations and research projects through existing cyberinfrastructure. In the next section, I describe the cyberinfrastructure, referred to as the Global Research Infrastructure (GRI), which forms the foundation of—or *materials* for—our infrastructure interventions.

2.2 Describing Infrastructure Intervention Materials

In the prior section, I've argued that because field stations are left out of the curatorial loop for research they support, they are often disconnected from their digital scholarly outputs. Here, I explain how those connections might be made by providing background on existing scholarly communication norms -- and the untapped potential in our global research infrastructure. The global research infrastructure underpins scientific reporting across the entire scientific enterprise. In this chapter, I will focus on three primary types of persistent identifiers[26] that make up this infrastructure. These identifiers allow researchers to uniquely identify and digitally register their work through digital object identifiers (DOIs), themselves with ORCiDs, and their organizations with RORs. Furthermore, these identifiers are persistent and globally unique, meaning they will always resolve to an online landing page, and they are distinct across the entire scientific enterprise.

Each identifier is a single record, a row, in the corresponding registry—a catalog—of each type of identifier. Individually, we can consider these persistent identifier registries boundary objects, where researchers across disciplines have agreed on and adopted a standard method for describing these types of items with forms (standard metadata) and contributing those records (filled out forms) to registries (another type of boundary object) (Star & Griesemer, 1989). In addition to the method standardization, these boundary objects provide interpretive flexibility, meaning that many communities can use them. Hence, field stations can use these persistent identifiers as building blocks for infrastructure intervention materials.

Connected, these building blocks form the Global Research Infrastructure (GRI), a 'boundary infrastructure' (Star & Bowker, 2002), or a stable assemblage of related boundary objects. Digital object identifiers (DOIs) form the backbone of this boundary infrastructure through structured relationships to

[26] Persistent identifiers (PIDs) are unique names to locate content.

other persistent identifiers, like the creators, the publisher, or other related work. With this standard method of making connections or defining relationships across these registries, the Global Research Infrastructure emerges (J. Jones & Habermann, 2025). Additionally, this stable, general digital infrastructure is the foundation needed for the infrastructure interventions to connect field stations to research. In the remainder of this section, I describe a brief history of how this infrastructure evolved to its current state.

With the rise of computational technology and the rapid adoption of the Internet, researchers began to share their work on websites, and a new mode of scholarly publication emerged. With this transformation, researchers began citing Universal Resource Locators (URLs) in scientific papers (Lawrence et al., 2001). The benefit of these links was the speed and ease with which a reader could connect with additional research or data immediately with the click of a link. However, with the rapid rise in the inclusion of these links, the research community realized that there was also a rapid rise in broken links (Lawrence et al., 2001). One study showed that published papers had broken links almost immediately, sometimes within months of publication (Dellavalle et al., 2003). These broken links led to the loss of access to valuable materials.

The problematic nature of these links made researchers question whether URLs should be included in bibliographies at all. The solution to broken links came from the publishing industry, which collectively organized to establish a persistent identifier (PID), called Digital Object Identifiers (DOIs) (Gilchrist & Mahon, 2004). These were location-independent names to resources across the scientific enterprise (Klump & Huber, 2017; Paskin, 2002). This switch to names allows for the location to change, but the link to persist. It has become important that identifiers are not just persistent, but also globally unique (Klump & Huber, 2017). Globally unique identifiers disambiguate resources. In addition to providing unique names, persistent identifiers allow for additional descriptive, standardized metadata. This metadata is machine-readable information about the entity and makes the entity self-describing.

Following the invention of DOIs, two organizations, CrossRef, formed in 1999, and DataCite[27], formed ten years later in 2009, were established as DOI registries (Gilchrist & Mahon, 2004). These organizations mint DOIs, or create the unique identifier, and hold the identifier metadata, which point to

[27] In this chapter we will only be concerned with DataCite.

the landing page for the resource. Crossref is the minting authority for most journals. DataCite, as the name suggests, was established several years later to mint DOIs for datasets. Both have evolved to mint DOIs for many types of resources, including journal articles, datasets, samples, projects, and dissertations.

While DOIs are now created for many types of objects (e.g., software, samples, instruments), initially DOIs were created for journal articles. They immediately had a multipurpose role to both uniquely identify the object and to create connections through structured metadata to references, publishers, and creators (Gilchrist & Mahon, 2004). This connectivity function led to the need for persistent identifiers for creators and contributors. Thus, two additional persistent identifiers and organizations were established for people, the Open Researcher and Contributor ID (ORCiD) in 2012, and organizations, the Research Organization Registry (ROR) in 2019. All of these global registry organizations state a strong commitment to long-term persistence and open, nonproprietary approaches.

In the interventions described in this chapter, I demonstrate the GRI functions available for connecting research to people, organizations, and other digital products through this existing infrastructure. As described at the beginning of this section, the Global Research Infrastructure (GRI) emerges when standard connections are made across these PIDs. These connections are visualized through the 'PID Graph'—a network of the connections related to a particular node (Cousijn, Braukmann, Fenner, Ferguson, van Horik, et al., 2021). I used PID graphs as another material to visualize the standard metadata connections in our infrastructure interventions. In the next section, I move from describing the technologies we built upon to considering the ethical and political implications encoded in different infrastructure configurations.

2.3 Infrastructuring in Intentionally Ethical Ways

Politics and biases are imbued into artifacts through both conscious and unconscious design choices. For instance, in Long Island, a set of bridges was intentionally built at a height shorter than public buses to exclude poor, often Black, people from traveling to those areas (Winner, 1980). In information science, Star and Bowker examined the politics of categories (Bowker & Star, 1999). Mundane metadata, when 'inverted', illuminates or reinforces ways of thinking (Bowker & Star, 1999).

Environmental science is not immune to the influence of politics embedded in existing systems. One study of natural history museums found there was both a historic collection imbalance, with more male than female specimens collected, and a present-day bias in how specimens were presented, with male specimens giving privileged placement (Machin, 2008). Field stations, the other end of the natural history specimen chain, encode design choices, too. These choices can make them a home for particular types of scientists and researchers and not others (Dumoulin Kervran et al., 2024; Geissler & Kelly, 2016).

The politics encoded in artifacts have often systematically, but silently, reinforced the dominant narratives and marginalized groups of people. Taking field stations again as an example, they evolved from research expeditions like those of famed Captain Cook (Wulf, 2012). Repeated trips and accumulation created powerful ‘centers of calculation’ in museums and universities (Latour, 1987). Those working from centers of calculation had the advantage of being able to see across many locations all at once and, from ‘seeing for a second time’, or the power of information to provide a foundation for return visits even if the individual had never been there (Latour, 1987). For decades, it was commonplace for environmental scientists to conduct ‘parachute science’, dropping into a location, collecting data, and leaving without engaging or sharing research benefits back to these same locations (de Vos, 2022). This was not necessarily malicious, but it was an uninterrogated practice.

Like many scientific practices, transformations toward data-intensive science also went uninvestigated. Terms like ‘cloud computing’ obfuscate the real-world material implications of the large data centers that underlie the cloud infrastructure (N. Jones, 2018; Zander, 2024). Yet, looking just at energy and carbon emissions, data-intensive life, science is included, needs over 200 terawatt hours and contributes 0.3% of carbon emissions annually (N. Jones, 2018). Inclusive of all information and communication technology (ICT), ICT contributes 2% of all carbon emissions today. However, ICT is forecasted to contribute 20% of carbon emissions by as soon as the early 2030s (N. Jones, 2018). The increased connectivity and possibilities that ICT provides reduced the friction for parachute science, making it even easier, faster, and more invisible to remotely extract environmental data with no connections to the locations or the communities from which the data comes (Dumoulin Kervran et al., 2024). The Fourth Paradigm, when it is uninvestigated, accelerates the systemic reproduction of harmful practices.

Starting around 2010, a small set of scholars in Human-Computer Interaction (HCI) began to investigate computing practices with a critical lens. Feminist HCI (Bardzell, 2010) brought feminist theories to HCI. Examining computing with concepts like intersectionality, which recognizes differences within groups (Crenshaw, 1991), or 'the matrix of domination', which identifies the ways that groups are differently affected by systems of power (Collins, 2008). Feminist HCI emphasized the situated nature of all systems and allowed for surfacing harms that might be invisible to designers (Bardzell, 2010). Postcolonial HCI considers the complexities of working across intercultural groups and how artifacts designed in one cultural context were used in another (Irani et al., 2010). Postcolonial HCI, like feminist HCI, again attends to power. These contributions and others initiated critical examination of the impact of computing, the ways that power is shared or not, who gets a voice, and how coloniality is reproduced (Das et al., 2021, 2024). This work laid the foundation for the present-day emergence of a justice wave in HCI, with many researchers making a commitment to social justice in their work regardless of topic (Benjamin, 2022; D'Ignazio & Klein, 2020; Semaan, 2019).

We see this same growing commitment to justice in environmental science. From the earliest calls from Rachel Carson of the human impact on the environment in *Silent Spring* (1962) to recent climate justice movements, like #FridaysForTheFuture (Mason et al., 2023), there is a similar justice wave in environmental science. Between 1962 and the present, the political ecology subfield brought similar ideas of feminist theories, postcolonial practices, and sustainability together (Perreault et al., 2015). Political ecology has become increasingly mainstream, and recent advocates are calling for an end to parachute science and a shift towards new ways of working with local communities (de Vos & Schwartz, 2022; Perreault et al., 2015; Stefanoudis et al., 2021). Similar to the FAIR and CARE principles, which are high-level aspirations, the turn towards justice can also be abstract and challenging to translate from theory to practice.

Infrastructure requires effort and is where theory becomes practice. 'Infrastructuring' refers to the labor required to 'grow infrastructure' or all the ways that it evolves or accretes over time, changing and shifting with the influence of those who build and use it (Karasti & Blomberg, 2018; Star & Bowker, 2002). 'Infrastructuring' within the justice movement has called for considering the approaches to design itself (Benjamin, 2019; D'Ignazio & Klein, 2020; Harrington et al., 2019). Benjamin encourages considering the assumptions that design thinking privileges and again brings feminist theory and postcolonial theories to challenge the dominant narrative (2019). Harrington, Erete, and Piper (2019) provided real-world cases to consider traditional design approaches. Materials often used in brainstorming, like markers and sticky notes, seemed childish to their participants, which in turn made them feel trivialized (Harrington et al., 2019). This is a powerful example of what Irani et al. refer to when they describe considering cultural contexts when transferring technology (2010). Finally, D'Ignazio and Klein take an unusual step at the end of *Data Feminism,* where they turn the principles described in each chapter into metrics (2020). They use the metrics to set aspirational goals and to evaluate their book project at the open peer review step, and when the volume was published (D'Ignazio & Klein, 2020). This translation from principles to metrics allows others to see how to put justice into practice[28]. In this chapter, I also take steps to translate value into practice through an infrastructure intervention approach, which I describe next.

3. Method

The research design for this chapter is informed by infrastructuring, specifically participatory infrastructuring, which is the exploratory work needed to form more permanent networks (Bødker et al., 2017; Cosley et al., 2012; Karasti, 2014; Karasti & Baker, 2004). Participatory infrastructuring is 'more than a string of meetings' and should be considered a 'longitudinal network of activities in which people and technologies are brought together' (Bødker et al., 2017, p. 10). Together with a field station director, we employed participatory infrastructuring to design and evaluate approaches to make field station-supported project metadata visible and to connect that metadata to stations and corresponding research outputs.

For these infrastructuring interventions, I used three existing global registries: DataCite to create DOIs for field station-supported projects, ORCiDs to identify and connect researchers working at the stations to their projects, and RORs to standardize organizational naming and connect researcher affiliations and the station to the projects. The interventions bridged these global registries and stations' internal application systems that are required for station access.

[28] An online copy of this table is available: https://data-feminism.mitpress.mit.edu/pub/3hxh4l8o/release/2

I augmented these participatory infrastructuring activities with 'design ethnography', which moves ethnography from an observation practice toward a reflective, creative practice (Pink et al., 2022). Through this approach, I applied my findings from the ethnographic work reported on in prior chapters to these interventions, I documented these ethnographically, and the learning from interventions informed my ethnographic work.

In the remainder of this section, I briefly introduce my collaborator and the infrastructuring sites. I then provide details on our approach to infrastructuring interventions and documentation, and conclude with how my positionality has shaped and is shaped by this work.

3.1 Description of Collaboration with a Field Station Director

My initial entrée to these two field stations came via my role as the data management advisor to the FAIR Island Project[29] (Robinson et al., 2023). The project name is a reference to the FAIR[30] (Findable, Accessible, Interoperable, and Reusable) principles, which can be considered a set of aspirational values that many researchers have adopted to make data machine-actionable and also use as a shorthand to signal the values of open and reproducible science (Wilkinson et al., 2016). The FAIR principles were intentionally high-level, serving as a guide rather than a prescriptive approach for enhancing the value of data contributions and use across the scientific enterprise (Wilkinson et al., 2016).

This project was a collaboration between "Nic," a field station director, with managing responsibilities across two stations, two technology partners (one from an R1 University and one was a nonprofit), and me. The other team members were spread across other projects, so this research was primarily a partnership between Nic and me. The work reported here from 2022 to 2024 is part of a larger, five-year longitudinal network of activities. This extended partnership with a single field station director allowed me to attend to the 'backstage activities' required to overcome the field station-to-research output project connection challenge over this longer period of time.

[29] This research draws in part on public deliverables developed under a subaward between Metadata Game Changers, LLC, and the University of California Office of the President (California Digital Library), supported by NSF Award #2132549 from June 30, 2021 to June 30, 2024.
[30] There are many acronyms. They will be spelled out on first use and a glossary of all acronyms used in this paper is included in Appendix A.

My role: From Nov 2020–Jul 2024, I served as research data management advisor and coordinated day-to-day activities for the FAIR Island project. I co-designed and implemented infrastructure interventions with Nic, translated user needs into technical requirements with support from computer programmers, and prepared presentations, blog posts, and reports. As part of my dissertation research, I augmented these activities from March 2023 to November 2024 with 'design ethnography', which moves ethnography from an observation practice toward a reflective creative practice (Pink et al., 2022). This involved actively, iteratively tacking back and forth between the ongoing ethnographic work and this participatory infrastructuring work.

Field Station Director Collaborator: Nic was interested in exploring how the FAIR principles could be implemented at their field stations to connect research outputs back to the field station in machine-actionable ways. Nic has managed field stations for over 20 years and is a geneticist by training, prior to his work at these stations. He is very interested in cyberinfrastructure development and has participated in and led data-intensive environmental science projects. For nearly his entire tenure as field station director, and long before we began to work together, Nic had a goal to digitally connect their field stations to downstream research outputs with an ambition to use those outputs for place-based decision support systems, which I refer to as the field station-to-research output project connection challenge[31]. This background and goal made Nic a particularly good collaborator for me because they were already well-versed in existing data management research, so there was not much technical translation between Nic, the developers we worked with, and me.

At the time our project started, there were very few examples of implementing FAIR principles in a real-world setting, so the rest of our team was interested in learning from the general approach, but did not have experience working with field stations. This lack of field station perspective from the technical team meant that Nic's participation was essential because it brought technology developers in direct contact with the 'user' and grounded the development in real-world needs, instead of developing technology away from the 'user' and then returning when something was 'finished' for feedback.

Working closely with Nic afforded me the ability to try infrastructure interventions in real-world situations to see how it responds. I sought to actively collaborate with Nic because he was an engaged

[31] I will call this the 'field station connection challenge' or 'field station challenge' as shorthand.

partner with subject matter expertise. Together, Nic and I developed infrastructure interventions to overcome the field station-to-research output project connection challenge by digitally registering *field station-supported projects* and establishing connections between the station, the researchers, and their downstream work through stable, machine-actionable metadata at two infrastructuring sites described next.

3.2 Infrastructuring Sites

As designed in the IRB protocol, all stations and associated people, organizations and projects are anonymized and referred to by generalized characteristics like approximate age (for the station) (Table 1) to avoid any reputational harm, an approach advocated by Vertesi (2020).

	Reef Station	**Atoll Station**
Established	1980s	2010s
Governance	U.S. University	U.S. 501(c)3
Annual Researcher Visits Supported	200	80
Local Population	20,000	None; Only visitors frequent the Atoll by reservation request
Pseudonyms for actors	Nic, station director Barcode project, conducted from 2007-2010 The Reef Cultural Association, a nonprofit partner of the Reef Station	Nic is also the science director

Table 1. Field Stations Summary

The Reef Station was established in the 1980s as a gift to an R1 U.S. university that manages it today as an active research facility. It supports extensive research on the local environment and has supported hundreds of scientific research projects over the last nearly 40 years. In addition, starting in the early 2000s, the Reef Station developed a novel partnership with a local community-based nonprofit organization, the “Reef Cultural Association”, dedicated to documenting, promoting, and preserving Traditional Ecological Knowledge (TEK).

The Atoll Station is a newer field station that started about ten years ago. It is located in a more remote location, about 40 miles from the Reef Station. The land the Atoll Station sits on is privately owned and has no permanent population. It is managed by a nonprofit 501(c) (3) organization. Given the proximity between the stations, the Atoll Station has modeled much of its infrastructure after the Reef Station and shares some overlapping staff, including Nic. However, the differences between the stations in size, governance, age, and geography allow for different types of interventions as I describe in the next section.

3.3 Infrastructure Intervention Approach

My active, dual role on the FAIR Island Project as ethnographer and research data manager is one mode of social science interventions, where I, at times, directed the infrastructuring work (Ribes & Baker, 2007). The focus of this chapter is on our infrastructuring activities related to project metadata, so the time period is March 2022 to November 2024. While Nic set the goal and what we worked on, I had technical flexibility that gave me the space to experiment with different infrastructure interventions, 'a bounded act' (Ribes & Baker, 2007, p. 108), to meet Nic's connectivity goal. The decision to treat these interventions as research objects from which we could learn was mine. As we built and tested, we learned new things about how Nic's field station infrastructure worked, and it became clear that part of the benefit of these interventions was not just to reach their goal. They also provided a way to surface and analyze the situated nuances of potential solutions to the broader field station problem.

I maintained my ethnographic sensibility developed through the work described in the prior chapters. However, I extended my ethnographic practice for this work. Design ethnography insists that design is continuous and that ethnographic insights feed back into new prototypes and a deeper understanding of future possibilities (Pink et al., 2022). Hence, my approach working together with Nic was active, reflective, and iterative.

I developed two ways of learning from interventions across scales, from a single project to a real, operational station at the Atoll Station:

1. **A retrospective single project:** I utilized a past research project at the Reef Station, the Barcode Project, which took place between 2007 and 2010. The Barcode Project was well-documented and

old enough that project-produced products, such as datasets and journal articles, were published, but not connected to the Reef Station. Using a past project retrospectively provided the autonomy to quickly test interventions as the first 'researcher' before I asked working researchers to try something.

2. **Small-scale tests at the Atoll Station:** As described above, the Atoll Station is a small station, with more controlled governance and access, so a few interventions were tested with the Atoll Station. These characteristics made it easier to act on the station directly.

After testing through these approaches, Nic and I reviewed the interventions and discussed what did and did not work. Following those conversations, we would repeat the cycle of planning revisions to the interventions, testing, and evaluating.

Through this iterative approach, we first developed FAIR interventions. These were designed to operationalize the FAIR principles (Wilkinson et al., 2016) using standard methods and existing digital infrastructure to connect stations, projects, and their outputs to the digital scholarly record. One critical insight we gained during this work was the broadening of the connections from the station to the local community that the stations are part of. The CARE Principles for Indigenous Data Governance, like the FAIR Principles, are a set of goals for Indigenous communities to have sovereignty over data and other related outputs derived from their environment (Carroll et al., 2020, 2021).

With this insight, Nic wanted the infrastructure interventions to incorporate the values of CARE, as they have been extended to other local communities beyond Indigenous communities. Like the FAIR interventions, the CARE interventions were designed to operationalize CARE principles at the field station. They utilized Local Contexts' existing infrastructure, digital infrastructure for Indigenous communities, to exert authority to control Indigenous knowledge. Collectively, the FAIR and CARE interventions accreted on top of each other in order to form an ethical, stable field station infrastructure that connects to the digital scientific enterprise, which I describe further in the analysis section.

3.4 Intervention Documentation

From 2022 to 2024, the FAIR Island team met monthly, where I updated them on the project activities and sought feedback. Between these meetings, Nic and I mainly worked at a distance, from our respective home locations, through weekly Zoom meetings. This represents over 200 hours of synchronous remote collaboration. Our at-a-distance collaboration was punctuated by in-person collaboration at the Reef Station in 2022, 2023, and 2024, totaling about 18 weeks of additional in-person time at the Reef Station. These in-person sessions were aligned with meetings or activities related to our collaboration. While my work is different from most working at the Reef Station, this cadence in and out of the field was helpful to understand the mobility of other researchers working at the station. During this period, we had regular conversations in which we discussed the challenges facing Nic, sketched out the process, reflected on the broad themes emerging from our research, and brainstormed intervention ideas.

Nic and I documented our working sessions with a running shared notes document that is now hundreds of pages long. During asynchronous work sessions and testing, I used autoethnographic methods, including field notes, memos, and sketches, to document my process (Adams et al., 2021). In addition to these internal documents, our collaboration process was documented through outward-facing materials, including the infrastructure interventions themselves, presentations, blogs, diagrams, and memos. I presented this work during three outward-facing meetings of field station directors in 2022, 2023, and most recently in the Fall of 2025. These opportunities provided informal member checks to validate our ideas with the broader field station community. All materials referenced are publicly accessible, and no confidential information is disclosed in this dissertation. The dissertation research presented here is my independent scholarly work and does not reflect the institutional positions of any partners or funders.

3.5 Positionality Statement

I approach this research as a white settler woman based in the United States who does not hold an affiliation with the stations in this study. In this chapter, I draw from my experience working with scientific organizations on data management issues, including the Reef Station and the Atoll Station. Although paid for portions of this work[32], I remained committed to following Nic's lead and addressing the needs of the Reef Station and the Atoll Station. Since I am not originally from the communities the Reef

[32] Portions of this work were supported through projects conducted via Metadata Game Changers, LLC, with funding from the U.S. National Science Foundation (Grant #2226425 – SEEKCommons) and the NSF (Award #2132549 – FAIR Island) through subaward RP20705-01, administered by the University of California Office of the President (California Digital Library).

Station and the Atoll Station are part of, I am committed to disrupting parachute science in and through my work. As part of that commitment, I maintain relationships with these field stations and the communities they are part of, even when this is at odds with grant cycles. I also intentionally went beyond the field station 'bubble'. I have been fortunate to participate in community outreach events and meetings with local community members and elders, building relationships and perspectives of the place. These experiences deepened my understanding of the situated places that the Reef Station and the Atoll Station are part of.

4. Analysis: How might infrastructuring interventions transform field station connections?

In the following sections, I organize my analysis to describe the current state of the shared field station infrastructure at the Reef Station and the Atoll Station, and some of the challenges it presents, and then move to interventions to explore possibilities of future field station infrastructure.

4.1 Existing Field Station Infrastructure

To develop infrastructure interventions, I needed to understand the current state of the field station application infrastructure shared by the Reef Station and the Atoll Station. I also needed to understand the researchers' collection and analysis infrastructure. The examination of these systems in depth, built on prior ethnographic research described in Chapter 3, that identified the types of work that field stations conduct, including facilitating access and cultivating a hub of connections (Robinson and Palen, in review), and on the current social organization of field station-supported projects, which makes cultivating the hub difficult for stations because of problematic 'dark projects' and missing connections between projects and downstream outputs (Chapter 2).

By examining practices at the Reef Station and the Atoll Station with Nic, we had a specific instance to repeatedly return, over five years, deepening and affirming the nuances uncovered in my prior ethnographic work. I will provide a brief summary of the current state of the field station and researcher infrastructure at the Reef Station and the Atoll Station. Then, in the next two sections, I describe intervention objectives and infrastructure interventions we developed to realize Nic's goal to connect research back to the station, described in 4.2 and 4.3.

4.1.1 Field Station Application Infrastructure

The Reef Station and the Atoll Station utilized a shared application system, the Reservation Application Management System (RAMS), with about 40 other stations using the system. The idealized workflow is depicted in Figure 1.

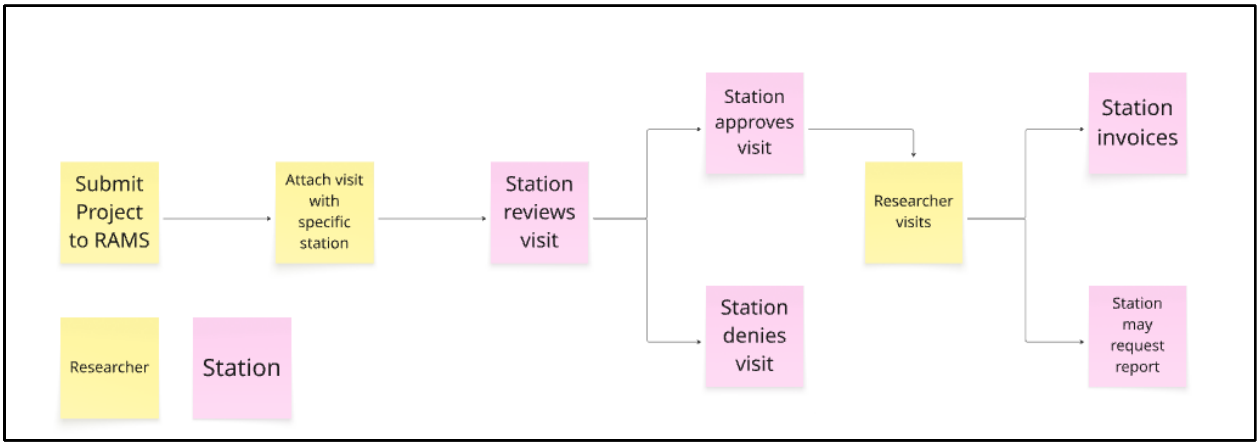

Figure 1. Idealized workflow of the existing field station application system process

Figure 1 shows the two information objects a researcher documents: (1) a 'project' describes what the researcher wants to do without specifying a station. Following the creation of a project, (2) researchers create 'visits' that specify the station and the equipment or space that they need for that visit. Projects can have visits to multiple stations. RAMS requires standard fields for all projects, but the visit form has some room for station-specific questions. For instance, some stations want to know if researchers are willing to do outreach while they are at the station, or some stations have permit-specific questions to make sure visiting researchers are aware of location-specific, legal regulations. Once the visit is submitted, it is reviewed and approved by the requested station. Each station has its own approach and criteria for review. If the visit is approved, the researchers' amenities are secured, and the next step is for the researcher to visit the station and conduct the work.

RAMS, while a step towards stabilizing bespoke infrastructure, still faces challenges in connecting downstream products back to the station or connecting researchers working at the same station to one another. RAMS projects and the associated visits remain 'dark' (Chapter 4) and are not findable by others interested in work happening at the station. The information for projects and visits is only visible to those denoted as staff for the station. Finally, this system stops at the point of access and does not have machine-actionable ways to connect to downstream research outputs, even if the researcher was inclined to do so.

4.1.2 Researcher Collection and Analysis Infrastructure

The application system sits outside of the researchers' practices, so it is just a gate to pass through. Researchers commonly start their data collection from the datasheets that they bring to the field. They collect their observations and samples along with associated metadata. Researchers move this information and material away from the places where it is collected through the cascade shown in Figure 2, a diagram derived from a scientist's depiction of the specimen metadata cascade (Meyer & Snyder, 2022).

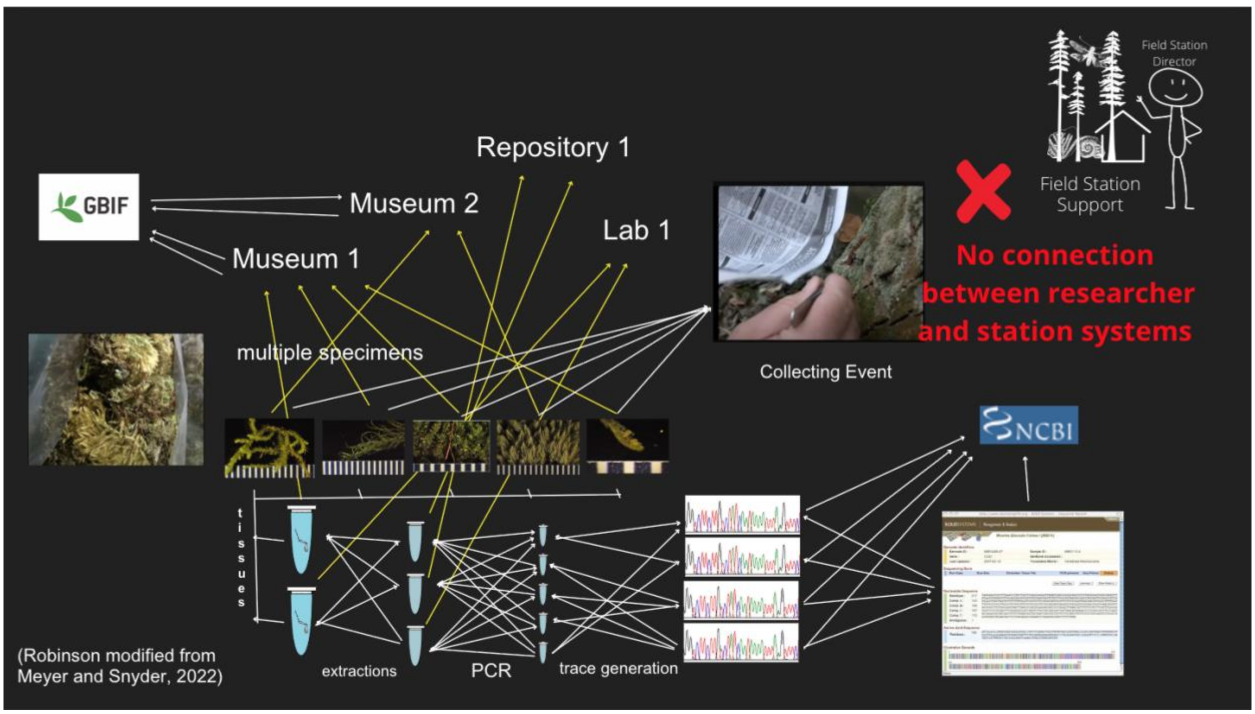

Figure 2. Specimen Metadata Cascade for a moss sample. The image was created by Robinson, derived from Meyer and Snyder (2022)

In Figure 2, the collecting event shows a hand with tweezers collecting the sample in the real world. The sample is then taken back to the station lab, where it is split into separate species. Those individual species in this example are run through scientific processes to extract and sequence the DNA from those samples. This analysis turns the physical material moss DNA samples into digital traces that are required to be archived at the National Center for Biotechnology Information (NCBI). The physical specimens themselves go to a variety of institutions, like museums and university laboratories. Some of those institutions also share metadata with environmental data clearinghouses, such as the Global Biodiversity Information Facility (GBIF).

Notable in this picture are the *missing* connections. Figure 2 has no connection to the field station, to RAMS, or any ethical or legal metadata that would document legitimate, legal collection activities. Also notable is that all the arrows move away from the collecting event and do not connect back to the station or the local communities that steward the location. Without these connections, we are missing critical contextual information about the research.

4.2 Interventions for Implementing the FAIR Principles

As previously discussed, researchers are most willing to participate in field station infrastructure when they need to gain access. At this point, field stations have the power to approve or deny access. The field station access process provides a window for infrastructure interventions controlled by stations (Robinson and Palen, in review). For this reason, Nic and I chose to focus on this point in the research project progression. We intentionally chose to use the global research infrastructure (GRI), persistent identifiers, and existing standards over building another separate, bespoke system, so that the field stations and the connections to projects they support would be established in the digital scientific record. The following summary table is provided as a reference to articulate the identified objectives for each intervention, the questions we asked of that objective, the intervention approaches we applied, and the section where these matters are described.

Objective	**Questions**	**Intervention Approach**	**Section**
Field stations need to be identifiable and findable by the digital scientific enterprise	How are stations digitally registered in the GRI? What identifier is appropriate for field stations?	DOI or ROR* Future work is needed to add facility subtypes	4.2.1
Research objects from field station-supported work need to be findable and	What does it mean to register field station research objects with a DOI?	Data (Research Output) Management Plan or Project Metadata with DOI*	4.2.2

identifiable by the digital scientific enterprise	How do you represent field station-supported work in the GRI?	and structured citation for the object.	
Field stations need to establish connection to the project and between the project, people, and organizations	How do you connect projects to the stations? How do you connect projects to people and organizations? How do we connect the project outputs to the project over time?	Structured DataCite metadata*	4.2.3
Projects need to be able to track evolving connections and impact across the GRI	How do we visualize project relationships? What are the results of the field station-supported projects? Who has cited this project?	DataCite Commons dashboard for research objects*	4.2.3
Field stations need to be able to show work happening at their stations	What projects are happening at the station? Who is working at the station?	DataCite Commons dashboard for organizations* In progress	4.2.4
Field stations need to show their impact by finding and connecting research outputs from station-supported projects	How do we automate finding and connecting downstream outputs?	In progress	4.2.4

Table 2. Summary of Interventions to Implement FAIR. Items with * were successful.

In the next sections, I describe the interventions we developed to connect stations, the projects they support, people, and other organizations to the digital scholarly record through the GRI.

4.2.1 Making Field Stations Visible in the Global Research Infrastructure

A pervasive challenge facing field stations is the inconsistent and variable names used throughout the GRI. Some researchers use the location name, but not the station name, and some acknowledge individual station staff. Sometimes, single stations change their names over time, which also makes finding field station contributions difficult because there are multiple names to search on. All these idiosyncrasies lead to difficulties uniquely identifying and finding field stations in the digital record, which results in incomplete representation of field station contributions (Robinson and Palen, in review). These name changes and inconsistencies are not unique to field stations. Persistent identifiers can be used to help address these challenges.

During 2017, the University of California Natural Reserve System (UCNRS) attempted to identify its 40 stations with DOIs[33]. This persistent identifier allowed for consolidating name variations of a single station. DOIs at the time were the only available working infrastructure that could be utilized for this experiment. The UCNRS classified field stations as 'collections' using the resourceTypeGeneral metadata element defined by DataCite[34] as: 'An aggregation of resources, which may encompass collections of one resourceType as well as those of mixed types. A collection is described as a group; its parts may also be separately described.' Using a term like collection, is an example of ways that existing infrastructure is reconfigured or stretched to accommodate a new use.

In retrospect, it became clear that DOIs are for research objects, and organizations are not really research objects. Organizations require a different standard form. The Research Organization Registry (ROR) was created to provide that form, so our first infrastructural intervention was to ensure that the Reef Station and the Atoll Station were included in the ROR registry[35]. This intervention makes these two stations findable and identifiable in the GRI.

Given the global nature of the ROR registry, we thought this registry might be a good way to find and maintain a list of field stations. We searched ROR for field stations using common field station labels and found three marine stations, four field stations, six marine laboratories, and 22 research stations, including the Reef Station. We found just 31 out of over 1,000 known field stations. This large difference is because of (1) non-standard names like center or ecostation, and (2) because many field stations do not yet have RORs.

ROR has a field to describe the type of organization, which could be used for this type of search. 'Facility' seems to be the most appropriate existing type, but it is very general. In future updates to ROR, it may be helpful to have subtypes of facilities to separate out 'field stations' from other types of facilities. This would enable using the ROR registry as a standard list of field stations.

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[33] https://ucnrs.org/research/research-resources/reserve-doi/
[34] https://datacite-metadata-schema.readthedocs.io/en/4.5/appendices/appendix-1/resourceTypeGeneral/#collection
[35] The scope for organizations eligible to have a ROR is still evolving. Both stations requested and received a ROR without issue. ROR does allow for parent-child relationships. However, university departments may not always be allowed depending on rules.

4.2.2 Registering Station Research Objects with DOIs

The scholarly record is based primarily on publications like journal articles, conference proceedings, or dissertations that emerge months to years after fieldwork is conducted, if at all. This lag means that the field station-supported scholarly record is potentially only partially visible and appears long after the work happens. However, field station-supported projects create many types of research objects prior to journal publications, which are not registered in the GRI, rendering them invisible.

The digitization of the scholarly record has led to the expansion of registering other types of research objects (e.g., datasets, software, physical samples) with persistent identifiers. The adoption of GRI also expanded the kinds of institutions that could register objects, allowing project traces to be visible earlier in the research progression. Together, these transformations made it possible for field stations to register research objects, i.e., become publishers. With the shift to consider field stations as publishers, we then considered what type of research objects might be published.

Field stations have the most power during the application process, and most field stations have an unpublished, but often digital record of research applications (Robinson and Palen, in review). Thus, this intervention focused on station-related research objects associated with the field station application. We explored registering two types of research objects, data management plans and projects, and evaluated each for use at field stations.

Nic's goal in this work was to connect downstream research outputs back to the station. Initially, our team thought that we would have all researchers applying to the station also create research output management (formerly data management) plans (DMPs). The DMP provides a mechanism for researchers to consider how they will manage their data ahead of time. It also sometimes identifies the planned data repository where datasets will be published and archived.

We tested the DMP approach with the Barcode Project by copying application information from RAMS into the DMPTool, a platform that creates DMPs with templates (Robinson et al., 2023). The DMPTool supports publishing the DMP with a landing page that has limited standard information and minting a DOI in DataCite. This intervention with the DMP showed the benefits of creating a citable research object for the field station-supported project. It also demonstrated the potential of shifting the first publication to earlier in the research process, not waiting for months to years.

During the evaluation of this approach, we found that DMPs required information already included in the RAMS application and three to five additional permit forms to work at the Reef Station and the Atoll Station. The burden of filling out repeated information was high. Further, DMPs are often required by funders at the time of proposal submission (National Science Foundation, n.d.). Some researchers already had a DMP, and we were asking for an additional DMP on top of any that existed. The field station DMP added redundancy to the researcher's workload, rather than streamlining the process, which was our goal.

During the evaluation of the DMP intervention, we observed that by the time researchers apply to access the field station, they have more clarity on the specificity of their projects. Hence, the project becomes the core research object. This observation was validated by prior ethnographic work (Chapter 4) as well. This motivated us to switch from registering DMPs as research objects to registering field station-supported projects. Because our DMP intervention used DataCite metadata, which is a general standard that supports both DMPs and projects as object types, the shift to registering projects only required the modification of two lines in the metadata (Figure 3). The ease of this modification highlights that the DataCite metadata record acts as a standard form type of boundary object (Star & Griesemer, 1989) for a diverse set of research objects, including DMPs and projects.

```
  "resourceType": "Data Management Plan",
  "resourceTypeGeneral": "OutputManagementPlan"
},
```

```
  "resourceType": "Project",
  "resourceTypeGeneral": "Other"
},
```

Figure 3. The left side shows the DataCite metadata of the DMP intervention. The right side shows the DataCite metadata change needed to describe the project intervention.

There are two metadata fields shown in Figure 3: resourceType is a free-text field, and resourceTypeGeneral is a controlled list. 'OutputManagementPlan' was part of the controlled list, but when we switched to 'Project', it was not yet in the controlled list. We used 'Other' and included 'Project' in the free text for resourceType. To test this intervention, we returned to the Barcode project and registered the project as a DOI. This DOI made the project itself a findable, identifiable resource. Our evaluation of the Barcode project DOI highlighted that prior to this formal research object, the project had been a missing type of node in our PIDGraph.

Like searching ROR to find other registered field stations, we searched DataCite for other institutions registering resourceType:Project and found that there were over 100,000 project metadata records (Habermann, 2023). This is a relatively small number of objects for DataCite, but it does represent an emerging community consensus around the approach of registering projects. Over the course of our intervention, DataCite evolved the possible resourceTypeGeneral from ‘Other’ seen in Figure 3 to ‘Project’ (DataCite Metadata Working Group, 2024). This addition recognizes the importance of ‘Project’ as a major type of research object in the digital scholarly record.

The project registration creates a digital object in the scholarly record representing work done at the station, similar to the practice of pre-registration in biomedical research (D. A. Moore, 2016; P. Simmons et al., 2021). Pre-registration has been adopted widely in clinical settings to overcome selective reporting bias. In the last decade, the rise in pre-registration is attributed to the direct personal benefits of getting credit for a fully planned study (P. Simmons et al., 2021). Beyond personal benefits essential for adoption, pre-registration has had the added benefit of increasing transparency and reducing selective-result publication (D. A. Moore, 2016; P. Simmons et al., 2021). For field station-supported projects, researchers already do this work to submit the application for access (i.e., the project description), so unlike our initial attempt with the DMP, it is not new or extra. Researchers have not gotten credit for this application work, so the citable project research object may be appealing as an early publication. Also, like pre-registration, extending this practice to field stations by registering field station-supported projects establishes a findable record, whether the work is ultimately published.

4.2.3 Documenting Relationships between Field Stations and Research Objects

Returning to the UCNRS DOIs minted to identify field stations, we retrospectively examined their use. Searching Google Scholar for these DOIs, we found that of the 40 stations, 8 DOIs have never been included in text indexed by Google Scholar, and 20 DOIs have between one and ten results. These results, however, are only included in the text and not in the structured metadata associated with the journal article. Without this metadata, persistent identifiers are useful as search terms, but there are no underlying connections between resources, people, and organizations. Using persistent identifiers in this way is a step toward moving from the name, an unstable, boundary negotiating artifact (C. P. Lee, 2007), toward a boundary object (Star & Griesemer, 1989). The surrounding infrastructure is still unstable, though, because there is no method standardization on where the identifier should be included in structured metadata. Further, in the traditional publishing scenario, field stations do not have control over adding the station identifiers to journal article research objects. This means they may be included in a variety of locations in the article or left out.

Bringing the first two interventions together, we began to document relationships to the project through the structured DataCite metadata. We designed and tested this intervention by updating the project metadata for the Barcode Project at the Reef Station. In this intervention, we developed an approach for connecting field stations to the standard metadata for projects, using the contributorType:Sponsor, as shown in Figure 3 (Robinson et al., 2023). We chose the field ‘sponsor’ for the field stations’ role because the usage includes in-kind support through the use of a facility.

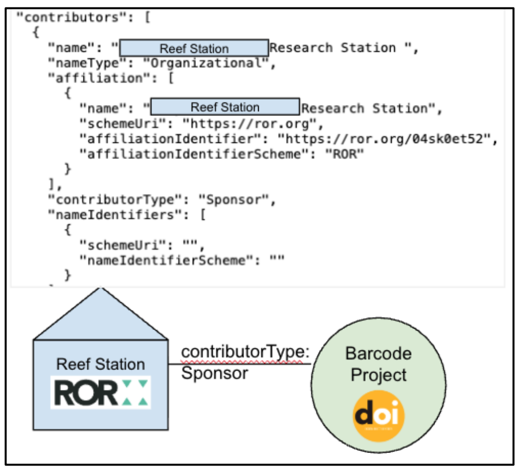
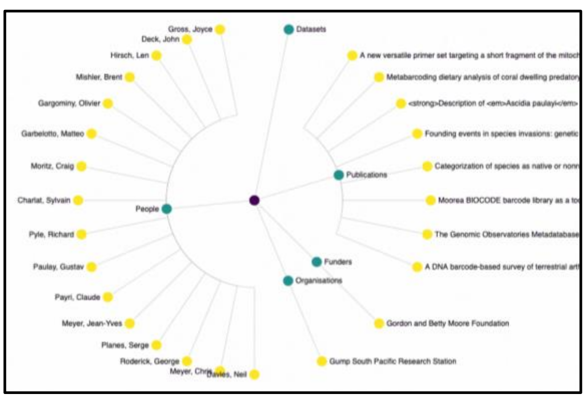


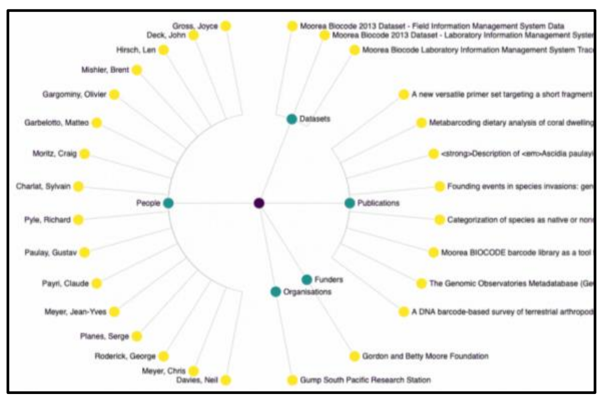
Figure 4. Structured DataCite metadata for including field stations as a contributor in field station-supported projects. Diagram of the relationship between the project and the station.

Figure 4 shows one connection in the graph enabled by PIDs, the PID Graph (Cousijn, Braukmann, Fenner, Ferguson, Horik, et al., 2021). The PID Graph assumes that each PID is a node. In addition to connecting the field station to the project metadata, projects are also connected to the people and to the funders through persistent identifiers and displayed as a PID Graph in Figure 5, which is the graph at the time of project initiation.

Figure 5. Project PID Graph at time = 0. The purple dot is the project. Green dots are types of nodes (funder, people, organization, publications, and datasets). Yellow dots are specific instances for each of these groups (Robinson, 2021; Robinson et al., 2023).

Choosing a retrospective project allowed us to link existing works to the Barcode Project through relatedIdentifiers in the metadata record. The three images in Figures 5 through 7 simulate the initial record and the addition of research outputs over time, adding parts to the project (Robinson, 2021; Robinson et al., 2023).





Figures 6 and 7. PID Graph at two later times when research outputs are added to the Project metadata record. The purple dot is the project. Green dots are types of nodes (funder, people, organization, publications, and datasets). Yellow dots are specific instances for each of these groups. Figure 6 shows research papers, and Figure 7 shows datasets being added (Robinson, 2021; Robinson et al., 2023).

For this demonstration, I updated the project metadata to create the connections, but in the wild, this could happen from the other direction. A journal article or dataset that is part of the project could cite the project, and this would also form the graphs shown in Figures 6 and 7.

The relationship between the project and related research objects is described by the metadata element ‘relationType’. In Figures 6 and 7, we only included the works produced by the project. These works have a relationType ‘isPartOf’. Since the Barcode project ended in 2010, enough time has passed that there are works external to the project, which referenced the Barcode project by citing one of these project-produced works. We connected these external works with the relationType ‘isCitedBy’.

Utilizing standard shared infrastructure and building on the GRI enabled us to benefit from shared tools. DataCite Commons, at the time of publication, is the only tool that displays most of the PID metadata and displays the relationships between the registries of research objects, people, and organizations across the GRI. Figure 8 shows the DataCite Commons view for the Barcode Project.

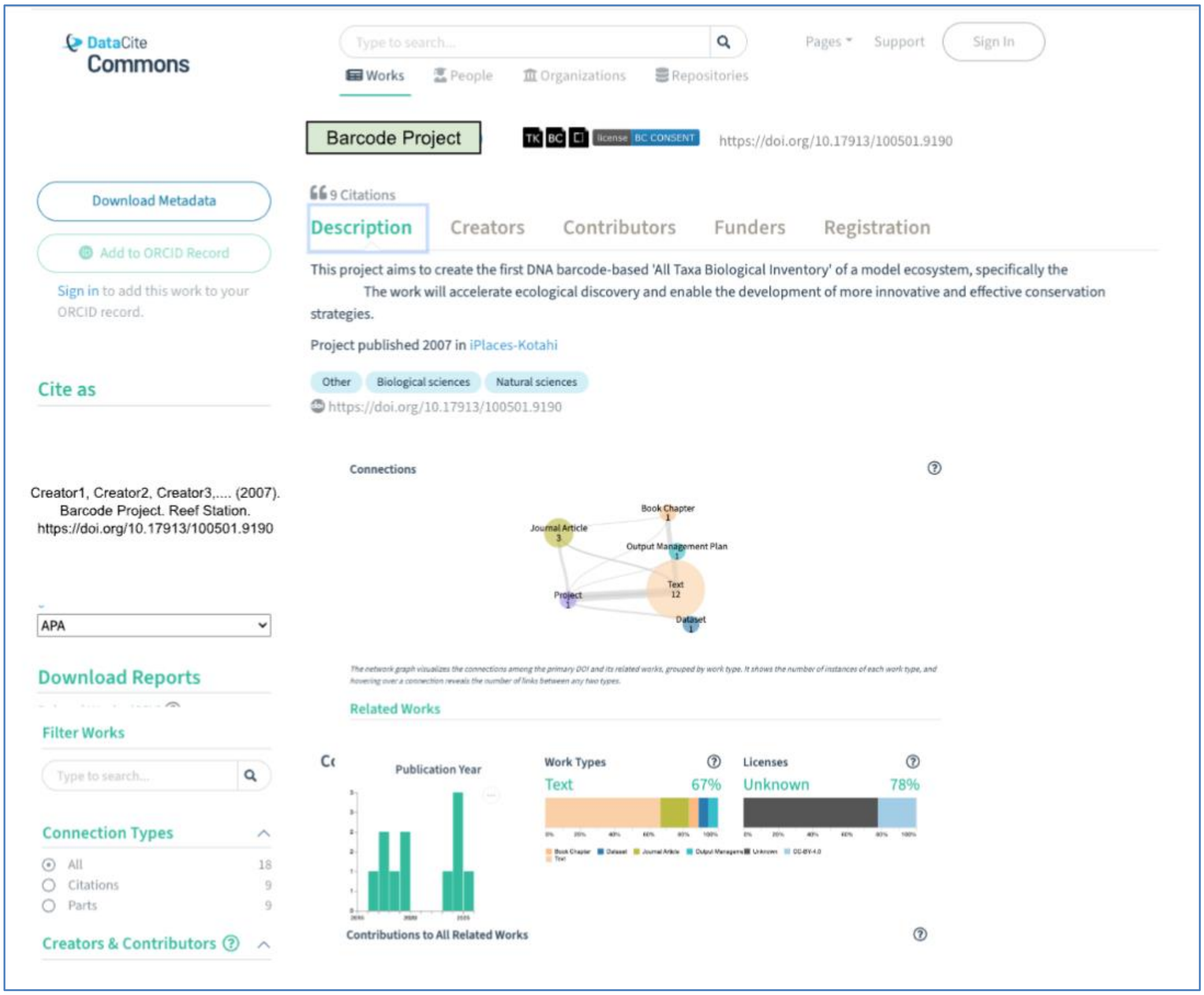


Figure 8. DataCite Commons DOI page for the Barcode Project[36]. The left sidebar indicates facets that related works for a project can be filtered on. The network map shows the connections between different types of objects. The histogram shows publication counts over time. The two stacked bar charts show the percentage of work types and licenses, respectively.

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36 Interface screenshots throughout this chapter are reproduced for illustrative purposes from publicly accessible services (e.g., DataCite, DataCite Commons, Local Contexts). Identifying details in figures are masked to preserve anonymization consistent with IRB approval. No proprietary or confidential materials are shown.

DataCite Commons displays the description of the object and features tabs to the right of the description label for creators, contributors, funders, and registration, providing links between these different types of relationships and the project. 'Cite as' on the left sidebar shows the appropriate citation for the object. The two relationTypes are also distinguishable on the DataCite Commons page as 'Connection Types' on the bottom left of Figure 8. When one of the radio buttons is selected, only the chosen relationType links are displayed in the middle of Figure 8.

Through our evaluation of this intervention, we became very aware of the meaning encoded in the citation. Creators refer to the authors either as individuals or organizations listed in the citation. Note that contributors do not show up in the citation, so if the field station was listed only as a contributor, as described above in Figure 4, the only human-readable location where the field station would be visible is in the contributor tab in DataCite Commons. To make the station visible in the citation, we intervened to add the Reef Station as the publisher, included in the citation.

One benefit of our intervention is that DataCite Commons provides an easy way to understand the impact of a field station-supported project. As new objects cite this identifier, they add new nodes and edges to the PID graph. Future work is needed to articulate and visualize further the value of the additional, invisible metadata traveling with the research object.

4.2.4 Visualizing Field Station Connections

Following the interventions with a single project metadata record, we applied these interventions to a set of projects from the Atoll Station. I mapped the project application content to DataCite metadata and, with support from a developer, created about 100 project metadata records. A partial PID Graph is shown in Figure 9.

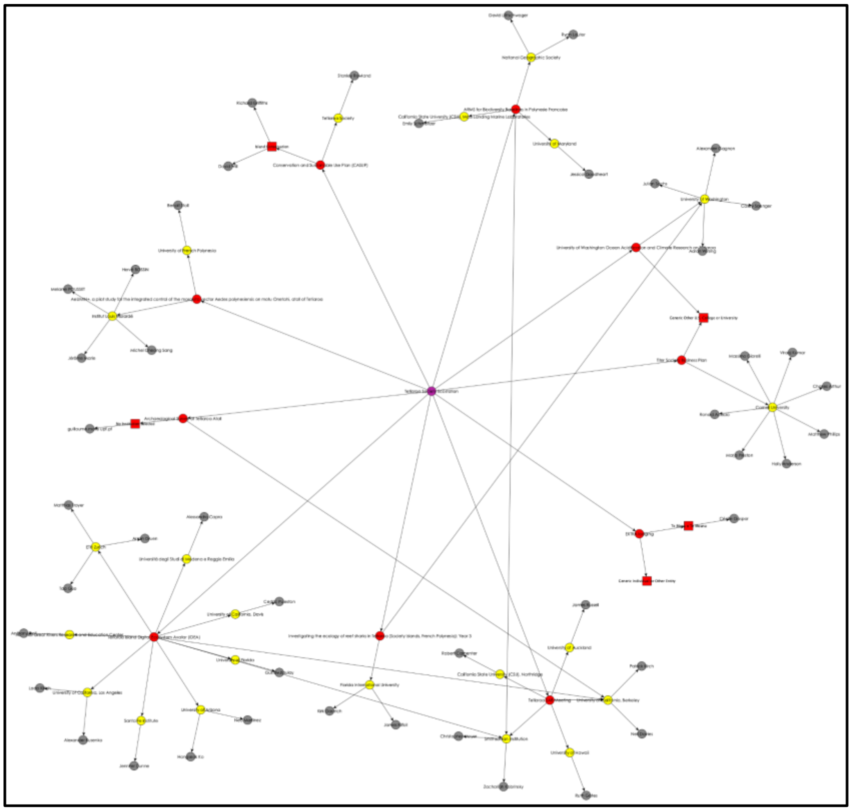

Figure 9. Partial PID Graph for the Atoll Station. Red dots are projects, yellow dots are organizations, and grey dots are people.

Like DOIs for research objects, there is a DataCite Commons interface for organizations with RORs, as shown in Figure 10.

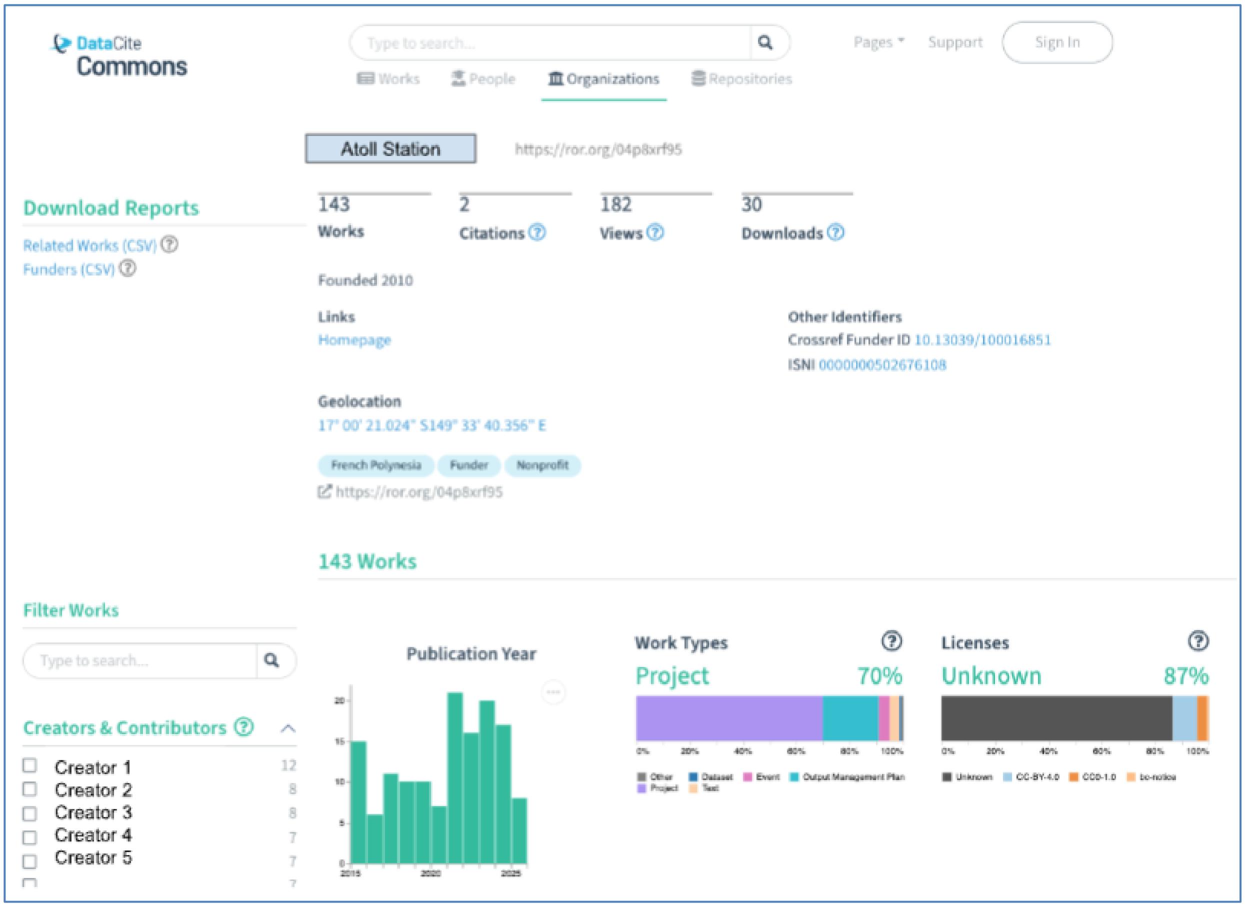

Figure 10. DataCite Commons organization page for the Atoll Station. The left sidebar has facets that can be used to view a subset of works. The right portion shows a dashboard of descriptive statistics about the works.

This organization dashboard, provided by DataCite Commons, shows all works connected to the Atoll Station's ROR. It allows field station directors and anyone interested in the Atoll Station's work to view projects and works connected to this organization. While we created 100 of the connections to the Atoll Station through the project metadata, 43 other research outputs have been connected to the Atoll Station organically since we started, because we had a publicly available ROR for the Atoll Station. The 'Work Types' bar chart shows that there are research output management plans, events, datasets, and other text that all include the Atoll Station's ROR in the structured metadata. This is an exciting, organic development. It shows the increasing addition of PIDs in research platforms and that researchers are taking advantage of this capability to add relationships.

Returning to Nic's initial challenge, which is to connect research objects to the station where they originated, this dashboard is a first step to doing this at the machine level. The dashboard shows all the projects at the station by year, along with other works that connect to the station. It also shows a list of creators. This is the first public view of the Atoll Station-supported work. With this public view, researchers can find complementary work and make connections to other researchers directly. The dashboard also shows a set of descriptive metrics: number of works, citations, views, and downloads. The metrics are low; two citations for the station is not impressive. It alludes to the ability to quantify the impact of a station through metrics, but it points to a way for organizations, like field stations, to more easily quantify their impacts. Future work is needed to interrogate these metrics to ensure they are aligned with the values we want the infrastructure and organization to move toward.

Through our evaluation of the project-level view and the station-level view, we identified a remaining challenge. In Figure 10, the station-level view only shows the connections directly to this ROR (i.e., Station <-> Project). As we showed above in Figures 6, 7, and 8, the projects have research objects connected to them (i.e., Project <-> Journal Article), but this is two steps from the station. Future work is needed to harvest research objects with certain relationTypes from field station-supported projects for a comprehensive station dashboard. This will ease the current efforts that station staff go through to find station-supported research objects by searching for the station name and derivatives like researcher names and place names.

These interventions showed the power of structured, standard metadata and documenting relationships with persistent identifiers. We digitally connected the station to the GRI with a ROR, established project metadata for field station-supported projects, and connected the projects to their related organizations, people, and other research objects. These connectivity interventions made the station and the project outputs FAIR. It provided researchers with a citable object for their work at the station, and it began to demonstrate the immense amount of research a single station supports. Thus, these interventions have primarily demonstrated an approach for implementing the FAIR principles for field stations, projects, and subsequent research outputs. In the next section, I turn to implementing the CARE principles through Local Contexts interventions.

4.3 Interventions for Implementing CARE Principles

As the FAIR principles gained traction across the scientific enterprise, a coalition of Indigenous data scholars raised concerns about machine-actionable FAIR data accelerating the reproduction of exploitation, knowledge extraction, and harm caused by dominant scientific practice. To counter these problematic practices, these scholars developed the CARE principles for Indigenous data governance, an acronym that stands for Collective benefit, Authority to control, Responsibility, and Ethics (Carroll et al., 2020). These principles complement the call for data to be FAIR and extend it by also considering the normative power imbalances in mainstream science (Carroll et al., 2020).

Initially, the CARE principles were limited to the protection of Indigenous peoples and their knowledge. More recently, they have extended to include other types of data, such as scientific data, and have been endorsed by other communities where the principles resonate (Carroll et al., 2021). The broad endorsement of the CARE principles by local and national governments, institutions such as the Smithsonian, and international bodies like the United Nations Educational, Scientific, and Cultural Organization (UNESCO) represents a shift in scientific culture toward accepting Indigenous data sovereignty and a more ethical approach to science. Yet, like with the FAIR principles, there is limited guidance or agreement on how to operationalize CARE principles in existing knowledge infrastructures.

Globally, the Indigenous Data Movement has organized around the CARE principles. These principles, like the FAIR principles, aim to suggest what should be done, but do not dictate how those goals should be accomplished. Local Contexts (LC)[37], digital infrastructure that allows Indigenous communities to reassert authority over Indigenous knowledge[38], is one of the few tools available to add structured Indigenous metadata to research objects.

To date, much of the work implementing CARE principles with LC has been done after the fact, adding Indigenous metadata to research objects as they are being archived (O'Brien et al., 2024). Following the advocacy of many researchers, there is a call to consider implementing CARE principles as part of ethical fieldwork prior to the start of data collection, instead of after the data have been taken

[37] https://localcontexts.org/
[38] I use the term Indigenous knowledge broadly. In this intervention, we consider all environmental scientific data to potentially be of interest to Indigenous communities.

(Carroll et al., 2021; Liggins et al., 2021). Field stations have a unique role in supporting this shift to implementing CARE pre-fieldwork.

Some field stations, like the Reef Station and the Atoll Station, have long-standing partnerships with local Indigenous communities. Over the last twenty years, the Reef Station and the Reef Cultural Association have collaborated to integrate traditional ecological knowledge (TEK) with scientific knowledge, communicating this to local communities around the Reef Station primarily through school events. The Barcode Project was an early example of this collaboration. They worked together to include Indigenous names along with Latin species names in the scientific metadata and developed educational and outreach activities to share their findings with local communities. This established rich connections between the Barcode Project researchers, the environment studied, and the local community.

The Barcode project was one success, but Indigenous communities are often only aware of a small fraction of the research happening in the places they steward. The ongoing partnership between the Reef Station and the Reef Cultural Association allowed Nic and me to explore the affordances Local Contexts' infrastructure provided to make the field station-supported projects and their downstream outputs visible and actionable to the local Indigenous community. A summary of these interventions is in Table 3 and depicted in Figure 11.

Objective	**Questions**	**Intervention Approach**	**Section and Figure 11 Location**
Field stations are open to collaborate and are findable by Indigenous communities	How do scientific institutions convey a willingness to collaborate with Indigenous communities?	Register the field station as a scientific institution in Local Contexts *	(4.3.1) (1a)
Indigenous communities are findable by scientific institutions and open to collaboration	How are Indigenous communities identifiable to scientific institutions?	Register the Reef Cultural Association as an Indigenous community with Local Contexts*	(4.3.1) (1b)
Field stations share scientific project applications with Indigenous communities	How do field stations notify Indigenous communities about scientific projects?	Create a project in Local Contexts and add Notices to the project*	(4.3.2) (2, 3a, 3b)

Communities need awareness and sovereignty over the scientific work happening	How do Indigenous communities provide review and express consent?	Local Communities provide review and apply Labels to field station-supported projects*	(4.3.2) (4a, 4b)
Projects need multiple types of review for field station-supported projects	What other types of review are necessary to articulate?	Future work: Consider additional legal and social reviews and input for station-supported projects	(4.3.2)
Projects need to maintain the connections to the communities as metadata travels across systems	How is the Local Contexts metadata connected to the GRI?	Add Local Contexts metadata to Project DataCite metadata and custom fields in downstream systems*	(4.3.3) (5)

Table 3. Summary of Interventions to Implement CARE

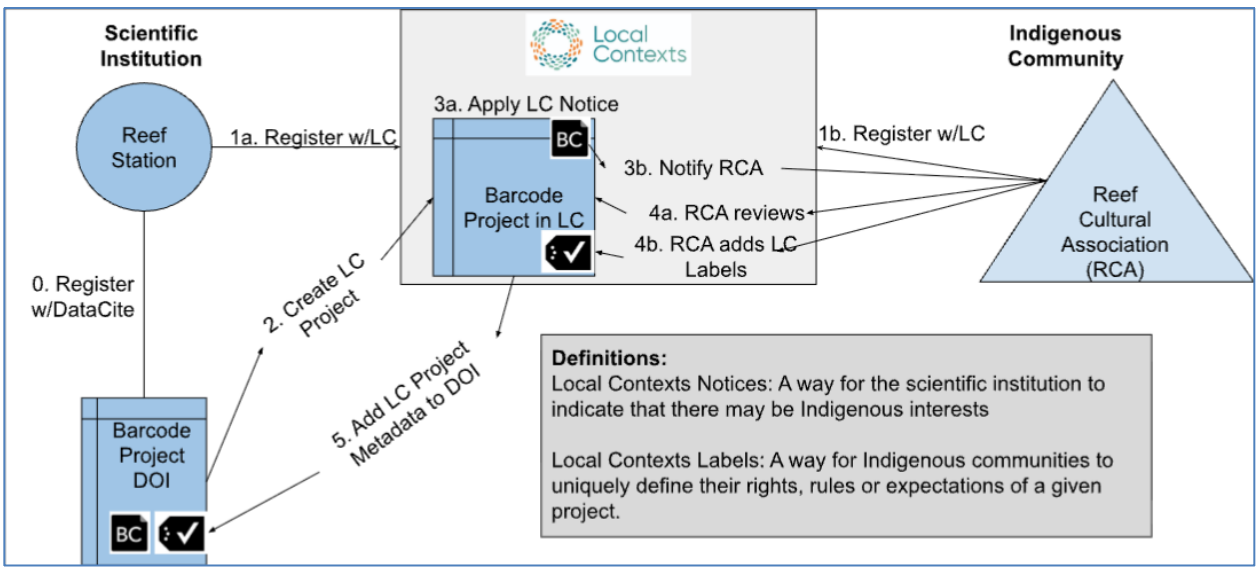

Figure 11. Local Contexts Interventions diagram.

4.3.1 Registering Field Stations and Indigenous Communities with Local Contexts

Local Contexts' infrastructure acts as a connection point between field stations as scientific institutions, and Indigenous communities. The first step to implementing CARE through the LC system was for the Reef Station and the Reef Cultural Association to both register[39]. Nic submitted a letter on

[39] All Local Contexts activities described in section 4.3 were done by the authorized Reef Station and Reef Cultural Association representatives. My role was facilitation, user support, and documentation of the process

official letterhead stating that they were authorized to establish a scientific institution in LC. Joining the LC registry is the first step for a scientific institution to make it known that they are open to collaborating with Indigenous communities broadly. This may seem like a small step, but the intent is to signal new ways of working. The Notice in Figure 12. shows the text often added to websites for scientific institutions.

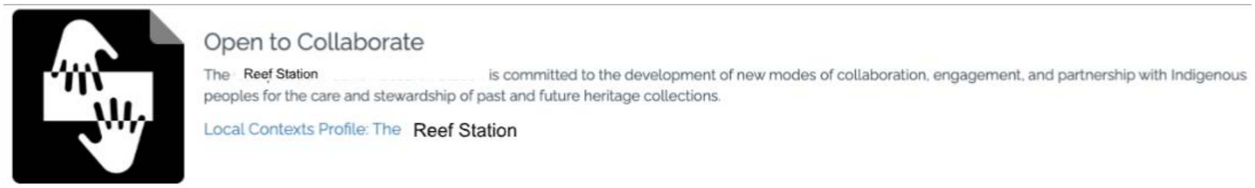

Figure 12. Open to Collaborate Notice on the Reef Station's website

The President of the Reef Cultural Association also submitted a letter on letterhead stating that they were authorized to establish an Indigenous community on behalf of the Reef Cultural Association. Joining the LC registry for Indigenous communities makes clear to participating scientific institutions that they want to express authority to control Indigenous data in the locations they steward. These two interventions are shown in Figure 11 as 1a and 1b.

In our intervention, I supported the Reef Station and the Reef Cultural Association joining LC. There was a lag between when the Reef Station was established and when the Reef Cultural Association was established. This meant that we had time to do preparatory work to use LC from the Reef Station side. When the Reef Cultural Association was established, it was possible to make machine-actionable connections between the Reef Cultural Association and the Reef Station through the project, described next.

4.3.2 Making the Connections between the Station and the Cultural Association Visible

Once registered, scientific institutions and communities can create projects in the LC system. For our interventions, we only made projects as a scientific institution. Those projects receive a universally unique identifier (UUID), a generic persistent identifier similar to a DOI. That project UUID can then have LC Notices or Labels associated with it. LC Notices indicate the project may have Indigenous interests. They are provided by scientific institutions. LC Labels are provided by specific Indigenous communities to indicate the rights, rules, or restrictions associated with the LC project.

Nic and I created the Barcode Project (step 2 in Figure 11) in LC to retrospectively add LC Notices and notify the Reef Cultural Association of this project (steps 3a and 3b in Figure 11). The LC Barcode Project and Notices are shown in Figure 13.

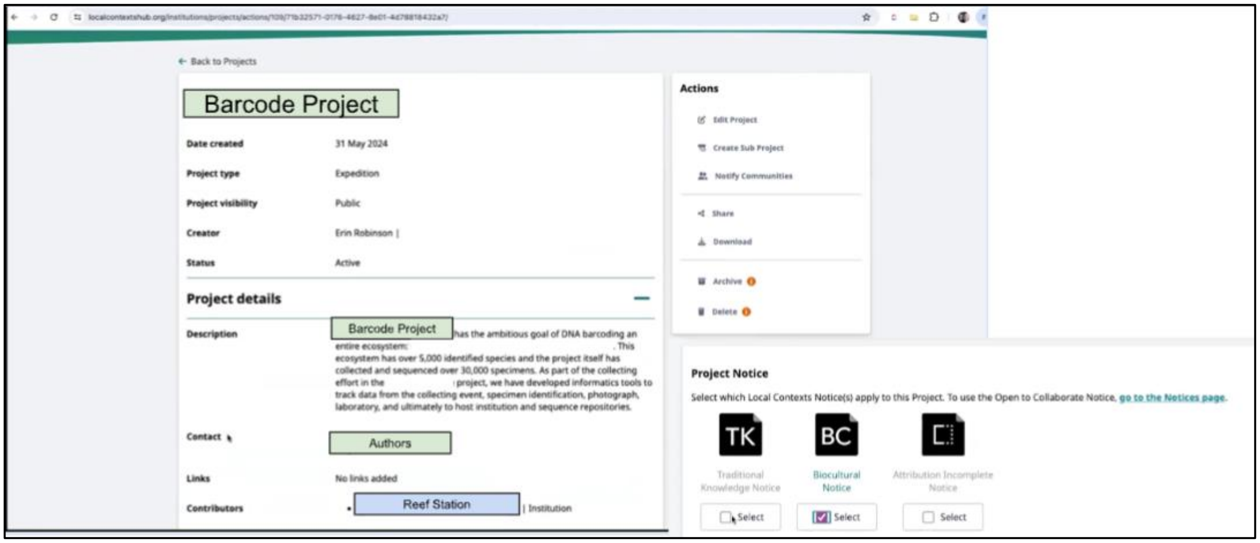

Figure 13. Screenshot of the Local Contexts Project Page and LC Notices for the Barcode Project

Figure 13 shows the three types of Notices that scientific institutions can apply as type-specific icons. These Notices are common across all institutions, and the text for the Notices is standard. The Notices indicate that there may be traditional knowledge (TK) or biocultural (BC) material, but it is not for the institution to determine if there is Indigenous knowledge or what the rights around that knowledge should be. Attribution Incomplete indicates that there may be additional information provided by the project.

While scientific institutions all share the same set of LC Notices, each community creates their own set of bespoke LC biocultural (BC) and traditional knowledge (TK) Labels that indicate community-specific permissions, rules, and expectations for the project and its resulting data. Often, the Prior Informed Consent Label is one of the first Labels for a community. LC has template text that communities can work with, but each Label is unique and has its own unique metadata.

The Reef Cultural Association established their first BC Label for Prior Informed Consent. They then reviewed the Barcode project in LC (step 4a in Figure 11) and added the Prior Informed Consent Label to the project (step 4b in Figure 11). Following our interventions with LC Notices and Labels, Nic is considering adding Notices to new projects applying to the Reef Station. Part of the researcher's agreement with the station will be to allow the station to establish prior informed consent. This approach would utilize the LC infrastructure for a cultural review of the project applications, along with the station review.

During the iterative implementation and evaluation of these interventions, questions and concerns arose from both the Reef Station and the Reef Cultural Association. This intervention highlighted the ambiguity that exists in the current practice: Who is considered to be a member of the community? Who should provide community review? It also raised questions about whether all projects need extensive community review, or, like Institutional Review Boards, can some projects be expedited? Prior to LC, it was not always possible for researchers to know what the approach to gain review and consent was. Therefore, this is a step towards making expectations explicit.

Another set of questions centered on changes in both researcher and community expectations. The Reef Station wanted to know 'what if the Labels change from when the fieldwork was done, and that makes the researcher seem out of compliance?' Similar to the ways researchers worried about Labels changing after they were applied, the community was concerned about how changes to the project might be communicated back, if at all. The Reef Cultural Association wanted to make sure that the prior informed consent Label wasn't seen as permission to do anything. In our discussions with the founder of LC, Jane Anderson, she observed that these questions and issues were not new. However, the value of the LC system is that it made them visible and provided an opportunity for discussion (J. Anderson, personal communication, August 2024).

The interactions with the LC infrastructure and the rich set of questions we still have yet to fully answer demonstrate the ways the existence of LC technology allowed for new types of reviews, changing the institutional structure and the individual's practice, known as 'structuration' (Orlikowski, 1992). With the implementation of this LC infrastructure between the Reef Station and the Reef Cultural Association, the researchers' conduct is being shaped in new ways that consider the ethical, social implications of their work. This exploration of infrastructure for a new type of project review led Nic to consider other possible types of review, such as legal review.

Establishing LC at the Reef Station and the Reef Cultural Association is an important step in postcolonial fieldwork. Community reviews prioritize multiple ways of knowing and provide an opportunity to shape the project before it starts. The possibility for the Reef Cultural Association to review the Reef Station-supported projects was a critical intervention that demonstrated a shift in power from only prioritizing scientific considerations towards an equal platform for the social considerations of a given community. Like registering structured metadata as the first publication close to fieldwork, including these additional perspectives in the review process early, is another shift. The community has agency to provide guidance about the project and is aware of it early in the project progression, instead of long after it happens, if ever. This new arrangement disrupts the colonial science pattern by asking for prior informed consent and establishing a connection between the Indigenous community and the project. In the next section, the interventions connect the LC infrastructure to the GRI.

4.3.3 Connecting Local Contexts Project Metadata to GRI and Traversing Systems

Prior to LC, project identifiers were changed when the project passed from the researcher to a management system. For instance, a researcher might use a field information management system (FIMS) to record metadata during fieldwork and then go back to their home institution and bring the specimen metadata into a laboratory information management system (LIMS), giving that same project a new identifier. This movement would break the connection between the multiple systems.

An important part of the LC infrastructure is that the LC metadata travels with the project to external systems. The LC project UUID and LC API provide a way to connect the LC metadata to the broader digital scientific enterprise. LC and DataCite collaborated to develop guidance on adding the LC UUID to DataCite metadata in the rights field. Adding this metadata to rights establishes a link between the project and the communities it is associated with, and rights are more commonly passed from system to system and not stripped. We added the LC metadata to our Barcode Project DataCite metadata record.

Displaying LC Notices and Labels is another important part of using this system. Figure 8, above, shows the DataCite Commons page with the three LC Notice icons.

We then experimented with interventions to “walk” the rights metadata from the project metadata record to downstream samples for the Barcode project hosted in a field information management system (Figure 14), and then to a broker, iSamples, that aggregates physical samples from many repositories. This showed how the project could propagate LC metadata as rights across these distributed systems. All of the systems that the rights propagate to are expected to display this information and link back to the

LC project page. Following the Reef Cultural Association's review, they added a Label to the Barcode Project. This LC update propagated to all external systems that call the LC API for the project UUID directly (Figure 14).

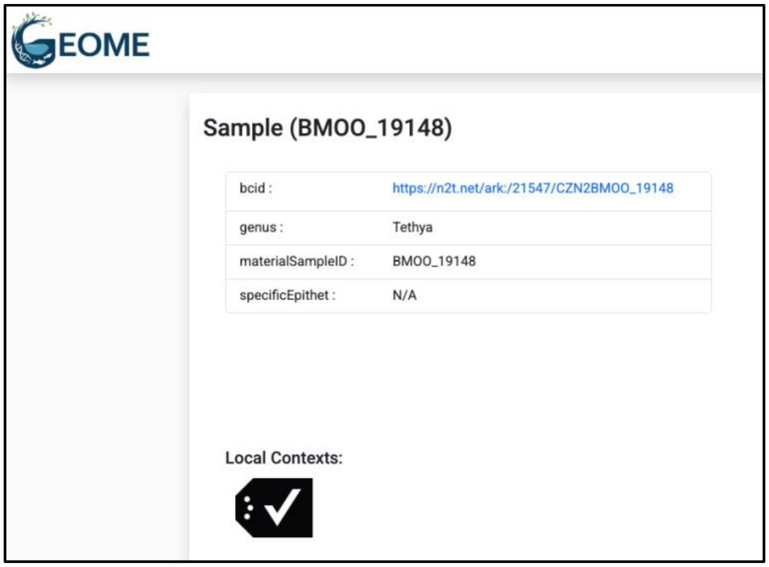

Figure 14. Example of a sample metadata record displaying the LC Label

These interventions taken together demonstrate an approach for implementing the CARE principles alongside the FAIR principles for place-based research. Nic and I have reflected on the problem of connecting research outputs over time. Ultimately, the goal of these interventions shifted from being solely for the benefit of the field station to seeing them as postcolonial moves to disrupt science as usual and empower the local communities from which this research is derived. They create pathways for the data to travel back to the places it originated from by bricolaging existing infrastructure in new ways.

5. Discussion

To begin the discussion, I return to the research question that frames this chapter: how might infrastructuring interventions transform the connections between field stations and the research projects they support, as well as connections across stations? My analysis suggests that using design ethnography and participatory infrastructuring, together, was effective for diagnosing the infrastructure problems and identifying points where field stations could make changes. With those points identified, Nic and I then experimented with different infrastructure solutions at their specific stations, accreting the parts that worked and discarding what did not work overtime, to develop new infrastructure. In the two pilot test cases with a single project, the Barcode project, and at the Atoll Station, this new infrastructure overcame the persistent challenge facing field station directors that despite being important for doing science, they were disconnected from the research trajectory and the broader scientific enterprise. This illuminated how a single station 'facilitate[s] a unique merger of natural capital, intellectual capital, social fabric, and infrastructure that leads to important scientific research required to understand our rapidly changing natural world' (National Research Council, 2014, p. 30). There is potential for other stations to follow our approach and with multiple stations together, realize the goal of connecting field stations as a global, neural network for science.

In the next three sections, first, I describe the implications of this research for infrastructuring, then I condense my analysis into a set of recommendations for other field stations, and finally, I consider the possibilities for field station collaboratories now that these digital connections to the scientific enterprise are real.

5.1 Implications for Infrastructuring

Drawing from the STS literature lent a vocabulary for describing and problematizing the infrastructural work at field stations reported in this chapter. When attended to, infrastructure was neither invisible nor static. Star and Ruhleder's famous question, "When is infrastructure?" emphasized the relational nature of infrastructure, which has proved essential for the station infrastructure interventions. They also alluded to infrastructure as a verb, *infrastructuring*, as a way to explore how infrastructure grows and evolves. Therefore, infrastructure can be seen as active, not static (Karasti & Baker, 2004; Karasti & Blomberg, 2018; Star & Bowker, 2002; Star & Ruhleder, 1996).

Often, I have found, infrastructuring is described in more abstract terms. I am left wondering what exactly the researchers did. I appreciate that every infrastructuring approach is situated, but each approach offers lessons that may be instructive for others. Practically, this chapter offers a more detailed accounting of participatory infrastructuring with the description of the interventions and the ways we implemented those tests. The two field stations in this chapter —the Reef and Atoll stations —and Nic, as a collaborator, provided an ideal research site for infrastructuring. Researchers and directors at field stations are already overburdened with paperwork and administrative tasks, so we could not directly infrastructure on their operational systems. Instead, first using the retrospective project, the Barcode project, I could take on the role of being the researcher and try the interventions. It was often here that we caught issues that would have frustrated a real researcher. Other scholars who are engaging in infrastructuring could take a similar approach, that is, using a past project and taking on a participant role to develop infrastructure.

The idea of infrastructure interventions is one mentioned in the literature (Ribes & Baker, 2007; Simonsen et al., 2020). The infrastructuring reported here was an open-ended process, making it difficult to recognize interventions when they were happening. Without recognizing interventions, I struggled to know exactly where to turn my ethnographic gaze. Through this research, I now listen for when Nic or other collaborators suggest a way to explore an infrastructure idea. Moving forward, I will mark this for future work and start taking more detailed ethnographic fieldnotes that I can come back to during analysis. I expect this approach to infrastructuring, and design ethnography will illuminate the tacit aspects of infrastructure or the ways researchers and field stations work that are taken for granted. I also found having the broader field station ethnographic work complemented the design work; it allowed for deepening my understanding of the challenges and possibilities to transfer intervention ideas to other stations. These two parts provided what Simonsen, and colleagues describe as a key feature of infrastructuring through infrastructure inversions: the process of interleaving empirical-ethnographic work with conceptual-design work (2020). Moving forward I will likely continue to find ways to broaden my ethnographic practice to include multiple sites with similar infrastructure challenges to interleave with infrastructuring design activities.

Another implication of infrastructuring reported here are the results of the infrastructure interventions, or its impacts. The spectrum from boundary negotiating infrastructure to boundary infrastructure provides a conceptual framework to consider interventions. I placed our interventions on this spectrum from *no standard methods or processes creating unstable infrastructure* to *standard processes creating stable infrastructure*. This spectrum is one of many that could be used. For instance, Strauss introduced spectrums of *simple to complex* and *routine to non-routine* to understand different types of projects (1988). These may also be useful for considering interventions more generally. Regardless of the dimension, each infrastructure intervention is applying a new force; having frameworks like these allow for analyzing the changes the infrastructure causes.

Infrastructure studies has long understood the politics of infrastructure. This research contributes to the body of work that is infrastructuring for justice (Costanza-Chock, 2020; Harrington et al., 2019). I argue that the research presented in this chapter has brought second-wave HCI together with fourth-wave HCI, meaning that I intentionally brought infrastructure and design justice together. I realized through our infrastructuring interventions that we were able to redistribute power from researchers to field stations and the local communities of which they are part. This redistribution occurs through stations and communities reviewing the research request and then providing consent before work is ever done. This may seem simple, but this redistribution moves from researchers having power over the station and community towards sharing power between stations, researchers, and local communities, which can be considered power *with*. Power with, gives way to power *to* do things like collaboratively design research with the community or to consider community needs for research. Hence, future infrastructuring research should consider the design justice movement to build infrastructure that intentionally disrupts harmful patterns.

5.2 Recommendations for Field Stations

Based on the interventions described in my analysis, I developed a set of recommendations for other field stations interested in following the successful parts of our approach, called the FAIR/CARE Toolkit (referred to as Toolkit)[40]. The successful interventions stabilize a field station's boundary negotiating infrastructure by utilizing the GRI boundary infrastructure. They illuminate formerly dark projects (Chapter 2) at the field station by registering them with a DOI, and in doing so, they provide a mechanism to connect downstream research back to the field stations through the existing global research infrastructure. Finally, they move toward more ethical fieldwork by indicating that the station is open to collaborating with Indigenous communities and using the Local Contexts' infrastructure for review before fieldwork commences.

[40] https://doi.org/10.17913/FAIRCARESTATIONTOOLKIT

The Toolkit consolidates these interventions with instructions to be transferable but still respects the situated contexts of other field stations. At a high level, the toolkit identifies three recommendations for field stations to consider: (1) Connect to the GRI with an ROR (4.2.1), (2) share researcher project applications with a DOI (4.2.2, 4.2.3), and (3) join Local Contexts as a scientific institution (4.3.1). These three recommendations are broken into a series of seven 'how-to' pages that guide a station through the steps needed to achieve these recommendations (Figure 15).

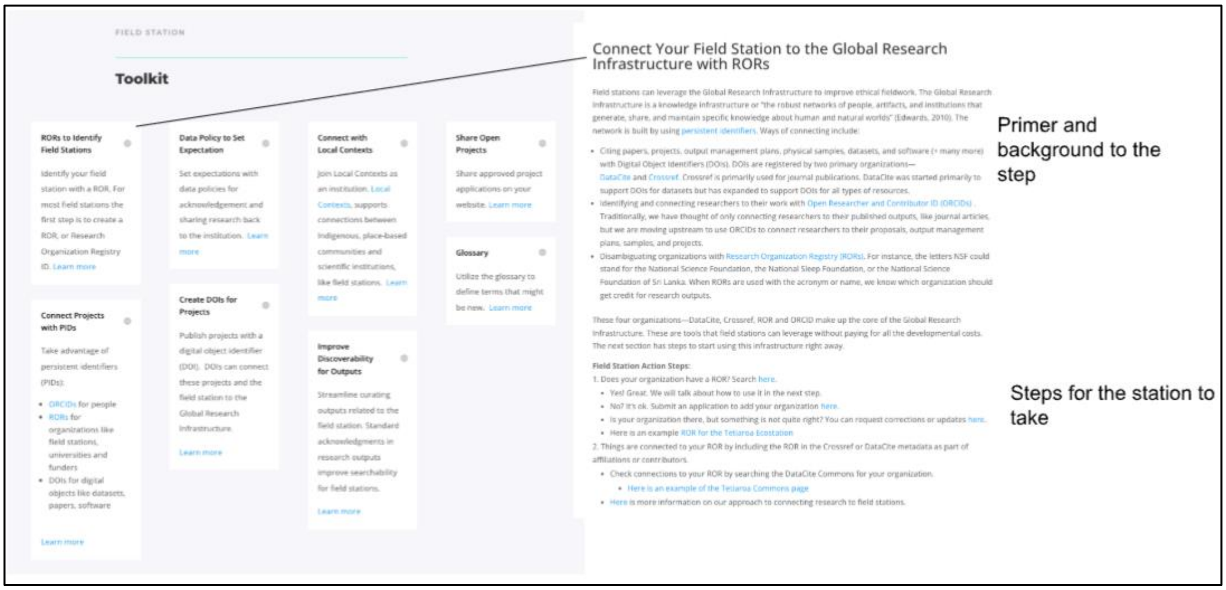

Figure 15. Field Station toolkit components and example page.

The Toolkit recommendations support methods standardization to move towards a boundary infrastructure (Star & Bowker, 2002). It provides a common approach to using shared infrastructure. By utilizing these recommendations, this approach aims to reduce the burden on field stations to each develop and sustain their own methods of finding and sharing field station-supported work. I am excited by the possibilities this shared, standard approach could provide for single stations and consortia of stations[41]. It will more easily make field station contributions visible for a single station's supported projects and in aggregate across these consortia. This approach takes tangible steps towards the ideas of field stations as model ecosystems.

While the Toolkit is a step forward, this approach still requires every field station to piece together existing boundary objects to build their own connections to the GRI boundary infrastructure and gain

[41] e.g., the Organization of Biological Field Stations or the World Association of Marine Laboratories

these benefits. Stations must each register with ROR, become DataCite members, find a way to register the field station-supported projects with a DOI, join Local Contexts, and manually transfer project information from DataCite to Local Contexts and back to display the Labels and Notices on field station-supported project landing pages. Future work could develop a platform to encompass many of these common functions, simplifying the work for all field stations and further stabilizing digital field station infrastructure. As described in the analysis, more work is still needed to understand the implications of these interventions as we continue to use them and expand the scope from a single project to a working field station, to a network of stations.

5.3 Steps Towards Field Station Collaboratories

Field stations have imagined the possibilities that digital representation would provide (Billick et al., 2011; National Research Council, 2014). Digital representation allows them to transform the collaborative support they provide in real life to the digital realm and become ‘laboratories without walls’ (Wulf, 1993). With the interventions we developed, we demonstrated the initial *field station collaboratory*, a collection of projects for a single station over time, researchers who worked at the station, and the connection between downstream products and the projects. This is a new way to provide digital access to the field station.

With digital access, generative artificial intelligence could consume this data for either benefit or harm. Field stations must be ready to combat synthetic environmental data and mis- and disinformation about the locations they steward. A digital field station collaboratory must be grounded with real-world stewards, such as field station directors. The station’s role in facilitating access, reviewing applications, and supporting researchers while they are at the station are all ways field stations can verify that the researchers did the work they are reporting on. The registered field station projects and connections to Indigenous metadata also provide a critical digital trace for researchers to prove that their research claims about this place were actually from said place.

Labs are places where power is reproduced. Field stations occupy a unique physical space in the real world, supporting a variety of researchers doing many different kinds of projects. The authors of ‘The Lab Book’ argue that ‘hybrid spaces’, such as field stations, offer an opportunity for institutional change and to reimagine new futures (Wershler et al., 2022). Field stations sit at the nexus of institutional change with the transformations of the Fourth Paradigm (Hey et al., 2009) and the move to a more just science. These transformations can either reproduce coloniality, making it easier than ever to exploit the biodiversity and the communities that steward these locations, or disrupt these same patterns with new types of postcolonial infrastructure, such as our interventions, which shift the authority to control these environments and the research done towards the community. Future work is needed to intentionally restructure the scientific enterprise in a just way. Speculative design and other types of futuring scenarios could be useful tools to identify the possible harm that field station collaboratories might cause and design mitigation strategies to avoid harm (Klassen & Fiesler, 2022).

6. Conclusion

The scientific enterprise is transforming, driven by data-intensive science, and calls for justice across domains. Further, the FAIR and CARE principles, widely promoted by funders and publishers as a set of values that researchers should adopt, have put pressure on both sides of researchers to change their practices. Yet, these principles provided no guidance on how to implement them. The GRI and new Indigenous infrastructure, like Local Contexts, provide the scientific enterprise with boundary infrastructure for implementing FAIR and CARE principles. Still, even with this infrastructure available, the actual steps to use it were unclear. Every researcher had to figure out how to bring these pieces of shared infrastructure together for their own practice, their teams, and their specific research domain.

Our interventions translated FAIR and CARE principles, values held by Nic and the researchers working at the station, into implementation with new types of metadata, persistent identifiers, and relationships between those things as interventions built with existing GRI and Indigenous infrastructure. Through these interventions, we demonstrate the possibilities of adequately representing field stations and the work they do in the scholarly record. As a further step towards standardizing this method to stabilize field station digital infrastructure, I also documented our successful pathways so that future field stations and researchers do not need to go through the long, often fuzzy path that Nic and I did.

When field stations and projects are adequately represented in the digital scholarly enterprise and connections to the projects they support and the valuable downstream outputs are made, both the place and the planet may benefit. The work presented in this chapter takes steps towards realizing the potential of field stations collectively as a global scientific asset by helping stations *digitally stand together*.

Chapter 5

1. A Review of the Dissertation Rationale

I opened this dissertation research with the question: *How could field stations, individually and collectively, address the problems that field station directors report of disconnection from the larger scientific enterprise?* As I come to the end of the dissertation, it seems, in one way, so strikingly obvious: we address challenges of disconnection by foregrounding the diverse array of field station-supported projects that stations facilitate.

Research projects *drive* scientific work. They provide the rationale for why a researcher and a field station are doing this cooperative work. Through this dissertation, I have shown how these projects evolve through highly situated work arrangements. For instance, the coordination needed to facilitate access to the station requires understanding projects specific facility needs, avoiding conflicts between them, and improving equipment to allow for more types of projects to be conducted. However, projects are not foregrounded in the scientific enterprise. Funding policies have placed value on tracking research outputs. Furthermore, most prior environmental cyberinfrastructure centered on environmental data, as the objects to attend, trace, and archive. This all means that grants and research outputs are perceived scientific capital. Thus, field stations have attempted to glean funding information and research outputs as indirect indicators of their own scientific status.

I argue in this dissertation that primarily valuing research outputs is a problematic approach to addressing stations' connection problems. These objects become public long after the work is completed and offer only a partial view of any given project. Because the project itself is dark, or only sensed indirectly through the production of other outputs, there are no standard connections between projects and upstream support, like stations or downstream outputs. Without standard representation, dark projects require 'boundary negotiating artifacts'—effortful, coordinating objects and work practices (C. P. Lee, 2007). The relationships made between projects, grants, and research outputs also did not follow agreed-upon approaches, creating *boundary negotiating infrastructure*. Specifically, field stations created bespoke infrastructure to negotiate across scientific discipline boundaries to bring research back to the station, and more recently to the local communities from which it is part.

In the next sections, I briefly summarize the dissertation, but this time by foregrounding projects. I then describe the contributions and future work that the dissertation makes to information science, scholarly communication, and environmental science. Finally, I conclude with hope for the impact the work that we—in the broadest sense including environmental researchers, field station directors, technologists, and social scientists—can have working together.

2. Field Station-Supported Research Projects Matter

This dissertation, at first glance, may have seemed to be about biological field stations, but through the execution, I found that my gaze needed to shift to *field station-supported research projects.* Every researcher coming to a field station has at least one project, but often they are bringing multiple projects to make the most of precious field time. Field station directors' and researchers' cooperative work centers around doing projects to produce research outputs. I showed in Chapter 2 that there are a variety of contexts that shape each of these projects, meaning that no two field station-supported projects are the same. As a result of examining field station-supported projects, I found that projects are often missing a corresponding digital object in the scholarly record—these I termed *dark projects*. Projects could be considered 'boundary negotiating artifacts,' artifacts or work arrangements required for cooperative work that lack an agreed-upon method (C. P. Lee, 2007). These projects are unstable and lack a standard method for digital representation.

Without a standard method for describing projects, there is no agreed-upon method to connect funders, scientific facilities (i.e., field stations), people, or their affiliated institutions. There is also no way to connect project-produced outputs. Thus, researchers have made these connections in non-standard ways, often in the acknowledgments of a journal article. The ripples of instability from projects as boundary negotiating artifacts have left field stations, funders, and research institutions all asking the same question: *How do I find the research outputs I (or my organization) supported?*

The answer to this question has, until recently, been through labor-intensive, bespoke ways. In Chapter 3, I dove into the specific role field stations have in facilitating projects. I found that field stations' evolution has been tightly coupled with the researchers they support. Like field station-supported projects, field stations have developed bespoke practices and infrastructures to do a set of common types of work. One of the specific bespoke approaches that I document is how field station directors cultivate a hub of research connections, which necessarily requires finding outputs. Through this analysis, I found that field stations also lack a standard method for digital representation. The lack of a standard digital representation for stations and projects led me to introduce the concept of *boundary negotiating infrastructure* to describe this accretion of boundary negotiating artifacts, which is unstable, fragile, and labor-intensive infrastructure that falls apart if it is not maintained.

The results of this boundary negotiating infrastructure are that every station had different, labor-intensive approaches to search for the station name(s), location names, or researcher names to try to identify work that was supported by their station. Field stations then often put links to these outputs into a bibliography, but as soon as they stop doing this work, the bibliography becomes out of date. In this example, we see that these artifacts are strung together into infrastructure. Everyone from the funder to the researcher to scientific facilities to journal publishers must independently figure out how to make connections to projects through proxies, like as the grant identifiers or a journal article meant to represent the project. Both of these proxies are insufficient and only a fragment of a project, and there are many parts of the project, like field stations or other scientific facilities, that are missing from these proxies. This human infrastructure is needed to create these connections, and means that it is nearly impossible to confederate or benefit from economies of scale with shared digital infrastructure.

To overcome this boundary negotiating infrastructure, this dissertation benefited from two fortunate coincidences. The first one was my dual position as a social scientist and data manager on an infrastructure project, FAIR Island. Edwards et al. advocate for social scientists to participate in research teams that include cyberinfrastructure developers and domain science experts (2007). This meant that we had key participants: the field station directors as the domain science experts, who grounded the development in real-world practice, cyberinfrastructure developers, and technologists, who had the tools and the ability to manipulate the technology to fit our needs, and me, a social scientist. I took a CSCW approach to understand the current field station practice and, with that understanding, translated needs into cyberinfrastructure requirements. Up to this point, field station solution teams mostly consisted of cyberinfrastructure developers and field station directors or staff. Without my CSCW approach, cyberinfrastructure developers had not studied the basis for the problems directors reported about feeling disconnected from the scientific enterprise, so they targeted data and journal articles, instead of projects. Yet standardizing projects is something stations can control, while the downstream data or journal articles are not elements that the station has control over. The second fortunate coincidence was that we overcame what Star and Ruhleder write about as the often-mismatched timing between the global and the local (1996). Our FAIR Island project identified project metadata as essential, just as the global research infrastructure began to allow projects to be recognized with a recognized digital object identifier. The addition of project as a recognized digital object identifier is one example of how this global infrastructure has been evolving for nearly two decades. I was fortunate to be poised to bring the global and local rhythms into alignment and take advantage of the addition of new types of persistent identifiers and new types of infrastructure that are just becoming operational.

With these two fortunate coincidences, I demonstrated in Chapter 4 a set of infrastructure interventions to give the field station a persistent identifier, Research Organization Registry ID (ROR, for short). The ROR transforms the station's internal application system into project metadata and registers that project with another persistent identifier, and then links these two identifiers together. This makes dark projects visible and connects the field station to the project in a standard method that has wide agreement across the scientific enterprise. Standard project metadata moves projects from a digital void where they could only be indirectly referenced to a digital object that can be directly referenced. This shift from indirect to direct standard reference, stabilized field station infrastructure, and moved it from boundary negotiating infrastructure to 'boundary infrastructure', a constellation of boundary objects connected via standard relationships (Bowker & Star, 1999).

In the way that the introduction of boundary negotiating artifacts clarified that everything is not a boundary object (C. P. Lee, 2007), boundary negotiating infrastructure provides a lens to view infrastructure as unstable or stable. This has proven immediately useful in how I understand other scientific infrastructure. It has become a tool to diagnose where interventions might be most effective. Further, the idea of infrastructure interventions has also proved immensely helpful. This idea of developing a small test to see how a particular system reacts and learn from that reaction moves away from monolithic cyberinfrastructure development toward an iterative accretion of infrastructure that works. The FAIR/CARE Toolkit is one outcome of that accretion, which provides a pathway from unstable current field station infrastructure towards stabilizing parts of the digital infrastructure. This was one practical outcome of my dissertation. I will elaborate in the next section on the additional dissertation contributions.

3. Dissertation Contributions and Future Work

This dissertation sits at the intersection of information science, environmental science, and scholarly communication. This dissertation benefits from them all, and it makes contributions to all three disciplines as well. Often, these disciplines sit in parallel tracks, each running into common challenges and not realizing there are solutions available to borrow from one of the others. This dissertation makes connections across the fields, drawing from CSCW perspectives to inform field station infrastructure and benefitting from scholarly communication solutions for field station-supported projects. Future work should continue to intentionally bring these three disciplines into conversation with each other.

For both information science and scholarly communication, this dissertation provides field stations and field station-supported projects as new research sites. Field stations are a microcosm of challenges that I have seen across institutions. They are scientific facilities, meaning they are science support institutions and often overlooked in scientific reporting (D'Ignazio & Klein, 2020). They often do not share the affiliation with the researchers that work there, so the researchers' affiliations in publications do not automatically connect research outputs back to the facility. This is a common challenge for both scientific facilities and funders. Field station directors have likened their facilities to what are known as 'model organisms' that are standards across the field of natural sciences (Billick et al., 2013; National Research Council, 2014), and in this way, the dissertation's deep dive into understanding field stations and field station-supported projects may provide the start of standardized approaches that are transferable to other research sites. Future work could either continue to deepen our understanding of field stations or could take these findings and approaches and apply them to other types of facilities and institutions.

For information science, this is a 2nd wave meets 4th wave dissertation (Bødker, 2006; Semaan et al., In Review). By that, I mean it drew from CSCW perspectives to understand the cooperative work field station directors and researchers required for projects. I then used a CSCW approach to translate that understanding into infrastructure interventions meant to make the work easier. With my field station director collaborator, we evaluated and iterated these approaches. Through this work, I contributed mid-range theories around *dark projects* and *boundary negotiating infrastructure* as ways to extend the CSCW perspective. However, these are not just second-wave theories. They incorporate chosen values and an orientation towards examining infrastructure and building infrastructure that intentionally counters the extractive, status quo of science.

Fourth wave HCI foregrounds justice. Throughout this work, I have brought a feminist lens to understand cooperative work practice and the invisible work required to do science. I have also explained where science-as-usual reproduces coloniality by stripping contexts away from the research, and how the interventions were intentionally designed to conduct postcolonial repair by adding connections back to the station and the local communities the stations are part of. Future work could formalize the FAIR/CARE Toolkit into a field station publishing platform and shift the power of publication from only the researchers to include the stations and communities. Further, scientific practice is changing at field stations as researchers work more closely with the local communities, particularly Indigenous communities. This is an exciting area of ethnographic and participatory action research.

The contributions to scholarly communication are practical. It provided an example of using the global research infrastructure more fully than has been previously done. With the extension of project metadata, creating RORs for field stations, and showing the power of related identifiers to connect research to projects, we have demonstrated seldom used but existing capabilities. This dissertation also offers an approach to translating principles like FAIR and CARE into practice. Boundary negotiating infrastructure again provides a lens to examine where the scholarly communication infrastructure is fragile or labor-intensive, and might that be an opportunity to consider how to shift towards stable, boundary infrastructure. A lot of what was demonstrated here requires significant human infrastructure or the people necessary to make the cyberinfrastructure work (C. P. Lee et al., 2006). Future work is required to smooth out those points. I am particularly curious about how these interventions work when a researcher cites their field station project in a publication. Future work is also encouraged to continue to incorporate the design ethnography approach of creating interventions and documenting the reaction. This documentation is often not reported, and this dissertation is one example of reporting on these incremental findings.

In environmental science, for both field station directors and researchers, this dissertation provides an approach to digitally connect field stations and projects to the scientific enterprise. This is an approach that does not put all the burden on field stations to change but instead offers ways that both stations and researchers can augment their existing practice. The dissertation begins to offer an approach for asking for consent ahead of fieldwork instead of researchers asking permission of the local community after materials are already taken. These are both infrastructure and practice that support the shifts I see in postcolonial fieldwork and disrupt what is known as ‘parachute science’ (de Vos, 2022). Further, this dissertation contributes to a way of making both researchers and field stations more resilient by ‘digitally standing together.’ Standing together through cooperative agreements and work allows for the diverse research projects at a single station to be visible and potentially enable new collaborations. Standing together across field stations allows for the global potential to be realized and to gain new scientific knowledge about our world.

Finally, this dissertation contributes language to describe the work stations and what researchers do. This is complex, invisible work that is often not acknowledged. Future work is needed to continue these interventions and support the slow organizational and infrastructural changes that are occurring. I am also excited for the potential opportunity of what field station collaboratories might offer this research community. I did not get there in this dissertation, but it does not feel far away now.

Many of these contributions and ideas for future work carry the techno-optimism tone that I have countered many times in the dissertation. I do not think that if we connect projects to field stations and their downstream outputs, that everything will be great. These decisions have consequences. What happens when we bring these diverse research projects together, and suddenly there is a wealth of visible place-based research. Separately, these data may have been benign to the local community or environment, but like others have shown, powerful and unexpected things occur when we bring together different types of information (Jackson et al., 2014; Zuboff, 1989). Future work should include speculative design to forecast and mitigate potential harms, and it should do it in the situated contexts of these field stations (Klassen & Fiesler, 2024; Puig de la Bellacasa, 2017). What does it mean for field stations to have a digital presence? Can a field station only be digital? Or how do field stations protect against the potential exploitations possible with powerful computing and the explosion of generative artificial intelligence? These questions are meant to provoke new research and to continue bringing the 2nd and 4th waves of CSCW together.

4. Looking Forward

In the last days of writing this dissertation on October 1, 2025, Dr. Jane Goodall died (Solarz, 2025). Among the many things that stand out about Goodall's work and her legacy, one that strikes me in the context of this dissertation is that she conducted the longest-running study of chimpanzees in the wild. I then started to wonder: did Jane work at a field station? Turns out the answer is yes! She built a field station, the Gombe Stream Research Centre, just five years after the start of her study in 1965, which turned 65 this year (Sylvie, 2025). It has facilitated science far beyond Goodall's own work. The data collected from this long-term chimp project and from the many other research projects the station has supported have well-documented benefits (Sylvie, 2025). However, looking at these lists of static publication tables, I speculate that even for the famous Goodall, it was tedious, if not difficult, for her team to find all the work made possible through this scientific facility.

The other part of Jane's legacy that strikes me is her activism. Through the work on this dissertation, my view of natural science has shifted from being what Haraway calls unsituated, or stripped of context and emotion, and it is moving towards this situatedness, which brings advocacy in as legitimate (Haraway, 1988). Jane's scientific work mingled with her deep care for the environments and the animals that she loved, and she took that to the world at a scale and with an energy that seems unfathomable for me now, much less me at 91. In the Netflix interview released after her death, she ended by saying: 'I want you to understand that we are part of the natural world. And even today, when the planet is dark, there still is hope. Don't lose hope' (*Watch Famous Last Words*, n.d.)

We are living through an 'era of transformation' (Johnson & Wilkinson, 2020, p. 374). In each location with a field station, the surrounding environment is changing at an ever-increasing pace, each in its own way. Fortunately, as I have described through this dissertation, there are also exciting opportunities for place-based scientific stewardship that can come from the boundary infrastructure interventions described here. These interventions allow us to form the 'we' that Johnson and Wilkinson reference at the end of the anthology, *All We Can Save*, when they are describing the choice of each word in the title:

> '"We" speaks to the collective, to collaboration, to community, to the relational work at hand. Addressing the climate crisis...will take everyone… "We" speaks to justice, to how we do the work that needs doing and whose contributions are valued. We cannot, we must not, go it alone…. We don't need to wait for new technologies or new practices; we just need to get to it'. (2020, pp. 371–372)

Connecting diverse research projects and their resulting products back to field stations is the 'work that needs doing', 'work that we can do', and that 'we just need to get to it' (Johnson & Wilkinson, 2020). It is one of the ways that we—researchers, field station directors, technologists, and social scientists—can support the communities we are part of to prepare for and mitigate the effects of these situated changes. Borrowing from environmentalist and scholar René Jules Dubos's famous phrase (1980), 'Think globally': Use standard infrastructure and common approaches. Do not go it alone. 'Act locally': Build relationships and work justly for our collective future, reorganize field stations. It takes them from standing apart to digitally standing together. This reorganization may finally provide the visible evidence of the global scientific assets and ripple to recognizing scientific support more broadly.

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Appendix A. Glossary of Acronyms

Acronym	Definition
BC	Biocultural. Used in Local Contexts Labels and Notices to indicate biocultural material.
CARE	Collective benefit, Authority to control, Responsibility, and Ethics. Principles for Indigenous Data Governance.
CI	Cyberinfrastructure. Defined by NSF as a “platform in service of research,” including high-performance computing, data management services, repositories, instruments, coordinating services, and the humans needed to sustain it.
CSCW	Computer Supported Cooperative Work. Field of study connected here to practice-centered computing.
DMP	Data Management Plan (also referred to as research output management plan in interventions).
DOI	Digital Object Identifier. Location-independent persistent identifier for research objects.
FAIR	Findable, Accessible, Interoperable, and Reusable. Principles for Scientific Data Management
FIMS	Field Information Management System. Initial digitization of datasheets used in field work to describe samples or observations.
GBIF	Global Biodiversity Information Facility. An environmental data clearinghouse where specimen occurrence metadata are shared.
GRI	Global Research Infrastructure. A collective term for the interconnected persistent identifier registries and their relationships.
HCI	Human–Computer Interaction
ICT	Information and Communication Technology. Encompasses computing and networking technologies
LC	Local Contexts. Digital infrastructure allowing Indigenous communities to exert authority over Indigenous knowledge.
LIMS	Laboratory Information Management System. Receives specimen metadata once material samples move into laboratory contexts.
LTER	Long-Term Ecological Research Network. Established by NSF in 1980 as a network of ecological monitoring projects.
NCBI	National Center for Biotechnology Information. Required archive for DNA sequence data.
NEON	National Ecological Observatory Network. U.S. ecological network using standardized sensors and methods across 81 sites.
NSF	National Science Foundation. U.S. federal funder establishing the LTER and NEON programs. An example funder that requires DMPs.
ORCiD	Open Researcher and Contributor ID. Persistent identifier for people (researchers).
PID	Persistent Identifier. A globally unique identifier (e.g., DOI, ORCID, ROR) that enables standardized, machine-actionable connections.
RAMS	Reservation Application Management System. Shared platform for field station project and visit applications.
ROR	Research Organization Registry.
RtD	Research through Design. Design practice used as a way to learn
STS	Science and Technology Studies.
TEK	Traditional Ecological Knowledge. Cultural knowledge documented by Indigenous communities.
TK	Traditional Knowledge. Referenced in Local Contexts Notices and Labels.
UCNRS	University of California Natural Reserve System. A network of 40 field stations in California

UNESCO	United Nations Educational, Scientific, and Cultural Organization.
URL	Universal Resource Locator.
UUID	Universally Unique Identifier.
WCS	Worm Community System. An early collaboratory platform for *C. elegans* research.

Appendix B. Interview Protocol and IRB Form

Semi Structured Interview Guide

This interview script will adapt to the individual/stakeholder I am interviewing. I also expect there to be necessary overlap among these categories. For example, a field station staff member is often also a practicing scientist as well.

Field Station Staff Interview Questionnaire:

General/introductory questions: *For the first part of the interview, I would like to ask you about the history of the field station.*

1. Could you please describe the history of science at the field station as you understand it?
2. What is the relationship between field station staff and visiting scientists with respect to data?

Site Access: *For this next set of questions, I am hoping to get a sense of what factors influence decisions about research team access used at the field station.*

1. Could you describe the system that research teams go through to gain access to the site?
2. What expectations does the site have for data sharing?
3. Is there a data policy?
4. How was this policy developed?
5. Are there tools or guidance to support research teams sharing data?

Data Collection, Analysis and Stewardship: *Next, I would like to get a better understanding of how data is collected and managed at the field station.*

1. Could you walk me through or describe some of the data collection activities?
2. Could you walk me through how data is analyzed after collection?
3. How is data collected managed after researchers leave the site?
4. How is the impact of the field station measured?

Closing:

1. Are there other topics that you think that we should discuss that I did not know to ask about?
2. Do you have recommendations about sources where I could learn more information about the field station data stewardship on my own?

Thank you for your time. May I follow up with additional clarification questions if I have any?

Visiting Scientist Interview Questionnaire:

General/introductory questions: *For the first part of the interview, I would like to ask you about the history of the field station.*

1. Could you please describe the history of science at the field station as you understand it?
2. What is the relationship between field station staff and visiting scientists with respect to data?

Site Access: *For this next set of questions, I am hoping to get a sense of what factors influence decisions about research team choice to access a field station.*

1. Why did your team choose to access this site?
2. Could you describe the process you go through to gain access to the field station?

Data Collection, Analysis and Stewardship: *Next, I would like to get a better understanding of how data is collected and managed at the field station.*

1. Could you walk me through the data activities from collection to publication?

2. How is data collected managed after you leave the site?
3. What are challenges to data sharing you experience?
4. What benefits have you experienced from sharing data?
5. How is the impact of research at the field station measured?

Closing:

1. Are there other topics that you think that we should discuss that I did not know to ask about?
2. Do you have recommendations about sources where I could learn more information about the field station data stewardship on my own?

Thank you for your time. May I follow up with additional clarification questions if I have any?

Interview Consent Form

Title of research study: Understanding Scientific Data Sharing and Coordination in Earth Science Collaboratories

IRB Protocol Number: 22-0128

Investigator: Erin Robinson

Purpose of the Study

The purpose of this study is to qualitatively examine how teams of Earth and environmental scientists collect, analyze and share their data to a larger consortium of international researchers with the hope of creating supportive and enabling “collaboratories” that will help support scientific pursuits.

Explanation of Procedures

This study will use open-ended interviews to understand how research teams collaborate with data at field stations. You are invited to participate in the open-ended interviews portion of the study. The focus of these interviews will be to ask about the history of the scientific infrastructure at the ecostation and/or scientific practice around data sharing past and present. Interviews will take approximately one hour and will be held via Zoom or onsite and recorded by Zoom, if the participant and PI are collocated. Interviews will be recorded and transcribed with participant consent. Data collected will be in the form of field notes and recordings. If a participant is identifiable in a photo or video, the PI will seek permission to include it in public-facing documents.

Voluntary Participation and Withdrawal

Whether or not you take part in this research is your choice. You can leave the research at any time with no penalty whatsoever.

Potential Benefits

There are no known direct benefits to individuals participating in the study. Findings may contribute to better data sharing, increased field station impact appreciation and a better understanding of the importance of data management for field stations.

Confidentiality

Information obtained about you for this study will be kept confidential to the extent allowed by law. Research information that identifies you may be shared with the University of Colorado Boulder Institutional Review Board (IRB) and others who are responsible for ensuring compliance with laws and regulations related to research, including people on behalf of the Office for Human Research Protections. Audio, video, photographic and textual data will be stored in password protected storage and kept while the researcher is analyzing the data and through publication and dissertation writing. It will then be deleted after those milestones are met.

Consent to Recording

The PI may ask your permission to record portions of the interview. Please initial your choice below:

___ I agree to allow photos, audio or video recording of the interview

___ I do not agree to allow recording of the interview.

Questions

If you have questions, concerns, or complaints, or think the research has hurt you, talk to the research team at erin.robinson-1@colorado.edu.
This research has been reviewed and approved by an IRB. You may talk to them at (303) 735-3702 or irbadmin@colorado.edu if:
Your questions, concerns, or complaints are not being answered by the research team.
You cannot reach the research team.
You want to talk to someone besides the research team.
You have questions about your rights as a research subject.
You want to get information or provide input about this research.

Signatures

Your signature documents your permission to take part in this research.

____
Signature of subject Date

____
Printed name of subject

____
Signature of person obtaining consent Date

____
Printed name of person obtaining consent