A Reflection: My Dual-Internship Capstone Experience

(Student Name)

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**Introduction**

This capstone internship was originally going to consist solely of an internship experience with The Nature Conservancy of Vermont. However, with the onset of COVID-19, three quarters of the internship with The Nature Conservancy could not be carried out, as these sections were designed to be in person or in the field. Fortunately, the remaining section of this internship could be carried out online, but The Nature Conservancy had only allocated 50 hours to be dedicated to this work. This left me 150 hours which I was fortunately able to pursue with Dr. Rachelle Gould, assisting her in her research. Generally speaking, my plan was to carry out a literature review for The Nature Conservancy focused on the impacts of beavers on Vermont’s landscape. I was to spend the remainder of my time doing qualitative analysis on Dr. Gould’s data which was to culminate in a creative project to help communicate our results.

Going into this internship experience, I had several goals for myself. I wanted to pursue a more involved and higher stakes experience of the scientific process that I haven’t followed previously. This is not to say that I feel my experiences in the classroom have not been valuable. Rather, this experience felt more valuable because my work was to be the basis of decisions made regarding management decisions in the state of Vermont (my work with The Nature Conservancy) and would contribute to genuine research operations within academia (my work with Dr. Gould). I also wanted to use this dual-internship experience as a trial run to help me determine which steps I might take to further my professional career. Specifically, is research something that I could foresee myself doing in the future? Or would I prefer working specifically in the field of conservation? Would I like to work in academia? Would I like to work for a nonprofit? Could I combine research interests and conservation interests? Next, I aspired to make some connections within the scientific community. I hoped to be exposed to new ways of thought or worldviews and ideally, create opportunities for the future through these connections.

On a more specific level, I hoped that my internship experience would help me pursue my newfound interest in water and fluvial dynamics. I have recently become more concerned about the state of our water in Vermont, but also more broadly at an international level. Having been schooled in climate science, I recognize that challenges surrounding water are likely to become more severe and difficult to manage. I hoped to harness this opportunity to learn more to become better prepared for the future as climate change ensues. Similarly, as it relates to my work with Dr. Gould, I hoped that I could use this internship experience to develop my skills in qualitative analysis. Up to this point, I have explored quantitative data fairly exclusively. As I have furthered my education, I realize that there is an entire arena of data and knowledge that I had not known existed. By learning qualitative skills, I am sure there would be much to be gained.

Finally, I hoped this internship experience would encourage me to become more assertive and confident in myself as a scientist. Looking back on this goal now, I didn’t realize just how important this goal was for me. I have been learning in my Research Methods class (ENVS 201) that an enormous part of doing research is simply being okay with not knowing the answers to questions. In fact, this is the point of pursuing research: to explore what we do not yet understand and to push the boundaries of human knowledge. Without a level of confidence at the outset, I assert that it would be immensely difficult to delve into research given uncertainty is inherent to the process. By encouraging myself to have a certain confidence in my abilities (but not beyond maintaining an open and receptive mind) and to be able to assert myself, I feel as if I set myself up well for entering these experiences.

Although I do not have a declared concentration, much of my coursework has been focused on ecology and wildlife studies. Specifically, I have taken Zoos, Exotics, and Endangered Species (ASCI 171), Ornithology (WFB 130), Principles of Wildlife Management (WFB 174), Conservation Biology (WFB 224), Ecology, Ecosystems, and the Environment (NR 103), and Sustainability Sciences (ENVS 188) to name a few. This dual-internship has been a culminating experience because it has delved deeply into both of these themes while simultaneously bringing new ways of thinking and new knowledge to the table.

The Nature Conservancy of Vermont had me look into beaver-based restoration. Beaver-based restoration is complex. Not only does one have to consider the behavior of the beavers, one must also place their behaviors within the context of the landscape, recognizing that each organism plays a role in said landscape within their specific niche. The dynamics are complex and can have cascading effects, some of which we may not understand or could not have anticipated. In this case, what would happen to the Vermont landscape if we actively supported/managed for the presence of beavers around the state? We anticipated there would be numerous consequences, both positive and negative, were beavers to be actively supported. To name a few, beavers would likely help flood water attenuation by reconnecting rivers to their floodplains. Beavers would also likely cause property damages through the felling of trees, and creation of dams and beaver ponds. Other changes are hard to identify as good or bad because it depends on the perspective with which one views the change. Simply put, we cannot manage for all species of wildlife at once. By supporting beavers on the landscape, it is conceivable that they could extend their range to account for a larger population. Importantly, beavers have been known to directly impact vegetation types and abundance present in their habitats (Little et al., 2012; Pollock et al., 2007). For some species, this change may be good, but for others, this could mean a loss of habitat, cover, or food.

My work under Dr. Gould is an area of study that I do not have much experience in yet, so it has challenged me to think about the world a bit differently. Namely, how do human relationships with the world impact how we treat the environment? What does this mean for society more broadly? This human dynamic is integral to environmental discourse, and I hope to highlight this dimension as I continue with my next steps in life.

**Background: Field of Study**

A large part of my internship was dedicated to understanding the relationships that exists between humans and nature, and to take this a step further, the impact this relationship has on human wellbeing. This is an incredibly interdisciplinary topic, drawing from fields including biology, sociology, psychology, and more. Importantly, our understanding of human and nature relationships is still developing, but our urgency to understand what lies at the core of this relationship has become more intense given climate change, land use change, and the rapid flow of humans into urban areas. According to Demographer Joel Cohen, since the 1820s, the percent of the human population living in cities has increased from a mere 2% to a whopping 50% (Lee et al., 2013, pp. 208). The concern is that access to nature can be minimal to nonexistent within cities, and we do not fully understand what the implications of this will be to human health (Williams, 2018).

During my internship with The Nature Conservancy, I was exposed to studying the dynamics between humans and the environment (including the wildlife that live on the landscape: in this case, beavers), but I was more focused on the ecological implications and dimensions. However, human values and perceptions of nature or wildlife are central to any conservation effort as well as to the field of conservation biology. Conservation biology is a well-established field focused on conserving life at multiple scales, from the landscape level through the ecosystem, community, species, population, and genetic levels (Cardinale et al., 2020). Conservation efforts do vary in their success because there are so many factors at play. However, multi-criteria decision making analysis is a powerful tool to help compare alternative management action plans while balancing stakeholder values. Our landscape is rapidly changing and degrading. However, with the right actions, efforts can help lead populations to long-term viability projections (Cardinale et al., 2020).

Central to the human and nature relationship is the idea of values. There are several value systems that dominate this dialogue. Firstly, humans value nature for its instrumental purposes. Specifically, humans are able to exploit the natural resources on our planet for their own benefit. This is referred to as direct use. We humans also benefit indirectly from ecosystem services provided by nature. One prime example is that wetlands provide flood water attenuation during storms, protecting human establishments from rising waters (Westbrook et al., 2020). This is an indirect use from which we benefit. Additionally, nature is valued instrumentally for (a) it’s option value: “assets that could be used in the future” (Cardinale et al., 2020, p. 119); and (b) for its non-use value: nature and its resources will be there to be utilized by future generations due to abstaining from overuse of those very resources in the present (Cardinale et al., 2020, p. 119).

Secondly, humans value nature intrinsically, meaning that nature is seen as valuable simply because it exists. Intrinsic valuation of nature can be broken down into three categories: moral, ethical, and religious. The moral valuation is based on the idea of right and wrong. For example, many people believe that nature and wildlife “have the right to exist” (Cardinale et al., 2020, p. 119) simply because that is what is right. The ethical valuation is established based on the social norms of a given place. These norms then influence how someone values nature. For example, many argue that wildlife should be protected and conserved because animals do not deserve to feel pain (Cardinale et al., 2020, p. 121).

I believe this sentiment is popular throughout much of the United States, and it is not a new idea. Since the early 1700s, “writers began to discuss animal feelings of pain and suffering…cruel treatment of animals raised and slaughtered for food, and the religious teachings that influenced humane treatment of both humans and animals. This emphasis on animals’ feelings of sensation in the early eighteenth century brought criticism of some forms of cruelty” (Guither, 1998, p. 1). Lastly, the religious valuation is based in a belief that higher powers have placed certain objectives on humans in terms of caring for wildlife, or similarly, that higher powers have placed valuations on wildlife.

Thirdly, and perhaps most central to what I studied, is that humans value nature because of the relational values that it provides (Chan et al., 2016) which is broken down into 5 categories: personal and cultural identity, social responsibility, history and education, biophilia, and aesthetic values (Cardinale et al., 2020, p. 119). Nature can be central to identity. Similarly, caring for nature (social responsibility) is often tightly woven into this identity and is informed by how ideas and teachings of nature are carried and passed down generationally (history and education). Still for others, the connection that life brings (biophilia) or the beauty inherent in nature (aesthetic) drive how people value nature (Cardinale et al., 2020, p. 119). More specifically to my studies under Dr. Gould, although applicable to conservation biology, is the concept of ecosystem services. Ecosystem services are “nature’s contributions to people” as articulated by Cardinale et al. (Cardinale et al., 2020, p. 143). The Millennium Ecosystem Assessment has broken down the multitude of what we have dubbed ecosystem services and categorized them into 4 main categories including supporting services, provisioning services, regulating services, and cultural services (Cardinale et al., 2020, p. 149). In our research, we were focused on the cultural ecosystem services which the Millennium Ecosystem Assessment identifies as “the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences” (Sarukhán & Whyte, 2005). These benefits are much more “intangible” than other benefits and are therefore much more difficult to measure (Milcu et al., 2013, p. 1). However, we wanted to know more about this process in Vermont as the concept of nonmaterial benefits is continuously developing. We went into this study open-minded, hoping to explore this topic in greater detail, and explore we did.

Dr. Gould has been integral developing knowledge around this ecosystem service, and I would argue that she is one of the key thinkers associated with the further development of the cultural ecosystem services framework. Of note, Dr. Gould and Noa Kekuewa Lincoln of the University of Hawai’i at Mānoa undertook a study of the “typologies” defining cultural ecosystem services arguing that the existing typologies were neither thorough nor updated enough (Gould & Lincoln, 2017, p. 117). Key to typologies are the ideas of how the nonmaterial benefits we as humans experience overlap, and the “relationships between services, benefits, and values” (Gould & Lincoln, 2017, p. 117).

Gould and Lincoln carried out 2 studies, both on Hawai’i Island. One study was carried out within an agricultural community while the other was carried out in the adjacent forest community. They surveyed each community (by carrying out semi-extensive to extensive interviews with individuals), probing them in regard to whether current typologies are sufficient and fully take into account individuals’ conceptions of cultural ecosystem services (Gould & Lincoln, 2017, p. 118). They then coded their qualitative data into themes and identified 3 new typologies that were expressed in both study groups. Gould and Lincoln coined these new typologies as (a) ingenuity; (b) life teaching; and (c) perspective (Gould & Lincoln, 2017, pp. 120-123). This new conceptualization of cultural ecosystem services is pivotal and played a significant role in the course of my internship, specifically in regard to this idea of perspective. Gould and Lincoln identify numerous occasions in which respondents voiced a sense of awareness for their place in the world due to their relationship with or experiences of nature (Gould & Lincoln, 2017, p. 122). Interestingly, many of the same components of perspective identified in this study were also quite apparent in Dr. Gould’s most recent survey, although they were carried out in distinctly different spatial locations, 3 years apart, with different sampling techniques, and on very different subsets of the greater population.

Central to my studies at The Nature Conservancy is the concept of stream evolution. Streams naturally proceed through a series of processes which result in changes to their shape, depth, surrounding vegetation, and flow velocity (Cluer & Thorne, 2014). There are many models that scientists in the realm of fluvial dynamics use to capture these processes. The first model pertains to morphological changes in stream structure. Essentially, stream shape can change horizontally through space as new channels develop and as stream banks erode away or build up through the deposition of sediments. Importantly, streams can also change morphologically in a vertical manner due to the erosion of stream bedrock and later deposition of said materials (Cluer & Thorne, 2014). Aggradation (the build-up of sediments) and degradation (the removal of sediments) continues in a dynamic fashion until the bed and the riverbank are stable (Cluer & Thorne, 2014). This process can be jump started again upon a weather or manmade disturbance.

This type of response is similar to responses inherent in terrestrial systems upon disturbance. The system responds successionally. There is some debate as to whether the system is headed towards a climax state or whether there even really is a climax state (Singer, 2016), but it remains clear that there is dynamism within systems in response to disturbance regimes.

The beaver (*Castor canadensis*) is integral in that it interferes within these fluvial systems, has marked impacts on the functioning of the system, and results in dynamic responses. Specifically, beavers are ecosystem engineers (Pollock et al., 2015). They specialize in building dams from woody debris and trees they fell. These dams significantly alter environmental conditions through retaining sediments, increasing water quality, impacting water temperature by altering river depth, by retaining nutrients, by decreasing contaminants downstream, and by decreasing stream flow velocity (Pollock et al., 2015, pp. 7-13). However, these dynamics are complex. We still do not fully understand how beavers impact these different realms, leaving many gaps in our knowledge. Researchers are now trying to fill in those gaps so we can develop a better understanding of the dynamics at play and the different mechanisms behind these dynamics.

Michael M. Pollock has been integral in this field, especially as it pertains to the impacts of beavers on fluvial dynamics and the process of stream evolution (National Oceanic and Atmospheric Administration, n.d.). Pollock is an environmental analyst who is passionate about reviewing and analyzing government policies, and how they impact the environment (National Oceanic and Atmospheric Administration, n.d.). He has helped establish our understanding of stream evolution beyond our linear conception into a circular and dynamic framework (Pollock et al., 2007).

**Sponsoring Organization**

The Nature Conservancy is a non-profit organization that works around the world, striving to protect lands and promote stewardship. The Nature Conservancy has its roots in ecology. In 1915, the Ecological Society of America was formed. At that point, the society was more dedicated to research than active management, but not everyone supported the purely research-based agenda (“Our History,” n.d.). In 1917, a committee branch of the Ecological Society of America formed. It was called The Committee on Preservation of Natural Areas for Ecological study, and it was headed by a man named Victor Shelford (“Our History,” n.d.). Notably, Victor Shelford studied at the University of Chicago where he undertook studies into why certain plants and organisms only appear in certain areas, continuing on to study succession. He published many important papers that were the basis for his work Animal Communities in Temperate America. Many assert that this publication catalyzed the naming of animal ecology as a field (Kendeigh, 1968, p. 99).

In 1945, the Ecological Society of America tried to denounce the Committee because the Society wanted to maintain its research focus, so Shelford and a group of colleagues responded by creating the Ecologists Union. Under the Ecologists Union, they carried out direct habitat management and conservation agendas as they felt was their responsibility as ecologists (Kendeigh, 1968, p. 100). It was in 1950 that the Ecologists was renamed as The Nature Conservancy and it was legally registered as a global non-profit (“Our History,” n.d.). The non-profit struggled in the beginning, with members using their own personal funds to help finance land acquisitions in the name of conservation. It wasn’t long before Americans began donating lands to the cause and the Conservancy began receiving monetary donations from prominent organizations including the Ford Foundation (“Our History,” n.d.). In the 1980s, efforts began to extend beyond lands in the United States via the International Conservation Program. Different management projects were soon being undertaken throughout the world, primarily in Central and South American, the Caribbean, and Malaysia (“Our History,” n.d.). Soon, The Nature Conservancy began engaging community members to participate in conservation.

Now, The Nature Conservancy is one of the most well-renowned conservation organizations in the world. The organization works tirelessly to maintain “a world where the diversity of life thrives, and people act to conserve nature for its own sake and its ability to fulfill our needs and enrich our lives” (“Explore TNC's Mission, Vision and Values,” n.d.). The Nature Conservancy is now able to take action at broad scales, engaging with people and landscapes all over the world. They have countless programs established to help carry out their goals, but they maintain a large focus in the areas of “tackl[ing] climate change, protect[ing] land and water, provid[ing] food and water sustainability, [and] build[ing] healthy cities” (“Our Priorities,” n.d.). The do this by using evidence-based science and technology, by working to drive policy changes, by working with companies to either change behavior or contribute to their mission, by investing in land and conservation projects, and by providing educational opportunities including their program “Nature Lab” (“How we Work,” n.d.).

The Nature Conservancy is a non-profit, so they receive their funds through donations, government grants, from investments, and from sales of lands (Allen, n.d.). They have a board of trustees that helps allocate funds to different parts of the world. They maintain a leadership board for the broader organization. The Nature Conservancy has state chapters which work at the state level to carry out the mission of the Nature Conservancy as a broader entity (Tercek, 2017). I worked remotely for the Vermont chapter whose headquarters are located in Montpelier, Vermont.

Additionally, I worked for the University of Vermont this summer. Not only was my internship with The Nature Conservancy sponsored by UVM, but I carried out research under the supervision of Dr. Rachelle Gould, an assistant professor in the Rubenstein School. The University of Vermont was founded in 1791, a process spearheaded by Ira Allen and paid for, in large part, by members of the surrounding Burlington Vermont community (“History and Traditions,” n.d.). UVM was originally a private university. However, in 1862, Justin S. Morrill, one of the Vermont Senators serving in the federal government, proposed the Morrill Land Grant College Act which was soon signed into law. This bill allocated federal lands to serve as building grounds for colleges dedicated to “benefit[ting] the agricultural and mechanical arts” (“U.S. Senate: The Civil War- The Senate’s Story,” n.d.). UVM then merged with the State Agricultural College and was dubbed a public university. UVM has made a point of pursuing equity for women, people of color, and those of various religion denominations (“History and Traditions,” n.d.). As of 2019, UVM receives 6.2% of its budget from the state, and has established an endowment in upwards of $550,000,000 (“Endowment,” n.d.).

The University of Vermont’s mission is as follows: “To create, evaluate, share, and apply knowledge and to prepare students to be accountable leaders who will bring to their work dedication to the global community, a grasp of complexity, effective problem-solving and communication skills, and an enduring commitment to learning and ethical conduct” (“Mission and Vision,” n.d.). The mission is carried out in many ways, but one method is through UVM’s programming. UVM has wonderful environmental, nursing, business, educational and arts programming to name a few.

UVM is overseen and run by the Board of Trustees, which is broken down into several committees. The committees include “the Audit Committee; the Committee on Board Governance; the Budget, Finance, and Investment Committee; the Educational Policy and Institutional Resources Committee; and the Executive Committee” (“Organization and Governance,” 2016, pp. 11). The board of Trustees elects the president of the university who helps them carry out their agendas (“Organization and Governance,” 2016). Under the Board of Trustees lies the President, the Provost, the Vice Presidents and Associate Provosts, the deans of each college, and the chairs and directors of each program. This group is dubbed the “senior leadership” (“Organization and Governance,” 2016).

**Methods**

My supervisor at The Nature Conservancy, Shayne Jaquith, began by organizing a group of scientists from the state (members from the Vermont Department of Natural Resources, the Vermont Department of Forests, Parks, and Recreation, The Nature Conservancy, and several universities) who were invested in the idea of beaver-based restoration. I was tasked with writing a literature review designed to respond to stakeholder interests or concerns surrounding possible impacts of actively promoting beaver presence on the Vermont landscape. This project was changed from a literature review to an annotated bibliography in the interest of gathering the most information given the limited time available to my internship. I was tasked with finding literature focused on questions posed to me by the stakeholders at a group meeting. The literature I collected was compiled on a Zotero account (free citation management software) that was then made accessible to The Nature Conservancy. This compilation was created with the intention of answering stakeholder questions, but also with the intention of streamlining the knowledge and responses that the stakeholders carry in order to ensure that the top scientists in Vermont are sending the same messages about the impacts of beavers on the landscape to Vermonters and beyond. Whether or not this message is in support of beaver-based restoration or not relies on what the stakeholders decide together as a group going forwards, but this will most likely springboard off the literature compilation.

On the other hand, Dr. Gould tasked me with cleaning her data set that had been collected via her statewide survey. Once this was completed, I was asked to use NVivo qualitative analysis software to code for predetermined themes within the open-response questions. I was given free rein to explore the data, and to code for new themes that became apparent as I made my way through the data. This was to culminate in a creative project to be sent around the state, to present our findings in a way that would engage Vermonters differently than your classic informational pamphlet. Table 1 provides a calendar of my planned break down of my internship hours over the course of the summer while Tables 2 and 3 indicate the work I ultimately performed.

Table 1 *Summer schedule of planned hours to work*

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*Note.* Calendar of my planned workdays. The start and end dates are indicated in yellow. Text in blue indicates hours planned to be dedicated to my work under Dr. Gould while text in purple are hours planned to be dedicated to The Nature Conservancy. Red text are days when I planned to be off.

Tables 2 & 3

*Hours Actually Worked*

Table

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*Note.* These tables document the days and hours I actually worked during the summer of 2020. Yellow highlight indicates the total hours worked in each internship.

**Results**

***Contribution to Organization:***

At the University of Vermont, my main service was that of a data analyst. I worked directly under Dr. Gould who spearheaded the project with the assistance of several of her graduate students, namely Tatiana, Diana, and Josh. Under their guidance, I cleaned the data collected from the surveys. Specifically, I kept track of all of the changes I made, and only made changes systematically according to our change book that Diana had established. Occasionally, I would come upon respondent entries that did not fit into any of the common entry mistakes. In those cases, I would reach out to Diana and together we would discuss what we thought would be the best course of action. Sometimes, this meant adding a new entry to our change book so that if the same error occurred again, we could easily address it. However, the bulk of my time was spent reading through the 3204 responses and coding them based on theme. The graduate students introduced me to coding by providing me with an a priori coding scheme. As I began to code, I began to notice new, emerging themes. I discussed these with Dr. Gould. For certain themes I felt confident about, I created new nodes for these new themes. While this process was taking place, I established a code book where I detailed each node and provided examples. This was to minimize any speculation when coding. Further, if anyone else in the group did any coding, they would know the scheme I was using to organize and differentiate the data into themes, allowing for us to be consistent in our placement. I coded for a plethora of themes including (a) geography- living in a rural or urban setting; (b) experiences during the pandemic- including loss, change, and enrichment; (c) important values of nature- like the aesthetic, mental health, physical health, and purpose that nature brings; (d) the meaning Vermonters find in Nature and whether the intensity or change in this meaning; (e) peoples’ feelings about COVID-19 restrictions and about being around other people; and (f) articulations of gratitude. Our analyses are now being incorporated into focused journal articles. I was invited to help write a piece on one of the themes we identified while coding the data: perspective. We sent in the paper on October 13th to the Lancet. The paper was rejected, but we plan to submit it to another journal any day now. We decided to look deeper into the identifies theme of “perspective.” Perspective as it relates to nature has been minimally researched up to this point. In this scenario, perspective is the experience of a “reality check” brought about through spending time in nature (Gould & Lincoln, 2017). This check involves one “becoming aware of relationships and how a person fits into them” (Gould & Lincoln, 2017, p. 123), and one’s place in this world. We identified several sub-themes that make up this broader vision of perspective within the data. We named these sub-themes as follows: centering and grounding, cycles and continuity, explicit perspective, humility (which includes the concepts of both scale and drawing out of self/reducing egoism), importance and priorities, and reducing rumination. The broader theme of perspective has only recently come into the conversation of cultural ecosystem services. In our own small manner, we are creating and sharing new knowledge with the world through our research. This information can be used to inform the global community once we are able to publish our paper (see Appendix). This process is distinctly aligned with UVM’s mission, specifically “[t]o create, evaluate, share and apply knowledge and to prepare students to be accountable leaders who will bring to their work dedication to the global community” (“Mission and Vision,” n.d.). At The Nature Conservancy of Vermont, I worked directly under Shayne Jaquith, the Watershed Restoration manager, and Megan Gordon, the Restoration and Ecological Management Fellow. My project with them took many different turns, but ultimately, I ended up creating an annotated bibliography as well as a large pool of academic journal articles to be used not only by The Nature Conservancy of Vermont to inform water and land management, but by other land, water, and wildlife managers from around the state. Notably, I was able to communicate and share our plans with Mike Kline (a river ecologist and geomorphologist and director of Fluvial Matters, a company providing restoration and conservation consultation throughout VT), Suzanne Gifford, Kim Royar, William Eldridge, and Tyler Brown of VT Fish and Wildlife, Rebecca Chalmers of the VT Department of Environmental Conservation, Rebecca Diehl from the Department of Geography at UVM, Elizabeth Doran (an environmental engineer currently working on her post-doctorate at the Gund Institute through UVM), Joe Roman (another Fellow at the Gund Institute), and Denise Burchsted from the Department of Environmental Studies at Keene State University. This stellar team of scientists were integral in helping develop the framework for my project. They helped develop frequently asked questions that they have been posed about beaver-based restoration and compiled them into a document. I used this document as the basis of the annotated bibliography. I looked for the most relevant articles containing data and information I knew could help answer many of these frequently asked questions. I ultimately found 65 articles and uploaded them all into a Zotero account. I then went through and picked out the most significant 25 articles, for which I wrote up annotations. Had the time permitted, I would have researched a more comprehensive annotated bibliography, but again, given the time constraints, this was not feasible. My findings were many, and I occasionally came upon conflicting evidence. It is suggested that beavers may aid in mitigating the effects of climate change by providing floodwater attenuation which is integral at this point in time given projections of increased flood frequency and severity (Westbrook et al., 2020). Further, beaver impoundments can act as long-term stores of carbon (Nummi et al., 2018), but simultaneously emit methane, a greenhouse gas which does contribute to the effects of climate change (Whitfield et al., 2015). Water quality and dynamics vary by river and beaver activity (Cazallo-Gatti et al., 2018). Others are concerned that impoundments will act as barriers to fish and other wildlife, but studies suggest that wildlife are still able to navigate rivers that feature beaver impoundments (Lokteff et al., 2013; Anderson et al., 2015). Overall, beavers can cause property damage (Janiszewski & Hermanowska, 2019), but they also provide significant benefits to humans and other wildlife (see Appendix). Although my work did not entail carrying out actual action plans associated with management decisions, my role and the resources that I collected will be integral in informing those very management decisions which will have cascading implications for many species of organisms. Thereby, we are helping to conserve nature and its functionality which will benefit not only humans, but the dynamism inherent in nature to begin with (“Explore TNC's Mission, Vision and Values,” n.d.).

***Personal Reflection:***

I knew going into this dual-internship experience that I wanted to learn a better sense of what it’s like to work in the higher stakes arena of careers in the scientific field; and (b) be able to compare my different experiences working for a large non-profit versus a university, in hopes of establishing which kind of work I prefer. Honestly, I enjoyed both of my experiences so much. When I was introduced to Dr. Gould’s project, I dove right into data analysis. It was an interesting experience in that I was not present for the beginning stages of our research, designing the questions of the survey. I was not able to get a clear sense of what this process had been like, besides the fact that the team had distributed a survey throughout the state. I was able to pick up important points upon listening to discussions between Dr. Gould and her graduate students. Importantly, I discovered that when you design a survey, one must consider what kind of data they want to be getting from the survey and what kinds of statistical tests will be used. In our case, the survey was sent out very quickly because COVID-19 was a sudden new reality, and the team wanted to capture this. However, I believe they felt had they had more time, they would have allocated more thought and energy into the survey design. Based on their conversations, I could tell that the graduate students were struggling with deciding what tests to use once the data was collected in order to provide an analysis that brought meaning to the data. This idea has been iterated to me via Dr. Gould in ENVS 201 Research Methods. We have been reading the book “Steal like an artist: 10 things nobody told you about being creative” by Austin Kleon because creativity is essential in research, contrary to what many believe. One notable comment I picked up is as follows: “‘garbage in, garbage out’” (Kleon, 2012, p. 102). In other words, how you design your methods and the thought/care put into this process will dictate what kind of data you get out. This is not to say this survey was garbage. We found some incredible insights within the data. However, I do recognize now that the design is just as important, if not more important, than the final stages of your research. Furthermore, by taking this Research Methods class as my 200-level class for my capstone, I have been exposed to the more comprehensive process of research, beginning from brainstorming and topic development. I am glad I have had the opportunity to take this class, as it has made me understand the complexities and the value of research. Based on my experience, I can now say that I would like to pursue research in future. I was part of an authentic research process that culminated in an academic journal article that is currently in the midst of being submitted to journals. This is incredibly scary and gratifying. At the outset, I was really questioning my ability to contribute significantly to this project. I felt like I didn’t know enough. Looking back on it, I spent 150 plus hours reading through the data. I became an expert in my own way. Under guidance from Dr. Gould, I have come to learn that, in order to be a successful researcher, you have to be comfortable with delving into the unknown and not always having the answers to questions. This is the reason why we perform research: to expand our bubble of knowledge (Schwartz, 2008). The more I spent time with the data, the more I realized that even if what I found didn’t seem that significant to me, having data that supports these ideas helps bring weight to them. As a result, I know that I have become a more assertive scientist. I also feel proud and privileged to be contributing to the world of academia, and perhaps more importantly, that this research could impact people. This is absolutely incredible. However, I have also become aware of the fact that research and active management of wildlife and the landscape do not have to be mutually exclusive. In fact, management decisions should be highly informed by research. During my experience with The Nature Conservancy of Vermont, I feel I most certainly was able to develop as a scientist and as a member of the scientific community. It was a unique feeling to be sharing what I had learned through my research with scientists and managers who will be responsible for carrying out management plans. I got a much better sense of how collaborative science can, and in my opinion, should be. I also feel I have a better understanding of how the scientific process is carried out in the real world. It is one thing to carry out laboratory experiments or read about incredible feats of science. It is an incredible experience to watch this happen before your own eyes. This was invigorating and fed that part of my soul that is absolutely enthralled by science.

At The Nature Conservancy, I found myself diving into areas of science that I hadn’t explored much before. I was particularly intrigued to learn about water and how it can be managed. I learned that Vermont’s rivers are in rough shape. About three quarters of all the assessed rivers throughout the state are incising, meaning that they are digging deeper and deeper into the bedrock (Kline & Cahoon, 2010, p. 217). This has serious implications for Vermont communities. The process of incision is causing rivers to disconnect from floodplains. Floodplains are important buffer strips that can contain floodwaters when rivers top their banks, preventing flows from simply tearing through the riverbanks and whatever nearby infrastructure that may come in its path. The resilience associated with these overflow networks can help to slow flow velocity during overflow events (Christin & Kline, 2017, p. 3). There are many other benefits of floodplains. They provide a platform for sediment deposition, retention, and continued water passage, thus reducing erosion (Christin & Kline, 2017, p. 5). They are an important habitat for many terrestrial and aquatic organisms (Christin & Kline, 2017, p. 5). Floodplains help maintain the surrounding human and non-human communities by attenuating waters. Importantly, beavers can play an enormous role by reconnecting rivers and floodplains. They naturally interfere in the natural accumulation of sediments in streams by creating barriers (dams) that collect sediments upstream, thus raising the bed of the stream upwards, facilitating vertical connectivity within the riverine system (Pollock et al., 2007). Beavers can jumpstart this process no matter where the system is in its natural aggrading and incising dynamism, thus decreasing the time it takes to reconnect the river and the floodplain (Pollock et al., 2007). Sediment retention has incredible value. It’s made more incredible by the fact that beavers are native, already a part of the landscape. If we were to help promote this aggradation process through the support of beaver communities, it would perhaps be more ethically sound than alternative options (Pollock et al., 2015, p. 2).

**Conflicts and Challenges:**

During my experience with The Nature Conservancy of Vermont, we faced several challenges. The primary challenge was that only a small portion of the proposed internship could be carried out due to the COVID-19 restrictions. 150 hours of the internship were projected to take place outside or in the Montpelier office with a focus on collaborative science. The other part of the internship was a proposed 50-hour literature review that I could complete remotely.

A large hurdle was assessing who wanted to be involved in this project and then assembling these stakeholders. From there, coming to a consensus in regard to the aim of my internship was difficult, but one objective remained clear: we wanted to gather the most up-to-date, reliable scientific literature on this topic. Some stakeholders thought that the proposed literature review would be a reasonable course of action while others leaned towards addressing questions on FAQ sheets or creating an annotated bibliography.

We soon realized that to do this topic justice, we either had to narrow the scope of our project significantly or alter the form of the project so that it could be completed in the 50-hour limit. Ultimately, Shayne and I decided that an annotated bibliography addressing the literature would be the best solution. This was a tough decision, but it seemed like the most feasible and realistic solution. Going through this process was difficult at times. I wanted to jump right in, but this was not possible until the group came to a consensus. I had to remain flexible and open. I appeased myself reading everything I could about the topic so as to build my knowledge base. I hoped that by learning the more basic information, I would have an easier time when I dove into the scientific literature. Upon reflection, I concur that this was an effective strategy.

I realize now that working with groups of people can be so valuable in that you are exposed to a multitude of perspectives, knowledge levels, and value systems. This was helpful during the development of the project because these differences are likely somewhat representative of those of the broader population. Although the scientists that I worked with are not a random sample of humans, we can recognize that their positionalities impact how they view the world, and therefore, their thoughts, feelings, and perceptions of beaver-based restoration. We can apply this more broadly when thinking about how the entire population of Vermont may react to the unique practice of beaver-based management. In that way, I really enjoyed working with such a large group of people.

On the other side of things, the bureaucracy of the workplace and the efforts required in organizing/coordinating all the parts and players involved in the project can be challenging. At times, I became frustrated. It would have been so much easier to carry out this project just within the frame of The Nature Conservancy. However, The Nature Conservancy can only do so much as an independent unit. Although the Vermont chapter is a part of a much larger, multinational non-profit, resources and money are limited within the smaller chapter. They cannot allocate their resources everywhere and carry out all the worthwhile conservation projects warranted around the state. This is where government agencies or alternative conservation groups can come into play. For example, VT Fish and Wildlife receive a portion of their funds from the federal government’s general fund. Similarly, money spent on fishing and hunting gear is allocated towards running the agency (“VT Official State Website,” n.d.). This consistent funding provides the agency with more opportunities, although I am sure they are limited in some capacities. However, when we combine the money, resources, knowledge, and assets of scientists from all over the state, then bold management plans and actions can more easily come to pass. In other words, by sharing the information that we found with all of these different scientists, then we are getting the word out and making beaver-based restoration more of a reality here in Vermont.

The more personal ethical challenge I faced was in not trying to impart my personal stance on beaver-based restoration into my work. I believe that beaver-based restoration would have a net positive impact on the landscape, and therefore, I think we should really invest the time and money into this pursuit. It is likely that I have this stance due to my education on the topic and the fact that I have never experienced property damage or other damages due to beavers. If I had, it is likely that I may feel differently about beaver-based restoration. Importantly though, my opinion couldn’t play a role in my work, as my goal was simply to present all the data we have on the topic and to allow the top scientists in the field to make the call. As a result, I tried to maintain as unbiased of a narrative as I could throughout the annotated bibliography. I tried to keep in mind that my epistemologies around beaver-based restoration will likely directly and indirectly impact which articles I am drawn to and which I chose to present fully in the annotated bibliography. I tried to present a wide variety of articles which presented supporting and countering arguments in regard to beaver-based restoration to counter this.

Contrastingly, my research experience with Dr. Gould was not difficult in that there wasn’t any consensus about what the project would entail. It was more challenging because I had to develop my qualitative analysis skills and my thinking on this topic. I haven’t studied human and nature relationships beyond the superficial in my introduction classes at UVM. I have always believed that this topic is pretty straightforward. In some ways it is, but there are definitely more layers of complexity than I ever imagined. I found myself broadening my worldviews on this topic. Dr. Gould’s support and knowledge were integral in this process. She challenged me to think deeply and critically about my assumptions and ways of thought.

This process was also challenging in that qualitative analysis can be very subjective. I struggled with interpreting survey responses that were not very descriptive. Sometimes I didn’t know if my reading and interpretation of a statement was completely off base, or if I was correct in my assumptions. In this manner, there is certainly a degree of uncertainty. However, I tried to maintain my consistency with these speculations and referred to our code book when I felt unsure. In some cases, I discussed the response with Dr. Gould. I would offer her my thoughts on how to code the themes and she would respond to my thoughts. With time, I became more adept and more consistent. I became well-versed with the qualitative analysis software, NVivo. I’m now recognizing how powerful a tool NVivo is, and I could foresee myself utilizing this resource heavily should I pursue a career in research.

**Conclusion**

Overall, I had a very positive experience during my dual-internship. I had an authentic experience and was able to meet my personal learning objectives including experiencing science in a high stakes setting, learning about fluvial dynamics, forming relationships with many wonderful and inspiring members of the scientific community, and getting a feel for the process of research, conservation and more social science related fields. I learned what it feels to work in both a university and a non-profit setting. I faced some challenges along the way. I struggled with finding the patience when working with a large group of people and with trying to remove my own opinions and biases from my work. However, I learned the value of being able to listen to other people’s perspectives and to be able to collaborate with those within the scientific community and beyond.

I was able to generate some tangible results. Through continued work with Dr. Gould, I helped write an academic journal article, a feat that I had never imagined I could have accomplished. With The Nature Conservancy of Vermont, I created an annotated bibliography that will be used to inform management decisions for the state of Vermont regarding beaver-based restoration. Now more than ever, I have a better understanding of the scientific process and how science can take so many different forms. I feel much more prepared for my future as a part of the scientific community, helping to expand our knowledge and conceptions of our natural environments and the role that humans play.

References

Allen, S. J. (n.d.). The Nature Conservancy (TNC). https://www.influencewatch.org/non- profit/nature-conservancy/.

Anderson, N. L., Paszkowski, C. A., & Hood, G. A. (2015). Linking aquatic and terrestrial environments: Can beaver canals serve as movement corridors for pond-breeding amphibians? Animal Conservation, 18(3), 287–294. https://doi.org/10.1111/acv.12170

Cardinale, B. J., Primack, R. B., & Murdoch, J. D. (2020). Conservation Biology. Oxford University Press.

Cazzolla-Gatti, R., Callaghan, T. V., Rozhkova-Timina, I., Dudko, A., Lim, A., Vorobyev, S. N., Kirpotin, S. N., & Pokrovsky, O. S. (2018). The role of Eurasian beaver (Castor fiber) in the storage, emission and deposition of carbon in lakes and rivers of the River Ob flood plain, western Siberia. Science of The Total Environment, 644, 1371–1379. https://doi.org/10.1016/j.scitotenv.2018.07.042

Chan, K. M. A., Balvanera, P., Benessaiah, K., Chapman, M., Díaz, S., Gómez-Baggethun, E., Gould, R., Hannahs, N., Jax, K., Klain, S., Luck, G. W., Martín-López, B., Muraca, B., Norton, B., Ott, K., Pascual, U., Satterfield, T., Tadaki, M., Taggart, J., & Turner, N. (2016). Opinion: Why protect nature? Rethinking values and the environment. Proceedings of the National Academy of Sciences, 113(6), 1462–1465. https://doi.org/10.1073/pnas.1525002113

Christin, Z., & Kline, M. (2017). Why We Continue to Develop Floodplains: Examining the Disincentives for Conservation in Federal Policy. Earth Economics.

Cluer, B., & Thorne, C. (2014). A stream evolution model integrating habitat and ecosystem benefits. River Research and Applications, 30(2), 135–154. https://doi.org/10.1002/rra.2631

Endowment. (n.d.). The University of Vermont. Retrieved October 18, 2020, from https://www.uvmfoundation.org/s/1690/19/interior.aspx?sid=1690&gid=2&pgid=481

Explore TNC's Mission, Vision and Values. (n.d.). The Nature Conservancy. https://www.nature.org/en-us/about-us/who-we-are/our-mission-vision-and-values/.

Gould, R. K., & Lincoln, N. K. (2017). Expanding the suite of Cultural Ecosystem Services to include ingenuity, perspective, and life teaching. Ecosystem Services, 25, 117–127. https://doi.org/10.1016/j.ecoser.2017.04.002

Guither, H. D. (1998). Animal rights: history and scope of a radical social movement. Southern Illinois Univ. Press.

History and Traditions. (n.d.). The University of Vermont. Retrieved October 18, 2020, from https://www.uvm.edu/history\_and\_traditions

How We Work. (n.d.). The Nature Conservancy. <https://www.nature.org/en-us/about-us/who-> we-are/how-we-work/.

Janiszewski, P., & Hermanowska, Z. (2019). Damage Caused by the European Beaver (Castor fiber L.) in Agricultural and Forest Farms in View of Selected Atmospheric Factors and Animal Behavior. Applied Ecology & Environmental Research, 17(6), 15633–15642. https://doi.org/10.15666/aeer/1706\_1563315642

Kendeigh, C. (1968). Victor Ernest Shelford, Eminent Ecologist, 1968. The Bulletin of the Ecological Society of America, 49(3), 97–100. https://doi.org/10.2307/20165761

Kleon, A. (2012). Steal like an artist: 10 things nobody told you about being creative. Workman Pub. Co.

Kline, M., & Cahoon, B. (2010). Protecting River Corridors in Vermont. JAWRA Journal of the American Water Resources Association, 46(2), 227–236. <https://doi.org/10.1111/j.1752-> 1688.2010.00417.x

Lee, K. N., Freudenburg, W. R., & Howarth, R. B. (2013). Humans and their habitats. In Humans in the landscape: an introduction to environmental studies (pp. 191–224). Essay, Norton.

Little, A. M., Guntenspergen, G. R., & Allen, T. F. H. (2012). Wetland vegetation dynamics in response to beaver (*Castor canadensis*) activity at multiple scales. Ecoscience, 19(3), 246–257. https://doi.org/10.2980/19-3-3498

Lokteff, R. L., Roper, B. B., & Wheaton, J. M. (2013). Do Beaver Dams Impede the Movement of Trout? Transactions of the American Fisheries Society, 142(4), 1114–1125. https://doi.org/10.1080/00028487.2013.797497

Milcu, A., Hanspach, J., Abson, D., & Fischer, J. (2013). Cultural Ecosystem Services: A Literature Review and Prospects for Future Research. Ecology and Society, 18(3). https://doi.org/10.5751/ES-05790-180344

Sarukhán, J., & Whyte, A. (Eds.). (2005). Millennium Ecosystem Assessment: Ecosystems and human wellbeing. Millenial Ecosystem Assessment. <https://www.researchgate.net/publication/40117503_Millennium_Ecosystem_Assessment> \_Ecosystems\_and\_human\_well-being\_wetlands\_and\_water\_synthesis.

Mission and Vision. (n.d.). The University of Vermont. Retrieved October 18, 2020, from https://www.uvm.edu/mission-and-vision

National Oceanic and Atmospheric Administration. (n.d.). Michael M. Pollock, Ph.D. NOAA. https://www.fisheries.noaa.gov/contact/michael-m-pollock-phd.

Nummi, P., Vehkaoja, M., Pumpanen, J., & Ojala, A. (2018). Beavers affect carbon biogeochemistry: Both short‐term and long‐term processes are involved. Mammal Review, 48(4), 298–311. https://doi.org/10.1111/mam.12134

Organization and Governance. (2016). The University of Vermont.

Our History. (n.d.). The Nature Conservancy. https://www.nature.org/en-us/about-us/who-we- are/our-history/.

Our Priorities. (n.d.). The Nature Conservancy. https://www.nature.org/en-us/what-we-do/our- priorities/.

Pollock, M. M., Beechie, T. J., & Jordan, C. E. (2007). Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. Earth Surface Processes and Landforms, 32(8), 1174–1185. https://doi.org/10.1002/esp.1553

Pollock, M. M., Lewallen, G., Woodruff, K., Jordan, C. E., & Castro, J. M. (Eds.). (2015). The Beaver Restoration Guidebook Working with Beaver to Restore Streams, Wetlands, and Floodplains. https://www.fws.gov/oregonfwo/Documents/BeaverRestGBv.1.02.pdf.

Schwartz, M. A. (2008). The importance of stupidity in scientific research. Journal of Cell Science, 121(11), 1771–1771. https://doi.org/10.1242/jcs.033340

Singer, F. (2016). Ecology in action. Cambridge University Press.

Tercek, M. (2017). State of the Conservancy. The Nature Conservancy. <https://www.nature.org/en-us/about-us/who-we-are/our-people/mark-tercek/state-of-the-> conservancy/.

U.S. Senate: The Civil War- The Senate’s Story. (n.d.). United States Senate. <https://www.senate.gov/artandhistory/history/common/civil_war/MorrillLandGrantColle> geAct\_FeaturedDoc.htm

VT Official State Website. (n.d.). Budget and Planning. Budget and Planning | Vermont Fish & Wildlife Department. https://vtfishandwildlife.com/about-us/budget-and-planning.

Westbrook, C. J., Ronnquist, A., & Bedard‐Haughn, A. (2020). Hydrological functioning of a beaver dam sequence and regional dam persistence during an extreme rainstorm. Hydrological Processes, 34(18), 3726–3737. https://doi.org/10.1002/hyp.13828

Whitfield, C., Baulch, H., Chun, K., & Westbrook, C. (2015). Beaver-mediated methane emission: The effects of population growth in Eurasia and the Americas. AMBIO - A Journal of the Human Environment, 44(1), 7–15. https://doi.org/10.1007/s13280-014- 0575-y

Williams, F. (2018). The nature fix: why nature makes us happier, healthier, and more creative. W.W. Norton & Company.

**Appendix**

***Annotated Bibliography***

Annotated Bibliography: Literature on Beavers

Annotated by Eliza Merrylees

August, 2020

Baldwin, J. (2017). Institutional Obstacles to Beaver Recolonization and Potential Climate Change Adaptation in Oregon, USA. *Yearbook of the Association of Pacific Coast Geographers*, *79*, 93– 114. https://doi.org/10.1353/pcg.2017.0005

Dr. Jeff Baldwin, a professor of Geography, Environment & Planning at Sonoma State University, delves into the philosophy underlying human degradation of the environment. In this study, Baldwin explores the idea of using beavers to mitigate the impacts of climate change in the state of Oregon. He begins by examining climate change in Oregon: stream flows are becoming more intense in the winter and are decreasing significantly in the summer months, a pattern that is projected to become exacerbated with the continuation of climate change. Baldwin asserts that the reintroduction of beaver throughout Oregon will help maintain steady stream flows year- round and simultaneously generate wetland habitat that benefits other Oregon wildlife.

Baldwin assesses whether beaver reintroduction should be considered as a management strategy in Oregon. He finds that this strategy may be ineffective due to loopholes in Oregon legislation and underlying negative perceptions held by Oregon residents towards beavers which he condenses into five “institutional obstacles.” They are as follows: a) the use of political neutrality so that reports will be passed by the legislature means strategic actions are infrequently considered, b) Oregon’s classification of beavers as predators allows for removal of beavers at a landowners’ own discretion, c) the perception that human takes do not interfere with beaver population abundance, d) the perception that beavers have already reached their maximal range within the state, and e) the perception that reintroduction practices are ineffective. Without addressing these obstacles, beaver reintroduction will pose serious conflicts in a multitude of realms.

Jonker, S. A., Muth, R. M., Organ, J. F., Zwick, R. R., & Siemer, W. F. (2006). Experiences with Beaver Damage and Attitudes of Massachusetts Residents toward Beaver. *Wildlife Society Bulletin (1973-2006)*, *34*(4), 1009–1021. JSTOR.

The Department of Natural Resources and Human Dimensions Research Units of New York, Massachusetts, and the state of Vermont, Jonker *et al*. undertake a study on human perceptions of beaver in the state of Massachusetts following a ballot initiative that prohibited the use of foothold and body-gripping traps on beavers in almost all scenarios. The result of the initiative was that beaver populations rebounded throughout the state, but at a cost. As beaver populations increased, so did associated damages, exacerbating the conflicts between humans and beavers. Jonker *et al*. examine “people’s experience with beaver damage, their attitudes and norms towards beaver, and their tolerance towards beaver and beaver damage in Massachusetts” as to better inform management policies and understand stakeholder values. The study takes place in three regions of Massachusetts, one urban setting, one suburban setting, and one rural setting. In 2002, Jonker *et al*. sent out a survey to 1,600 people living in each area to gauge the aforementioned areas of concern. Residents included were those who had submitted beaver damage complaints to MassWildlife. In the end, 2,486 surveys were usable.

All groups of respondents demonstrate positive perceptions of beavers but respond that some form of beaver management should be put in place. About half of the respondents indicate that they feel beavers are a nuisance. Of the respondents, those with the most negative attitudes towards beaver are respondents who have submitted beaver damage complaints in the past. Respondents in all areas report beaver damages, but the mean rating of damage severity is much higher for those who have submitted beaver damage complaints. Those who experience higher-severity damage respond more negatively than those whose damage due to beavers is less severe. These respondents are also less likely to value beaver life and feel that aggressive management strategies are appropriate. These findings are consistent with other surveys gauging human perceptions of beavers: attitudes are positive but are directly impacted by experiences with beavers. Jonker *et al*. end by emphasizing that we will only be able to reduce human-beaver conflict by understanding people’s values.

Whitfield, C., Baulch, H., Chun, K., & Westbrook, C. (2015). Beaver-mediated methane emission: The effects of population growth in Eurasia and the Americas. *AMBIO - A Journal of the Human Environment*, *44*(1), 7–15. <https://doi.org/10.1007/s13280-0140575-y> Colin Whitfield, an assistant professor in the School of Environment and Sustainability at the University of Saskatchewan and a member of the Global Institute of Water Security investigates the fall and rise of beavers on the landscape and the impact this has had on global methane emissions and wetland habitat. Whitfield *et al*. estimate the global methane emissions associated with beavers for the year 2000 by combining estimates of beaver abundances unique to North America, South American, Europe, and Asia, the prominence of beaver ponds on the landscape, and methane efflux rates associate with beaver ponds. They use a Monte Carlo uncertainty analysis to simulate methane emissions released by each continental population, conducting 1000 simulations for each of these populations.

Since the reintroduction of beavers following their near global extinction, Whitfield and his team estimate that beavers approach a global population 3.0x107, with an associated increase of pond habitat in the span of 9,500-42,000 km2. This, in turn, is estimated to have increased global methane emissions “400-fold since the early twentieth century, reaching 0.18-0.80 Tg CH4 year-1 in 2000.” Whitfield *et al*. caution that although this seems extreme, beaver populations have also been growing near-exponentially. Once population growth decreases, the increase in methane emissions will also decrease. That said, they project that as populations continue to grow, there will likely be increases in global methane emissions as a result because emissions are directly linked to population size.

Cazzolla-Gatti, R., Callaghan, T. V., Rozhkova-Timina, I., Dudko, A., Lim, A., Vorobyev, S. N., Kirpotin, S. N., & Pokrovsky, O. S. (2018). The role of Eurasian beaver (Castor fiber) in the storage, emission and deposition of carbon in lakes and rivers of the River Ob flood plain, western Siberia. *Science of The Total Environment*, *644*, 1371–1379. <https://doi.org/10.1016/j.scitotenv.2018.07.042>

Roberto Cozolla-Gatti and team, a group of primarily Russian scientists well- studied in the fields of biology, geochemistry, geoecology, and animal and plant sciences, conduct a study of the impacts of Eurasian beaver on carbon dynamics within one of the largest floodplains on earth: the River Ob system in Siberia. They compare 5 beaver-dominated sites on the river to 5 river segments free of beaver during the 2016 flood season on the River Ob. They are particularly interested in measuring the flux in dissolved CO2. They also measure the water turbidity, temperature, conductivity, and pH, and observe concentrations in dissolved oxygen, dissolved methane, dissolved organic carbon, blue-green algae, orthophosphate, and particulate nitrogen above and below dams in order to get a thorough understanding of the differences in water chemistry and quality between the site types.

They find that the dissolved methane, dissolved organic carbon, phosphate, particulate nitrogen, and dissolved CO2 concentrations are significantly higher in streams with beavers than those without beavers. Interestingly, water temperature, pH, dissolved oxygen, turbidity, depth, and green algae concentrations are higher in the beaver-*free*environments. This contradicts other studies, in particular, with regards to water temperature. Cazzolla-Gatti *et al*. provide a detailed explanation of the carbon cycle that takes place within a beaver pond and note the important role that beavers play in making nutrients like phosphate immediately accessible within the ecosystem. Ultimately, they assert that beaver dams are a significant source of methane, a source that is likely to grow as beaver populations expand, but dams also “act as sizable sinks of carbon” within the larger watershed. Cazzolla-Gatti *et al*. finish by stating that beavers should be conserved on the landscape.

Nummi, P., Vehkaoja, M., Pumpanen, J., & Ojala, A. (2018). Beavers affect carbon biogeochemistry: Both short‐term and long‐term processes are involved. *Mammal Review*, *48*(4), 298–311. <https://doi.org/10.1111/mam.12134>

Petri Nummi and his co-authors are a team of Finnish scientists who have studied forest science, environmental science and the atmosphere and earth systems. Together, they research the long- and short-term carbon cycling catalyzed by beavers by conducting a review of the existing literature. They find varied messages regarding whether beaver ponds are sources or sinks of carbon. In the short-term, they note that beaver ponds can play both roles (carbon source and carbon sink) during their successional progression of wetland to meadow. Emission fluxes in CO2 and CH4 vary between ponds locally and on a larger spatial scale, although beaver ponds at higher latitudes tend to have greater CH4 emissions and older ponds tend to have greater fluxes in CO2 emissions. Fluxes in emissions also occur at many different time scales. Dissolved organic carbon (DOC) is highest when water levels are raised behind beaver impoundments, flooding terrestrial plants along the shore and inundating terrestrial soils, both of which contain plentiful carbon stores.

Nummi *et al*. find that beaver ponds also act as long-term stores of carbon. Beavers bring a lot of wood into the pond for damming purposes and food caches. Given the anaerobic conditions present in beaver ponds, it can take thousands of years for this wood to decompose, meaning that all the carbon present in the wood is being stored over that time period. Similarly, beaver ponds impound sediment and soils which contain carbon. These are stored long after beavers abandon the lot and will only return to the atmosphere once the river aggrades through the sediments, a process that can take decades or longer. Overall, they encourage that humans acknowledge the source/sink dynamics that exist through the various successional stages of a beaver pond and warn of the repercussions of trying to contain these dynamics.

Lokteff, R. L., Roper, B. B., & Wheaton, J. M. (2013). Do Beaver Dams Impede the Movement of Trout? *Transactions of the American Fisheries Society*, *142*(4), 1114–1125. https://doi.org/10.1080/00028487.2013.797497

As scientists schooled in watershed sciences and fish and aquatic ecology, Lokteff *et al*. are poised to address misconceptions regarding beaver dams and whether they truly act as barriers to fish passage/migration as many people, scientists included, believe. It is recognized that beaver ponds can serve many benefits to fish including a) generating habitat heterogeneity that serves fish during their different life history stages, b) providing rearing and spawning habitat, and c) providing pools for overwintering. The scientific community agrees that beaver ponds provide this habitat heterogeneity, but it remains unclear whether the dams themselves act as direct barriers to these patches of habitat.

Lokteff *et al*. survey 3 species of trout (the native Bonneville Cutthroat Trout, and the non-native Brook Trout and Brown Trout) found in beaver habitat along the Logan River in Utah. From 2008-2011 they put PIT tags on 1,375 trout above and below 21 beaver dams within the tributaries connecting into the Logan River (Spawn Creek and Temple Fork) to track the fish. Over the course of the study, they record “481 passage events by trout at beaver dams.” Of that, the Bonneville Cutthroat Trout have the highest proportional number of crosses (15.9% of their tagged population) and the Brown Trout have the lowest proportional number of crosses over beaver dams, logging in at 4.5% of their tagged population. The Brook Trout passes as much as was expected. Results suggest that the Brook Trout and Bonneville Cutthroat Trout pass beaver dams with relative ease.

McRae, G., & Edwards, C. J. (1994). Thermal Characteristics of Wisconsin Headwater Streams Occupied by Beaver: Implications for Brook Trout Habitat. *Transactions of the American Fisheries Society*, *123*(4), 641–656. <https://doi.org/10.1577/1548->8659(1994)123<0641:TCOWHS>2.3.CO;2

McRae of the University of Wisconsin Department of Fish and Wildlife, and Edwards of the U.S. Forest Service undertake a study regarding thermal temperature changes associated with beaver dams, and the impacts this can have on fish ranges and distribution (particularly of Brook Trout) throughout Wisconsin. They are particularly curious about the impacts that dam removal will have on water temperature and the surrounding habitat. McRae and Edwards sample four headwater streams in the Peshtigo River watershed located in northeastern Wisconsin that all exhibited healthy beaver populations during the summers of 1990 and 1991. They collect data on water temperature, soil temperature, air temperature, stream flow, impoundment area, shadiness, river orientation, and the topography of the landscape at each of their test sites. They also remove dozens of beaver dams over the course of the study.

They determine that there is a strong positive correlation between water temperature and air temperature, a relationship that becomes increasingly less sensitive when beaver dams were removed. There is less temperature difference upstream and downstream of beaver dams once the dam is removed, although temperature fluxes are frequent. Water temperature is also associated with size of the river or pool. Due to the high specific heat of water, wide deep pools warm far less quickly than narrow shallow pools. Overall, some areas of the river warm and some cool following dam removal, suggesting that temperature regimes are site dependent. Therefore, removal of beaver dams does increase habitat suitability for cold-water fish in some areas but not others. McRae and Edwards ultimately caution against the removal of beaver dams as this can cause disastrous changes to benthic sediments downstream and jeopardize habitat for other organisms.

Cutting, K. A., Ferguson, J. M., Anderson, M. L., Cook, K., Davis, S. C., & Levine, R. (2018). Linking beaver dam affected flow dynamics to upstream passage of Arctic grayling. *Ecology and Evolution*, *8*(24), 12905–12917. <https://doi.org/10.1002/ece3.4728>

Scientists from Montana’s Department of Fisheries, Biology, Environmental Sciences, and Land Resources along with experts in the study of fisheries and conservation biology investigate how beaver dam features, stream hydrology, and fish characteristics impact the ability of spawning Artic grayling to maneuver through low-gradient Montana rivers, and whether this movement is hindered by beaver dams. They use radio-telemetry to track Arctic grayling (49 tagged in September of 2013 and another 49 in September 2014) passage for 2 years (surveyed 3x per week between 2014 and 2015) within Upper Red Rock Creek, a tributary to the upper section of the Missouri River that is abundant with beaver. This allows them to then model fish passage probabilities and daily fish movements. Cutting *et al*. also inventory beaver dams within the river, noting the condition of the beaver dams and how they change over the course of the study. Finally, they keep track of changes in environmental conditions.

They find that Arctic grayling passage across dams is influenced by the breach status of the dam, the temperature of the air, and the flow velocity in the stream. Passage probability increases at breached dams and increases yet again in warmer water temperatures with low flow velocity and high scour pool depths. That said, the passage probability over unbreached dams is still high at 88%, though particular dams cause fish more trouble than others, thus decreasing passage probability to 50% at times. Overall, Cutting *et al*. assert that beaver dams do not pose a significant barrier to Arctic grayling passage, but that this study can help inform managers on how to identify dams that could pose a risk.

Smith, J. M., & Mather, M. E. (2013). Beaver dams maintain fish biodiversity by increasing habitat heterogeneity throughout a low-gradient stream network. *Freshwater Biology*, *58*(7), 1523–1538. https://doi.org/10.1111/fwb.12153

Scientists Joseph M. Smith and Martha E. Mather of the University of Massachusetts, Amherst, study the interaction between beaver dams and the presumed increase in habitat heterogeneity. Their goal is to identify the impacts that this relationship has on fish biodiversity in Fish Brook, a fourth-order stream and a tributary of the Ipswich River located in Massachusetts. They inventory all of the beaver dams within the study area and take measurements of upstream catchment area, stream gradient, stream length, stream depth, and flow velocity in both control and beaver-influenced sites. Control sites are located within 100 meters of a beaver dam, in order to sample river with similar conditions. This is done with the intention of identifying whether beaver dams really do initiate changes in habitat, and if they do, if this increases the habitat heterogeneity overall, and therefore fish diversity. Next, they sample fish upstream and downstream of 15 beaver dams and randomly within 9 control sites for 12 days in August of 2009.

They find that beaver dams do alter the surrounding habitat, but specific dams impact habitats differently in terms of the water velocity up and downstream of dams, the river depth, the river width, and the coarseness of river substrate. In general, the river upstream of beaver dams is wider and deeper with slower flow and finer substrate. Contrastingly, habitat downstream of beaver dams is narrower, shallower, faster, and is composed of coarse substrate. Overall, this creates habitat heterogeneity which impacts the types of fish that are present. Species diversity is higher in beaver habitat than it is in control settings. Smith and Mathers hope this can inform management and conservation decision making, especially as we enter the sixth mass extinction which will impact organisms beyond fish species.

Pollock, M. M., Beechie, T. J., & Jordan, C. E. (2007). Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. *Earth Surface Processes and Landforms*, *32*(8), 1174–1185. <https://doi.org/10.1002/esp.1553> Michael Pollock, Timothy Beechie, and Chris Jordan of the National Oceanic and Atmospheric Administration (Northwest Fisheries Science Center, Seattle, WA) investigate whether beaver dams can help reconnect incised rivers to their floodplains and restore riparian habitat within the Columbia River basin, Oregon. They believe that restoring the river’s hydrological and geomorphic conditions to conditions prevalent in the basin’s past will catalyze the restoration of riparian vegetation, benefiting many species of aquatic and terrestrial organisms. Interestingly, many scientists working to restore rivers have focused on how to slow incision, but Pollock *et al*. hope to jumpstart and speed up the aggradation process via beaver dams. Their study takes place on Bridge Creek at 13 beaver dams between the ages of 1 and 6 years (they receive data from the Bureau of Land Management regarding the age of the dams which BLM have been monitoring for some time). Pollock *et al*. measure the sediment depth aggrading behind the dams and take orthophotos to document the amount of riparian vegetation present. Finally, they measure the bed slope above the dams.

They determine that aggradation rates are generally very high (up to 0.45 m per year) in the early years of a given beaver dam but slow as the dam ages. As sediment accumulates behind the dam, this changes the bed slope, making the slope steeper. At dams where aggradation is occurring, the channel in close proximity to the dam does not change much in width, but the bank from water level to 0.5 meters in elevation significantly increases in width. Riparian vegetation is observed to quickly establish itself in this area. Based on data from other studies regarding aggradation rates above intact and active dams, the team projects the increase in channel height over the next 90 years, and how this will be impacted by different biotic and abiotic factors. The presence of the dams is projected to increase the width of the riparian zone sixfold over the next 90 years. Overall, Pollock *et al*. find that the addition of beaver dams could quickly reconnect incised rivers to their floodplains.

Błȩdzki, L. A., Bubier, J. L., Moulton, L. A., & Kyker-Snowman, T. D. (2011). Downstream effects of beaver ponds on the water quality of New England first- and second-order streams. *Ecohydrology*, *4*(5), 698–707. https://doi.org/10.1002/eco.163

Leszek Błȩdzki of the Environmental Studies program at Mount Holyoke College, Bubier and Moulton of Oregon State University Department of Horticulture, and Kyker-Snowman in the Division of Water Supply Protection in Massachussets present a compelling study of the impacts of active and inactive beaver dams on water chemistry, specifically as it pertains to drinking water supplies and the risks to downstream communities. They hypothesize that 1) the presence of beaver dams will increase water quality downstream by retaining sediment and nutrients, 2) that water quality will continue to increase with greater proximity from the dam, 3) that if the dam is breached, water quality downstream will decrease, and 4) that beaver dams will generate prime habitat for species of zooplankton. Błȩdzki *et al*. carry out their survey on Underhill Brook (featuring 2 active and 2 abandoned beaver dams) and the nearby Bachelor Brook (featuring 3 active beaver ponds) in Massachusetts. They collect weekly data from June to October 2000 on water temperature, pH, and conductivity, and the concentrations of chlorophyl, nitrate, ammonium, phosphate, and dissolved organic carbon at the 24 collection sites on the two rivers. They also collect sediments to use in laboratory simulation of a dam breach, breach an abandoned dam in the field, and collect zooplankton samples.

In Underhill Brook at sites *without* beaver, NO3, dissolved organic carbon (DOC), NH4-N, chlorophyl concentration, and water temperature are significantly *lower* in comparison to sites with beaver. Water pH, PO4, and dissolved oxygen are *higher* in these same areas than those found in the sites with beaver. Water turbidity is a major concern upon experimental and laboratory dam breaches, but it is noticeably higher when the chosen experimental dams had been abandoned beforehand.

Other studies indicate that DOC is generally lower in beaver ponds than beaver-free habitat. Błȩdzki *et al*. find the opposite: DOC levels in beaver habitat are higher than DOC levels in beaver-free river. They hypothesize that high DOC will create conditions ideal for denitrification to occur (which they infer will improve water quality downstream), but they find that this is not the case: nitrogen concentrations are higher in beaver waters. To conclude, the relationship between beavers and DOC remains unclear, but it is safe to say that beavers significantly alter water chemistry, which could certainly be a concern for communities living downstream of beaver dams. One finding from this study is clear: beaver dam breaches increase water turbidity downstream.

Law, A., Gaywood, M. J., Jones, K. C., Ramsay, P., & Willby, N. J. (2017). Using ecosystem engineers as tools in habitat restoration and rewilding: Beaver and wetlands. *Science of The Total Environment*, 1021–1030. <https://doi.org/10.1016/j.scitotenv.2017.06.173>

Law *et al*., Scottish researchers studied in the sciences of biology and environmental studies, explore the impacts of beaver reintroduction on plant biodiversity over the course of 12 years on a landscape that has been significantly depleted by agricultural activities. They hope that beaver “rewilding” will restore the ecosystem. In 2002, the team reintroduce a pair of beaver onto a 13-hectare plot fed by a series of drainage ditches. They create control plots within the larger plot inaccessible to beavers, but that remains accessible to foraging ungulate as to establish the impact of beaver grazing on vegetation. In their study, Law *et al*. use plant biodiversity as an indicator for ecosystem health: the greater the biodiversity, the healthier the ecosystem. They measure diversity as the number of plant species in each plot and control for “environmental drivers” of species richness change using a variety of methods.

Over the course of the 12 years, the beavers modify the landscape significantly by damming the water inflow. This in turn increases the area of open water found in the test plot. The canopy layer thins or disappears completely in much of the plot due to tree felling. Soil moisture increases from 34% to 93% and plant species richness increases by an average of 46% in the beaver-influenced habitat, resulting in much greater diversity than found in the control plots. The types of plant species present also shift dramatically. By the end of the 12-year study period, the habitat is dominated by shallow wetland plants. Meanwhile, nitrophiles decrease significantly. Overall, habitat heterogeneity increases. This study demonstrates that beavers can help restore a depleted landscape by altering the conditions, allowing a multitude of plant species to thrive. Law *et al*. warn that the beavers’ ability to flourish will be limited by the amount of woody vegetation available to feed them. Furthermore, the implications of rewilding are not fully understood. It can be foreseen that there will be consequences of rewilding (like increased beaver-human conflict) because beavers will disperse when given the opportunity, but these consequences will likely extend past scientists’ understanding at this time. That being said, beaver rewilding has been illustrated to be an effective strategy to passively restore wetlands in depleted landscapes.

Majerova, M., Neilson, B. T., & Roper, B. B. (2020). Beaver dam influences on streamflow hydraulic properties and thermal regimes. *Science of The Total Environment*, *718*, 134853. https://doi.org/10.1016/j.scitotenv.2019.134853

Milada Majerova and Bethany Neilson of the Department of Civil and Environmental Engineering at Utah State University along with Brett Roper, of the Department of Watershed Sciences at Utah State University and a part of the Fish and Aquatic Unit of the U.S. Forest Service study the feedbacks and interconnections between river hydraulics, temperature regimes, and river geomorphology at multiple scales in response to the presence of beavers on the landscape. In general, beaver dams and beaver ponds decrease river flow velocity, allowing sediments in the river to be deposited. This fundamentally alters the geomorphic patterns within the river, which in turn is a deciding factor in what the surrounding habitat looks like. This can then alter temperature regimes. Majerova *et al*. want to get a deeper understanding of whether there is a “consistent relationship” between these river properties, so they conduct a study on a first-order headwater stream called Curtis Creek, located in northern Utah. Three beaver dam complexes are present in Curtis Creek as the team undertake the study. They take measurements of the river at the reach scale, the beaver dam complex scale, and the geomorphic unit scale. They gather data on topography, water depth, water velocity, water temperature, and air temperature. They use software to map the channel type and morphology and they run regressions to determine whether a relationship exists between these river characteristics.

By comparing the characteristics of the river free of beaver influence with the beaver impacted reaches, Majerova *et al*. are able to assess how beavers impact the hydrology, geomorphology, and temperature regimes in Curtis Creek. Beaver complexes and reaches have very similar characteristics for flow depth and velocity with a “50% increase in depth and 31% decrease in velocity when beaver dams are present.” There is a large amount of temperature variability but there remains some consistency based on the geomorphology of the given unit. For example, riffles above and below beaver ponds show little variation in temperature associated with water depth, but plant life quickly turns over (low residence time). Temperature regimes are also characterized by unique hydrology which is deeply connected to geomorphology. Overall, Majerova *et al*. find that variability in geomorphic units and associated hydrology can cause large temperature fluxes (of up to 10.5 degrees Celsius at the complex scale). This creates unique habitat heterogeneity, which in turn supports a variety of organisms. The team stresses the importance of studying these relationships at multiple levels.

Dalbeck, L., Hachtel, M., & Campbell-Palmer, R. (2020). A review of the influence of beaver Castor fiber on amphibian assemblages in the floodplains of European temperate streams and rivers. *Herpetological Journal*, *30*(3), 135–146. <https://doi.org/10.33256/hj30.3.135146>

Germany’s Dalbeck and Hachtel of the Biological Institute of Conservation, and Campbell-Palmer of Edinburg, undertake a literature review examining the relationship between beavers, their associated landscape modification, and the impact on amphibian populations living in low-order temperate riverscapes in Europe. Beavers change the structure, hydrology, and water chemistry of rivers, all of which can impact amphibians significantly. This relationship is important to understand as many amphibians living throughout temperate Europe are currently endangered. The team begins by classifying amphibians into 4 groups: pioneer species, open country species, forest species, and ubiquitous species. They catalogue these according to the specific habitat needs of each species. In total, Dalbeck *et al*. catalogue 19 species of amphibians mentioned among the literature.

They observe that species richness is highest in beaver ponds associated with low order rivers (many reviews of low-order rivers demonstrate that low-order rivers have significant species richness of up to 9 species in one pond), and that the presence of amphibians depends on the hydrological/morphological condition of the river and the distribution of the species. 10 of the amphibian species analyzed were found in more than 50% of the beaver ponds. The common frog and moor frog are found in high densities. The wide-ranging common frogs, common toads, water frogs, moor frogs, and smooth newts are detected in many beaver ponds, in part because they are widely distributed across the landscape. The other 14 species detected are far rarer and less abundant in beaver ponds throughout Europe. The data indicates that beaver ponds and wetlands are critical habitat for amphibians in Europe.

Anderson, N. L., Paszkowski, C. A., & Hood, G. A. (2015). Linking aquatic and terrestrial environments: Can beaver canals serve as movement corridors for pond-breeding amphibians? *Animal Conservation*, *18*(3), 287–294. https://doi.org/10.1111/acv.12170

Biologists from the University of Alberta, Anderson *et al*. want to know whether amphibians utilize beaver canals dug within the soft substrates lining riverbeds throughout Miquelon Lake Provincial Park located in Alberta Canada. Specifically, they want to know how beaver canals play a role in dispersal during the transition of wood frogs from aquatic-dwelling young to terrestrial adults. They hypothesize that beaver canals act as “movement corridors for pond-breeding amphibians during their initial juvenile movements and adult migrations.” Anderson *et al*. follow beaver canals connecting to 6 beaver ponds to riparian feeding grounds in Miquelon Lake Provincial park, capturing newly metamorphosed wood frogs with 4.5-meter-long fences spanning along the edge of the ponds and observe during visual encounter surveys.

In 2011 they count 3273 young of the year and 71 adult wood frogs, and in 2012 they count 1200 young of the year (YOY) and 208 adult wood frogs. There are significantly more individuals of both stages found on the inside of the fence than the outside of the fence facing the bank. There are significantly fewer YOY encountered further away from the pond, decreasing with decreasing proximity. However, based on the visual encounter surveys, YOY and adult wood frogs are significantly more abundant (for YOY this was 6-9x more abundant) along beaver canals than they are on “unmodified shorelines.” Anderson *et al*. suggest that habitat heterogeneity created by beaver canals is crucial for migration and contributes to overall habitat connectivity for wood frogs, and likely amphibians more broadly. This bodes well as the scientific community has become concerned over amphibian extinctions and increasing habitat fragmentation. Anderson *et al*. finish by noting that although beaver dams could cause some problems, beavers can also facilitate amphibian habitat restoration.

Washko, S., Roper, B., & Atwood, T. B. (2020). Beavers alter stream macroinvertebrate communities in north-eastern Utah. *Freshwater Biology*, *65*(3), 579–591. <https://doi.org/10.1111/fwb.13455> Washko and Atwood, of the Department of Watershed Sciences at Utah State University and Roper of the USDA Forest Service investigate whether macroinvertebrate communities differ between beaver-impacted and beaver-free rivers in Utah, inferring that if they do, this could alter the entire food web and functionality within the riverine ecosystem. Macroinvertebrates are essential within the ecosystem because they “control detritus processing and nutrient cycling in streams, [and] influence stream primary productivity.” Washko and Atwood carry out their study on three nearby rivers located in Utah called Right Hand Fork, Spawn Creek, and Temple Fork, each river characterized by unique habitat features. They compare moderate-moving lotic habitats to habitat directly upstream of the beaver impoundments during the summer of 2017, sampling for elevation, dissolved oxygen, water temperature, water flow, water depth, surface area, and the size of sediments grains found in the riverbed. They also collect one macroinvertebrate sample at each site.

They find that the macroinvertebrate density and biomass are 75% and 90% higher respectively in lotic habitats than in beaver habitats. Species diversity is also significantly higher in all of the lotic habitats. Mayflies and caddisflies are among a few species much more abundant in lotic reaches while *Psychoglypha, Lepidostoma,* and caddisfly/Chironomidae larvae are significantly more abundant in beaver ponds. Overall, beaver do alter macroinvertebrate communities, although how these communities are altered is, to a degree, site specific. This suggests a real change in river functionality. Washko and Atwood assert that these relationships demand further study.

Hood, G. A., & Larson, D. G. (2014). Beaver-Created Habitat Heterogeneity Influences Aquatic Invertebrate Assemblages in Boreal Canada. *Wetlands*, *34*(1), 19–29. <https://doi.org/10.1007/s13157-013-0476-z>

Glynnis Hood, a freshwater and wetland ecologist who teaches at the University of Alberta and colleague David Larson present a study regarding beaver and how they alter the biotic and abiotic characteristics of wetland habitat, impacting the diversity of aquatic invertebrates and the functional feeding groups present in Miquelon Lake Provincial Park, Canada. They survey 8 active beaver ponds and 8 inactive beaver ponds within the park from 2008-2010 in order to compare whether invertebrate abundances and taxa are different in beaver environments. They measure for wetland area, depth, and water chemistry and collect invertebrate samples randomly within each of the 16 wetlands.

Wetland channels and pond depths are on average deeper in the beaver environments, although Hood and Larson suggest that water depth is not a determining factor in aquatic vertebrate distribution. The team collects 46 species of invertebrate during the study. The taxa *Daphnia* is by far the most abundant throughout the study, represented in both beaver active and inactive wetlands. *Gerridae* and *Gyrinidae* are found only in beaver channels associated with active beaver wetlands. Contrastingly, *Culicidae* larvae (mosquito) are positively correlated with inactive beaver habitat, and Hood and Larson believe that beavers actually decrease the amount of habitable habitat for larvae by keeping pools deeper. Predator invertebrates are the most abundant in both wetland types followed by collector-gatherers, but species diversity is overall higher in the active beaver habitat. The study suggests that active beaver wetland and beaver channels are important for many species of invertebrates.

Bush, B. M., Stenert, C., Maltchik, L., & Batzer, D. P. (2019). Beaver-created successional gradients increase β-diversity of invertebrates by turnover in stream-wetland complexes. *Freshwater Biology*, *64*(7), 1265–1274. https://doi.org/10.1111/fwb.13302

Bush *et al*., entomologists and scientists from the laboratories of Ecology, Monitoring of Aquatic Invertebrates, and Conservation of Aquatic Ecosystems in Georgia (USA) and São Leopoldo, Brazil, want to know if the successional gradient associated with beaver complexes has a significant impact on invertebrate beta diversity. They carry out their study in Piedmont, Georgia where the unstable environment has contributed significantly to creating a “mosaic” of successional stages within the beaver wetlands. They categorize 4 different successional stages: stream channels, newly created ponds, mature ponds, and abandoned ponds. In 2013 and 2014, they collect invertebrate population samples during May and October (Spring and Fall) in two beaver wetland complexes, each of which supports all 4 of the defined successional stages. Bush *et al*. then compare beta diversity of invertebrate populations in the beaver wetland complexes to beta diversity found upstream in the same catchment free of beaver influence.

Overall, abandoned wetlands have higher species richness than the other stages. In Spring, only the mature wetland stage supports a unique community of invertebrates, while in the fall, invertebrate communities have distinct structure between all of the successional stages excluding new wetlands versus abandoned wetlands and new wetlands versus mature wetlands. Beta diversity is high in all successional stages within the beaver wetland complexes and can be explained by the change in successional stage. In summary, each successional stage supports unique species of invertebrates, and are therefore deemed very important within the landscape. Bush *et al*. finish by noting that beavers could certainly be used as a management strategy to restore wetlands and associated biodiversity throughout the United States and beyond.

Nummi, P., Kattainen, S., Ulander, P., & Hahtola, A. (2011). Bats benefit from beavers: A facilitative link between aquatic and terrestrial food webs. *Biodiversity & Conservation*, *20*(4), 851–859. https://doi.org/10.1007/s10531-010-9986-7

Nummi, from the Department of Forest Ecology at the University of Helsinki (Finland) and him team undergo a study to identify whether beavers might be a natural management strategy to conserve bat populations that rely on ever-declining wetland habitat for food and roosts. Many species of bats from the suborder Microchiroptera are insectivores that forage for insects in riparian areas where hunting is generally “low risk.” Importantly, habitat alterations caused by beaver can change stream structure and function, influencing which plant and animal species (insects included) can live in the riparian zone. Beaver make key nutrients available to organisms at the bottom of the food chain which can theoretically have a positive bottom-up effect on bats. However, this relationship is not fully understood and has become the task of Nummi *et al*. to identify. They study a boreal stream in Finland composed of about 100 ponds. They observe 11 control ponds (beaver free) and 11 active beaver ponds over the course of 3 years. They observe bats during the summer months from 2001-2003 by randomly selecting 2 spots on each pond to observe from. They specifically watch for signs of group foraging. The team use echolocation detection devices to identify and record bats.

Two species of bats (*Eptesicus nilssoni* and *Myotis daubentoni*) are observed. The bats prefer foraging over the active beaver ponds and flowages as opposed to the beaver-free ponds, often foraging in groups of 2-4 individuals. Bat abundance is also greater at the active beaver pond locations, specifically over beaver flowages. Nummi *et al*. infer that this pattern is associated with a larger number of insects in beaver habitats than in beaver free zones (previous studies in the area have exhibited that “emerging insects are 5 times higher in beaver flowages than in other water bodies”), although they have no direct evidence supporting this inference. Nummi *et al*. suggest that there could be other methods undertaken to increase insect populations for vulnerable and endangered bat populations but that beaver reintroduction is one strategy that requires minimal human effort and comes with other benefits as well: beavers are an important link between aquatic and terrestrial organisms and food webs.

Sroka, J., Giżejewski, Z., Wójcik-Fatla, A., Stojecki, K., Bilska-Zając, E., Dutkiewicz, J., Cencek, T., Karamon, J., Zając, V., Kusyk, P., Dąbrowska, J., & Kochanowski, M. 2015). Potential role of beavers (Castor fiber) in contamination of water in the Masurian Lake District (north-eastern Poland) with protozoan parasites Cryptosporidium spp. and Giardia duodenalis. *Bulletin of the Veterinary Institute in Pulawy*, *59*(2), 219–228. https://doi.org/10.1515/bvip-2015-0033

As researchers in the fields of parasitology, veterinary sciences, biological health hazards, and invasive diseases, Sroka *et al*. are well qualified to investigate the risks that beaver pose to human health through the transmission of water-borne zoonotic diseases, in particular, *Cryptosporidium* and *Giardia*. Their study takes place between the years of 2010-2014 in the Masurian region of northeastern Poland where beaver populations are abundant. Water samples are taken from 14 bodies of water where beaver live in this region. Samples are taken at 3 distances from beaver lodges (zone 1 at 0-2 meters, zone 2 at 10 meters, zone 3 at 30-50 meters) to identify if contamination risk changes in regard to proximity to the lodges. Samples are collected in the spring and autumn to determine if there is seasonal variation in risk.

Of 79 water samples collected, 45.6% contain *Cryptosporidium* oocysts and 32.9% have abundant *Giardia* cysts. *Giardia* cyst density is four times greater in the spring than in the fall. *Cryptosporidium* oocysts are highest in density in the fall. For *Giardia*, cyst density is highest in zone 1 (0-2 meters from the lodge) and lowest in zone 3 (30-50 meters from the lodge). This suggests that beaver are directly responsible for contaminating the water with *Giardia*. Contrastingly, *Cryptosporidium* oocysts are much higher in zone 3 (30-50 meters from the lodge) than anywhere else, meaning that this contamination may not be directly related to beaver presence. However, Sroka *et al*. emphasize that parasitic protozoans are present in the studied beaver waters and therefore, they do pose a risk to human health.

Girling, S. J., Naylor, A., Fraser, M., & Campbell‐Palmer, R. (2019). Reintroducing beavers Castor fiber to Britain: A disease risk analysis. *Mammal Review*, *49*(4), 300–323. https://doi.org/10.1111/mam.12163

Scientists from the veterinary department at the Royal Zoological Society of Scotland, Girling *et al*. undertake a literature review to identify whether the reintroduction of beaver into the U.K. might pose a risk to human health, as many rodents (including beavers) have been known to be hosts or vectors of zoonotic disease. The team uses Disease Risk Analysis as prescribed by the IUCN guidelines in an effort to stem transmission of diseases associated with wildlife reintroduction. Disease Risk Analysis has four steps: 1) problem description, 2) hazard identification, 3) risk assessment, and 4) risk management which Girling *et al*. carry out using data from existing scientific literature. The team categorizes risks based on the “hazard severity” and “likelihood of occurrence” and rank them as low, medium, or high risk. If risk is medium or high, the team collected data on testing methods available.

Girling *et al*. categorize haemoparasites, endoparasites, ectoparasites, bacterial pathogens, fungal pathogens, and viral pathogens associated with beaver that are addressed in the literature. Ultimately, the pathogens at highest risk of transmission from beavers to humans or beavers to other wildlife/livestock are “*Cryptosporidium parvum*, *Echinococcus multilocularis*, *Eimeria* spp., *Fasciola hepatica*, *Giardia* spp., *Trichinella britovi*; [several] bacteria, specifically *Escherichia coli*, *Franciscella tularensis*, *Mycobacterium avium*, *Salmonella* spp., *Yersinia* spp.; a fungus *Chrysosporium parvum*; and terrestrial rabies virus.” Girling *et al*. recommend that each individual beaver in line for reintroduction be tested for these before they are reintroduced to minimize possible transmission. They also suggest that the U.K. introduce captively bred individuals or individuals from areas where these pathogens have not been identified. Ultimately, the team asserts that while there is some risk of transmission, the risk to health is low, and it would feasibly remain low as long as strict reintroduction procedures were followed.

Baker, B. W. (2003). Beaver (Castor canadensis) in heavily browsed environments. *Lutra*, *46*(2), 173- 181.

Bruce Baker of the U.S. Geological Survey studies the trophic cascades present within the Rocky Mountain National Park in Colorado (a case study) to illuminate how these relationships can impact where beaver will be on the landscape and whether they will be able to persist. Baker is concerned that thriving and unchecked elk populations are decimating riparian areas where beaver feed upon willow. Baker suggests that beaver forage processes actually stimulate willow growth, thus creating a mutualistic relationship between these two species, a relationship that could “collapse” under feeding pressure from large ungulates such as elk and deer. He asserts that grazing management could help restore riparian habitat by acting as a control on ungulate populations, allowing beavers to harness their mutualistic relationship with willow, thereby stimulating riparian regrowth.

Grazing management could mean putting predator controls on ungulate populations or allowing hunters hunting privileges. Baker also suggests that the development of alternative water resources could help reduce ungulate grazing on riparian vegetation along riverbanks. Baker cites a case from 1975 when the Bureau of Land Management was able to restore the deeply incised Douglas Creek Watershed by: a) prohibiting cattle grazing in some areas along the river altogether, b) creating other water resources for cattle to utilize, and c) demanding that ranchers utilize rest-rotation systems to allow riparian vegetation to rejuvenate. When beaver were reintroduced into the area, riparian vegetation was thick enough that the beavers were able to persist, facilitate the growth of new vegetation, and help restore the incised river through the construction of multiple dams.

Westbrook, C. J., Ronnquist, A., & Bedard‐Haughn, A. (2020). Hydrological functioning of a beaver dam sequence and regional dam persistence during an extreme rainstorm. *Hydrological Processes*, *34*(18), 3726–3737. https://doi.org/10.1002/hyp.13828

Westbrook and Ronnquist of the Center for Hydrology at the University of Saskatchewan and Bedard-Haughn, of the Department of Soil Sciences, also from the University of Saskatchewan provide one of the first looks into “beaver dam persistence and water storage capacity during floods.” This topic has become increasingly important to the scientific community because evidence suggests that dams are most vulnerable to breach events during floods, and floods are projected to become more frequent and severe due to climate change. Many scientists argue that beaver ponds cannot attenuate much water and therefore pose a risk to human safety. Westbrook *et al*. hoped to quantitatively measure the risks associated with beaver ponds and associated floodwater attenuation. Their study is based on a natural experiment that occurred in Kananaskis County, Alberta, Canada in 2013 when a massive flood comes through, wiping out much in its wake. The flood is labeled “disastrous” and is estimated to be at least equivalent to a 40-year flood. A hydrometeorological station located in Kananaskis County has been able to measure the hydrological characteristics of the flood, gathering information on weather and precipitation for some time before the event occurs. The team is on site when they hear a flood event is on the way. They are able to install water level loggers before the flood begins within Bateman Creek. The team has also already collected data on beaver dam locations throughout the region, amounting to 74 dams. Following the flood, the researchers travel to each dam and classifies them based on their breach and damage status.

194.6 mm of rain fell from June 19-22 in the 2013 storm event. The water table reaches 0.492 meters above ground level and saturates the soil to a depth of 0.25 m. They monitor 3 dams during the flood. During the flood even, water rises above the peak of each of the dams. One of the three dams breaches, which results in an outburst flood. Stream discharge peaked at 1.443 m3/second. Across the county, the team finds that “42% of the beaver dam cascade systems they study persist after the event, 32% are breached, and 26% persisted but are affected.” Dams are more likely to persist in wide valleys. Failure is not explained by the amount of rainfall at each site. Further, persistence links to beaver pond fullness at the time of the flood event. Ponds at less of their full storage capacity to begin with attenuate much more water and dams are less likely to fail. Contrary to popular belief, the results indicate that beaver ponds do attenuate a significant amount of floodwater, decreasing flood risk downriver, and that beaver dams are relatively resistant to destruction and breaches during flood events. Overall, Westbrook *et al*. assert that while beavers aren’t the end all solution, they can significantly help in flood water attenuation and therefore should be included in flood management strategies.

Puttock, A., Graham, H. A., Cunliffe, A. M., Elliott, M., & Brazier, R. E. (2017). Eurasian beaver activity increases water storage attenuates flow and mitigates diffuse pollution from intensively-managed grasslands. *Science of The Total Environment*, *576*, 430–443. <https://doi.org/10.1016/j.scitotenv.2016.10.122>

Scientists of geography and wildlife biology from the United Kingdom, Puttock *et al*. are interested in how reintroduced beaver and beaver dams impact water quality, water storage, and water pollution associated with “intensively managed grasslands” in Devon, southwest England. The study takes place on a controlled 23-hectare site on a first order river beginning in March 2011. Before the reintroduction, the team takes measurements of pond surface area, pond depth, water quality, and flow velocity. Upon reintroduction, they retake these measurements above and below beaver dams to identify whether they can or cannot reject null hypotheses associated with their three alternate hypotheses stated as follows: “H1. Beaver constructed features including dams, canals and burrows/ lodges, significantly increase water storage within the landscape. H2. Beaver dams significantly alter flow regimes resulting in attenuated storm flows. H3. Beaver ponds act as sinks for diffuse pollutants, significantly improving water quality downstream.”

The beavers construct 13 dams which significantly increase the pond surface area and volume of water stored behind the dams. The dams do attenuate flow, slowing water velocity significantly. Sediment loads in the water measure lower directly below the dams as opposed to above the dams. Sediments and associated nutrients accumulate behind the dam, thus improving water quality downstream. Puttock *et al*. assert that more research needs to be done, but they hope their study helps support the idea that beavers might be used as a “nature-based solution” in the management of lands and waters.

Butler, D. R. (1989). The failure of beaver dams and resulting outburst flooding: A geomorphic hazard of the southeastern Piedmont. *The Geographical Bulletin*, *31*(1), 29–38.

David Butler is a professor in the department of geography at Texas State University, sporting a PhD in geography from the University of Kansas. He specializes in geomorphology and biogeography. In 1989, Butler undertakes a review of case studies regarding the impacts of flooding associated with beaver dam failures in Piedmont, located in the southeastern United States following beaver reintroductions in the 1930s-1950s. Butler asserts that beaver dams fail when “stream discharge reaches a critical strength threshold,” a threshold that has not been measured nor quantified. That said, beaver dam failures are most associated with short, intense, and localized thunderstorms as opposed to other rainfall or snowmelt events that represent the main cause of failure in other types of natural dams (like glacial or landslide dams).

In 1969, scientist Pullen studies a series of beaver ponds located in Georgia and South Carolina. Pullen observes that the surface area of one of the ponds he has been studying, Dyer Pond, shrinks from 4 to 0.2 acres, dropping 3 feet in depth following a sudden dam breach. Butler utilizes a regression equation created by Cutler (1985) to predict the maximum discharge associated with dam failures. He calculates the maximum discharge for Dyer Pond to be 62 m3 sec-1. Butler describes other records of cars being washed away and granite blocks “being moved like cotton balls” as a result of flood waves from failed beaver dams in Georgia. Butler finishes by noting the importance of having beavers and beaver dams on the landscape, but noted that dam failures can cause serious flooding and damages.

Janiszewski, P., & Hermanowska, Z. (2019). Damage Caused by the European Beaver (Castor fiber L.) in Agricultural and Forest Farms in View of Selected Atmospheric Factors and Animal Behavior. *Applied Ecology & Environmental Research*, *17*(6), 15633–15642. <https://doi.org/10.15666/aeer/1706_1563315642>

Janiszewski and Hermanowska of the Department of Fur-Bearing Animal Breeding and Game Management at the University of Warmia and Mazury in Poland present a study on the types of damages caused by beavers to farmlands in northeastern Poland from the years of 2009-2016, and the economic implications this has on the area. They also want to know if there is a relationship between beaver behavior and weather conditions in the area. Janiszewski and Hermanowska feel this study is important because it is clear that beavers can have a substantial impact on the environment: from selective tree felling, altering the composition of forests, to flooding that causes landslides in the region. They utilize data collected by the Regional Directorate for Environmental Protection in Olsztyn where citizens report damages and types of damages to their property from beaver activity and where they file compensation claims. Janiszewski and Hermanowska also access data logs of annual precipitation and annual mean temperature.

Over the course of the study, the number of compensation claims increases significantly from 640 to 1807 in the span of four years. Janiszewski and Hermanowska infer that this might be due to increasing beaver populations. They also compare damage types proportionally, finding that 53% of the claims are due to flooding of meadows and pastures, 40% are related to the loss of forested lands from flooding or tree felling by beaver, and a small proportion relate to the loss of cropland from beaver activity. Claims are filed more frequently in the spring and summer when beavers are most active and when croplands are most fertile, indicating that perhaps more notice is given to private lands during this period. Janiszewski and Hermanowska assert that there could be a positive correlation between the weather and the severity of beaver damages. Although the results are not significant, Janiszewski and Hermanowska find that higher temperatures are associated with greater beaver activity and dam building, which in turn result in greater flood damages. Overall, beaver activity causes substantial economic damage. A study of 709 filed claims in the same area between 1995 and 1997 result in compensation payments totaling US $141,000. Although the total economic compensation is not stated for Janiszewski and Hermanowskas’ study, it can be inferred that the compensation might be much greater based upon the significantly greater number of claims, the larger beaver population, and inflation.

***Research Paper***

**During COVID-19, perspective from nature reduces rumination and benefits mental health**

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**ABSTRACT**

**Introduction:**

Recent research suggests that exposure to nature may reduce ruminative thinking, which is associated with anxiety, depression, and suicidal thoughts. Yet though this phenomenon has been observed, the mechanism behind it is not clear: *why* does nature reduce ruminative thinking? We suggest that the non-material benefit of perspective from nature counteracts ruminative thinking in several ways.

**Methods:**

We analyze responses to open-ended questions in a survey (n=3204) focused on how residents of Vermont, USA, experienced nature during the height of the COVID-19 pandemic. We use qualitative coding and content analysis techniques to identify instances of “perspective from nature,” which we define as an increased, or more accurate, sense of where one ﬁts and what is important (what some people call a “reality check”).

**Results:**

We find 511 instances of participants mentioning concepts related to perspective. Within these references to perspective, we identify seven sub-categories: specific references to reducing rumination; explicit mentions of perspective; humility—drawing out of the self; humility—sense of scale; importance and priorities; grounding; and cycles and continuity.

**Discussion:**

Participant comments related to perspective resonate substantially with existing research on factors that may reduce rumination.

**Conclusion:**

Naming concepts can help to identify them and create guidance for future study. We name and define “perspective from nature,” and hope that this encourages future research into the concept. Our results suggest that nature access and the perspective-related benefits that arise from it may play an important role in maintaining societal health, perhaps especially in tumultuous times.

**INTRODUCTION**

Extensive research demonstrates that exposure to nature benefits mental health and cognitive function.1–4 The phenomenon is clear; what is less clear is the mechanism. We know that nature is helping people to cope with the tensions of the COVID-19 pandemic.5–7 In this article, we analyze peoples’ reflections on how nature helps them during the pandemic to offer a unique window into understanding *why* nature is so beneficial for mental health.

This unique view into this mechanism may arise because, as with so many other issues, the pandemic strips away window dressing and lays bare underlying structures.8 We conducted a survey about people’s interactions with nature during the pandemic, and responses resonate strikingly with emerging research that explores potential mechanisms of nature’s benefits to mental health. Below, we describe this emerging research, then present results from our survey that lend explanatory power to previous experimental findings. We suggest that the clarity inspired by the pandemic may lead to a concise conceptual advance in our understanding of why nature is so helpful.

Research suggests a potential reason that nature exposure helps mental health: nature exposure reduces rumination.9 Rumination is defined as “the process of thinking perseveratively about one’s feelings and problems” (p 400).10 Research shows that rumination predicts multiple undesirable conditions: depression, anxiety, substance abuse, and eating disorders.10 Rumination is also strongly connected to suicidal ideation (thinking about suicide) and provisionally connected to suicide attempts.11

Experimental research that suggests the mechanism of rumination as an explanation of nature’s healing qualities is in its early stages. A study that explores this mechanism found that rumination – both self-reported and as measured by MRI – was lower for participants who walked in a natural area versus a city street. 9 A later study, this one based on qualitative data about how nature benefits people, suggested a “meta-mechanism” – i.e., a reason that nature may reduce rumination. The study found that being in nature provides “perspective:” nature helps people transcend their personal problems and situations and gain perspective on the world. 12 This increased sense of perspective supersedes (or makes more difficult) self-focused, circular rumination.

During the first few months of the COVID-19 pandemic in the United States, we conducted a large-scale survey focused on peoples’ experiences of nature during the pandemic (we surveyed residents of Vermont, USA). Responses to multiple open-ended questions strikingly and resoundingly support the mechanism suggested by a combination of past research: that nature exposure increases perspective and relatedly decreases rumination. This increase in perspective and corresponding decrease in rumination, in turn, may account for many of the mental-health benefits of nature. Here we briefly present these results and give ample voice to peoples’ own descriptions of *why* nature is helpful – i.e., in psychological terms, the mechanism behind nature’s positive impact on their mental health.

**PANEL – RESEARCH IN CONTEXT**

**Evidence before this study**

To find studies that address precisely our study topic, we searched Web of Science and Scopus for studies related to “rumination” AND (“nature” OR “outdoor\*” OR “environment\*”) (end date: Aug 30, 2020). We found only one study that addressed this intersection (we excluded studies for which “environment” did not indicate the “natural environment”). To find studies that pertain to rumination and its causes and impacts, we used recent and highly cited reviews on rumination.

**Added value of this study**

This study corroborates and greatly expands upon findings from the one experimental study that suggests that nature reduces rumination. Qualitative analysis illuminates *how* nature may reduce rumination: through providing a sense of perspective.

**Implications of all the available evidence**

This study confirms suggestions that rumination reduction is a mechanism behind nature’s mental health benefits, but many questions remain. A primary outstanding area of inquiry relates to the details of the “nature” that provides rumination reduction: Do amount or type of “nature,” or duration of exposure, matter?

**METHODS**

We conducted a survey about why nature matters to people during the pandemic. People learned about our survey through paid advertisements on a state-wide email listserv (54% of respondents); via social media and email networks of partner organizations (environmental NGOs and government agencies) (41% of respondents); and friends and family (5%). We incentivized participation by entering respondents (of the survey analyzed here and a follow up in October 2020) into a raffle for one of 20 $50 gift cards. The survey ran from May 3-19, 2020, through the last two weeks of Vermont’s “Stay Home Stay Safe” executive order. This yielded a convenience sample of 4,826 responses; we excluded incomplete responses and respondents who were not Vermont residents over 18 years old for a final sample of 3,204 complete, valid responses. Our sample’s demographics were very similar to those of the Vermont population in most ways, but female and urban respondents are slightly over-represented and low-income and non-White respondents are slightly under-represented.

The survey took 16.5 minutes to complete, on average (median time was 12 minutes). Items inquired after multiple types of pandemic-related changes in nature interaction; these included changes in nature-related activities or distance travelled to partake in them; reactions to restrictions on nature access; and changes in 13 nature-related values or ways that nature benefits people (e.g., recreation, social interaction, mental health). We also asked people to complete the 1-item Inclusion-of-Nature-in-Self scale 13 and collected basic demographic information. At the bottom of each survey page, we asked an open-ended question and allowed respondents to enter written responses. Table 1 presents the open-ended questions and the survey sections they followed.

**Table 1.** List of open-ended questions used in the survey and a brief description of survey sections they followed.

|  |  |  |
| --- | --- | --- |
| **Survey section** | **Description of section** | **Open-ended question** |
| **Nature use** | Participants selected their frequency of participation in 15 outdoor activities in a typical month, compared to the same time last year | Are there any other ways that the COVID-19 restrictions have altered your participation in these activities? If so, tell us how. |
| **Nature values** | Participants rated their level of agreement with 13 value statements about how they related to nature during COVID-19 restrictions. Then, they could rank up to three value statements that were most true for them during COVID-19 restrictions | Feel free to explain your selections if you like. Why did you choose the one(s) you chose as more important to you now, during COVID-19 restrictions? |
| **COVID-19 restrictions** | Respondents answered 4 questions about their experience of nature given the current COVID-19 restrictions | Is there anything else you would like to tell us about how the COVID-19 restrictions relate to your experience of nature? |
| **Inclusion-of-Nature-in-Self Scale** | Respondents selected the set of two circles that they feel best describes their relationship with the natural environment (Schultz 2002) | We have one final question about nature and COVID-19. Is your experience of nature more or less meaningful to you right now, during the COVID-19 restrictions? If so,  can you tell us why or why not? |

Analyses for this paper include descriptive statistics for the values-related items, but focus on responses to the survey’s open-ended questions (Table 1). We analyzed all open-ended responses together (i.e., did not distinguish between responses to the different questions). We used NVivo qualitative analysis software (QSR) to facilitate coding, which we completed using a hybrid from of thematic coding and content analysis.14,15 First, we read through all data to code for a few themes selected *a priori*: 1) identification with urban/rural landscapes, and definition of social arenas; 2) feelings of loss, enrichment, fear, change, and gratitude; 3) discussion of mental health, physical wellbeing, spiritual value, aesthetic value, or unchanged values related to the pandemic; 4) identification with remote or essential worker status; 5) obedience/disobedience, frustration, and impressions of other people in relation to social distance restrictions; and 6) change in meaningfulness of nature relationships.

We then reflected on these results (which we do not directly use in this paper) and noticed a distinct pattern of people discussing aspects of the construct of perspective, defined as an increased, or more accurate, sense of where one ﬁts and what is important (what some people call a “reality check”).12 We combined our experience with the data and our knowledge of the literature on rumination to create a codebook comprised of seven aspects of perspective. In a second stage of coding, re-analyzed all qualitative data to code for comments related to perspective. We coded comments to multiple perspective-related themes when appropriate.

**RESULTS**

Participants rated and ranked 13 benefits from nature during the pandemic. Participants rated mental health highest (6.63 of 7) and ranked it within the top three benefits changed by the pandemic by far most often (72%; the next highest such ranking (i.e., benefit ranked in the top three most important during the pandemic) was a tie between beauty and exercise, both at 36%).

Qualitative analysis of responses to open-ended questions suggests that an important reason for nature’s impact on mental health relates to an expanded sense of perspective. The concepts listed below, taken together, provide a rich and enlarged understanding of the idea of “perspective” from nature.

**Aspects of nature’s perspective-providing qualities**

In free-response items in our survey, we coded participant comments to one of the perspective categories listed below 533 times. These instances came from 388 different people (because we sometimes coded multiple comments from the same person). We divided these instances into seven categories. Below we describe each category and provide examples of how each was evident in people’s reflections during COVID-19.

*Specific reference to reducing rumination.*Some participant comments identify how nature reduces rumination (without using that word). Participants described how nature decreased anxiety, worry, and focus on their own concerns and issues – all states closely associated with rumination. Examples include: “being out in nature is a way to distract my mind from anxious thoughts, more so now than before the pandemic” and “I find [being in nature] is one time I can count on to get out of my head and focus on the beauty that surrounds me.”

Scholars of rumination describe two types of rumination: brooding (which focuses on reasons for distress) and reflection (which focuses on consequences of distress).11 It was often difficult to distinguish brooding from reflective rumination, but we found evidence of both. Examples of nature reducing *brooding* rumination include: “Grounding myself in a natural setting can stop trains of thought about falling skies and other things outside of my control” and “[nature] helps to counteract all the negativity and fear in the media and in the world and my own fear of the unknown and fear of where this is all leading and how this will affect my loved ones.” Another provided an example of nature reducing *reflective* rumination: “right now [nature] is vital for keeping me from sinking into deep depression. My job will end on June 30th and the prospects of a new job are not great so I am very concerned about how I will live in the future. When I start to feel overwhelmed with fear and anxiety I go for a walk in the woods or by the lake and that grounds me and helps me to feel safer. … Nature is my medicine, my religion.”

The remaining categories capture aspects of perspective that likely contribute to rumination reduction.

*Explicit mentions of perspective.* Many respondents used the *word* perspective in describing why nature mattered to them during the pandemic. Respondents’ comments often encapsulated our definition of perspective (i.e., that nature helps people transcend their personal problems and situations and gain perspective on the world). Two respondents wrote, for instance, that time in nature “is paramount to keeping the larger picture in perspective” and “provides me with a sense of perspective regarding my place in the grand scheme of things, which I find very important.” One respondent noted that nature experience “helps remind me … that there is a bigger picture, a bigger world beyond my limited perspective.” Another commented that through walks outside, “I get a bigger and better perspective on my life, and feel connected to something bigger than me.”

*Humility*. The core of definitions of humility is a reduced focus on the self and a reduced sense of self-importance.16 Our data contained two clear concepts that are conceptually nested within humility: reductions in egoism (or “drawing out of the self”), and reminders of the world’s grand scale. We treat each as a separate category and elaborate below.

*Humility: Reducing egoism.* Many respondents expressed that nature helped them move away from a more self-focused state. Many described that natures inspires in them a sense of insignificance – a recognition that the world and the Earth’s systems do not revolve around them as an individual. One respondent noted that “being out in nature gives a sense of a larger world that absorbs your life and goes on without you. Personal issues are of no consequence. Being a responsible, caring, and respectful member of [a] community is what matters.” Another reported being “humbled by how life is so much bigger than human experience,” and another that “being in nature reminds me that I am only a small part of the world.” Numerous respondents noted that nature encourages them to draw not only out of their individual self, but out of a more shared human sense of importance and dominance – for example, nature is an “eye-opener” in regard to “human hubris.”

*Humility: Scale.* Another aspect of humility-related perspective stems from nature’s tendency to make people more aware of scale, both spatial and temporal. Many respondents noted that nature reminds them of spatial scale, and in particular their small size relative to the immense world. One respondent wrote that “during a time of such intense stress,” nature serves as a reminder of “how immense my world is and how small a presence in it I am.” Another made the point metaphorically: “Nature helps me see that I am a leaf or a grain of sand, and society is a tree or the entire beach.” Other respondents noted how nature reminds them of temporal scale – specifically, the short span of human life. Two respondents succinctly captured the essence of how temporal scale provides perspective in the comments “that the natural world has been around before me and will go on when I’m gone” and that experiencing nature “put[s] current day issues into a millions of years perspective.”

*Importance and priorities.*Respondents also frequently mentioned that nature helped them to remember what really matters. In a time of turmoil and confusion, many people wrote, nature helped avoid being consumed by more petty concerns. Respondents wrote that being in nature “soothes anxiety and reminds me of what matters” and “maintain[s] my perspective of what is truly important.” Another shared that “the reflection I have had in nature is reminding me of many important things in my life.”

*Centering and grounding.* Many respondents noted that spending time in nature engendered a sensation of groundedness “amidst the 'noise' of the pandemic.” Respondents used the exact words “grounded” or “grounding” often (78 times in total). Their comments conveyed that nature helped them to get a more solid, situated perspective of reality. One respondent stated: “My relationship with nature has kept me grounded, helped me to understand and be comfortable with the lack of control I feel right now.” Another wrote: nature “brings me into the present, reconnects me with my senses and the world around me,” which “is very grounding.” In many cases, examples of “centering and grounding” overlap with discussions of “cycles and continuity.” One respondent wrote that they “felt out of control during COVID-19 and confused/fearful” but that “it is grounding to be outside and witness things that are happening in spite of the world feeling like it has come to a screeching halt.” Another put it simply: “There is something grounding … and reassuring about the constancy of the ever repeating cycles of life.”

*Cycles and continuity.* Many respondents noted that the cycles and continuity inherent in nature reminded them of the bigger picture and brought perspective. The seasonal timing of the pandemic’s emergence in the U.S. played prominently in this category; the height of COVID-19 restrictions, and therefore implementation of this survey, coincided with the height of spring. Given Vermont’s strong seasonality, spring is a time of dramatic change, when rebirth and regrowth are powerfully evident in many ways. One respondent encapsulated this theme in a comment about how observing seasonal rhythms reduced both ruminative single-track thinking and anxiety: “Noting the incremental seasonal changes is soothing, it reminds me that the nonhuman world has its rhythms and dynamics, which helps me shift my focus. All of this has become crucial to managing the anxiety that comes up around the pandemic.” Another more explicitly addressed continuity, noting that “nature is a reminder that life goes on in spite of setbacks.”

**Table 2.** Sub-categories of perspectives and examples

|  |  |
| --- | --- |
| ***Sub-category*** | ***Examples*** |
| Explicit perspective | “Being in nature helps me to understand my place in the overall universe, and with this epidemic it helps me maintain perspective.”    “Being in nature gives me perspective, is calming, and grounds me in what really matters in life.”    “What being out in the woods, and looking at the sky at night, does is give perspective on the views presented on the news.” |
| Specific reference to reducing rumination | “I feel an increasing need to be alone in nature where I am truly alone and happy. That experience really takes me away from all of the troubles of the world and my personal difficulties.”    “Under the stress of the world situation, worrying about my vulnerable relatives and concern for possible job loss the time in nature is my single biggest coping mechanism.”    “I'm very grateful to still be able to get out and enjoy the Natural world, mostly for mental well-being (woods walking draws away tension and offers beautiful sights and sounds to take precedence over social worries).” |
| Humility: Reducing Egoism | “Being able to still access nature - the same hiking/running trails and road bike rides I was able to pre-COVID helps remind me that some things are the same, and that there is a bigger picture, a bigger world beyond my limited perspective.”    “With the isolation, nature helps me feel connected to the world outside my home, and feel a part of something big. I also tend to think of the virus as a part of the world in which we live, and the way it impacts the eco system of which we are a part, not totally in a negative way. Though we humans tend to see it that way since it is attacking us. But there are too many of us on this earth and we humans are having a negative impact on the earth. Being [in nature] helps me see this bigger picture beyond the homo sapien view we usually focus on.”    “[I] it reminds me that people are only a small part of the system on Earth and that nature will carry on with or without humans.” |
| Humility: Scale | “The bigger picture of creation is before us in nature - humanity is but a small part of the whole.”    “Interacting with the natural world helps me remember how ancient the world is and that the current circumstance will pass. I feel very fortunate to have access to the natural world right out my door.”    “[Nature] reminds me that we are a part of something much larger than ourselves, that life continues on even as our current routines are disrupted, and that there is still life all around us.” |
| Importance & Priorities | “The COVID plague is putting us in a position of consciously prioritizing what is meaningful in our lives.”    “As the whole country has been forced to slow down, I think we all are learning or RE-learning to weigh our priorities, and maybe stop and smell those proverbial roses. Personally, I’ve added bird houses to my yard, and am reexperiencing the joy of watching nesting pairs use them, which I did as a young girl with my parents.”    “My experiences in nature help me remember what's important and what's lasting.” |
| Centering & Grounding | “[Nature is] more meaningful, in that it gives me a sense of being grounded in a larger context despite the uncertainty and stress inherent in living during a pandemic.”    “The vulnerability that is palpable has made me appreciate this jewel we have in the natural world. While humans suffer and experience stress, the frogs are still croaking, the turtles are sunning, the geese are laying eggs, the beavers are building dams, and the plants are rising up out of the snow. It is so grounding to know that we can be resilient like nature and rise up out of the snow ourselves.”    “[Nature is] my go to sanctuary that keeps me grounded.” |
| Cycles & Continuity | “Spring is coming, I am listening to the sounds of nature more than ever, watching and documenting the growth of plants, buds, etc. Watching the animals and birds in their springtime rituals as if nothing in the world had changed. I believe my current sanity is being protected by the nature of VT around me.”    “More meaningful. The ability to go outside and commune with the forest, mountains, or a stream bring solace and peace to my life during an uncertain time. If we don't take care of our natural environment and the species that depend on it, we will continually to find ourselves in these pandemic and crisis cycles. Retreating to nature and experiencing nature's cycles reminds me that there is a rhythm and purpose to life outside my own needs.”    “I like knowing that these natural processes continue, in the midst of human turmoil. It puts humanity into perspective and calms me.” |

**Figure 1.** Number of total mentions and number of participants who mentioned each theme.

A picture containing text

Description automatically generated

**DISCUSSION**

Our results suggest, via over 500 coding instances of open-ended responses on a statewide survey, that what we call a sense of “perspective” is a mechanism behind nature’s mental health benefits. Participants’ reflections on how nature benefitted them during the height of the COVID-19 pandemic provide a rich potential explanation for why nature reduces rumination, as neurobiological studies have shown occurs. The pandemic has helped to illuminate this mechanism, and our results suggest that nature access may play an important role in maintaining societal health in tumultuous times.

Though research on factors that reduce rumination is not extensive, existing findings intersect with themes in our data. First, mindfulness-based cognitive therapy reduces rumination, and a core aspect of that practice is to focus on bodily sensations and thoughts without judgement.17 This relates to our finding that nature “grounds” people and helps them to accept reality. Second, a hallmark of rumination is excessive self-focus;18 our findings show that nature-inspired humility directly counteracts excessive self-focus. Third, many respondents described how the perspective nature provides reduces anxiety, which is highly correlated with rumination.19,20

*Limitations and Future research.*Our results—in line with most work on nature’s mental-health benefits—have an important blindspot. The majority of research on the neural benefits of nature has been conducted with W.E.I.R.D. populations (exceptions, specifically important work from Japan and Korea, exist).21–23 As currently conceptualized, W.E.I.R.D. describes participants in Western, Educated, Industrialized, Rich, and Democratic societies.24,25 We add that “W” might appropriately denote not only “Western,” but also “White.” Crucial to the conversation of how nature impacts people is that for some people, going outside *engenders* anxiety – instead of *reducing* it. This is particularly true for people of color in the United States and elsewhere.26,27 This discrepancy is, we argue, the most important future research direction in this field. Our study sample, mirroring the study area population, was overwhelmingly White. Next steps in this research must explore this phenomenon in more diverse contexts, with a focus on how the mental-health benefits from nature may differ for people from different backgrounds and with different racial or ethnic identities. If being outside is scary – especially for reasons related to systemic –isms (e.g., racism, sexism) – it is unlikely that nature will offer the sense of out-of-oneself perspective that our research suggests is so powerful for people who can move freely, without fear, outside. This equity issue, with its spiraling causes and implications,28 is unignorable, especially in our current social-ecological context.

This study suggests many possible pathways for future research. First, the phenomena should be explored in many more contexts, including in societies that are less individualistic than the United States, and therefore where self-focused rumination may operate differently. In addition, when the present study is paired with the experimental study described above (which suggests rumination reduction as a mechanism for nature’s mental health benefits), we have two studies that reach similar conclusions but approach the issue from very different angles: one experimental and based on brain imagery and survey scales from 31 respondents, the other descriptive and based on qualitative data from 3200 respondents. The fact that their results are highly consistent strengthens both studies, but there is still an enormous amount to learn about this phenomenon. One important area of future work relates to drilling down into the “nature” part of the interaction; as has been previously addressed, the “amount” and “type” of nature that benefits people is poorly understood.4 The methods we use are highly effective at identifying a new phenomenon but are not suited to test causal or mediative effects. The idea of rumination reduction as a possible mechanism first arose from experimental research, and this study offers a nuanced set of possible explanations of the effect observed in that experiment.

Naming concepts allows us to discuss them with more nuance and richness. We hope that naming this idea of “perspective” from nature, and suggesting its links with reductions in ruminative thinking, allows research on this phenomenon to deepen and expand.

**Works Cited**

1Bratman GN, Anderson CB, Berman MG, *et al.* Nature and mental health: An ecosystem service perspective. *Science Advances* 2019; **5**: eaax0903.

2Houlden V, Weich S, Albuquerque JP de, Jarvis S, Rees K. The relationship between greenspace and the mental wellbeing of adults: A systematic review. *PLOS ONE* 2018; **13**: e0203000.

3Thomsen JM, Powell RB, Monz C. A Systematic Review of the Physical and Mental Health Benefits of Wildland Recreation. *Journal of Park and Recreation Administration; Urbana* 2018; **36**. DOI:http://dx.doi.org.ezproxy.uvm.edu/10.18666/JPRA-2018-V36-I1-8095.

4Bratman GN, Hamilton JP, Daily GC. The impacts of nature experience on human cognitive function and mental health. *Annals of the New York Academy of Sciences* 2012; **1249**: 118–36.

5Kleinschroth F, Kowarik I. COVID‐19 crisis demonstrates the urgent need for urban greenspaces. *Front Ecol Environ* 2020; **18**: 318–9.

6Slater SJ, Christiana RW, Gustat J. Recommendations for Keeping Parks and Green Space Accessible for Mental and Physical Health During COVID-19 and Other Pandemics. *Prev Chronic Dis* 2020; **17**: 200204.

7Venter Z, Barton D, Gundersen V, Figari H, Nowell M. Urban nature in a time of crisis: recreational use of green space increases during the COVID-19 outbreak in Oslo, Norway. *Environ Res Lett* 2020. DOI:10.1088/1748-9326/abb396.

8Matthewman S, Huppatz K. A sociology of Covid-19. *Journal of Sociology* 2020; : 1440783320939416.

9Bratman GN, Hamilton JP, Hahn KS, Daily GC, Gross JJ. Nature experience reduces rumination and subgenual prefrontal cortex activation. *Proceedings of the National Academy of Sciences* 2015; **112**: 8567–72.

10Nolen-Hoeksema S, Wisco BE, Lyubomirsky S. Rethinking rumination. *Perspectives on psychological science* 2008; **3**: 400–24.

11Rogers ML, Joiner TE. Rumination, Suicidal Ideation, and Suicide Attempts: A Meta-Analytic Review. *Review of General Psychology* 2017; **21**: 132–42.

12Gould RK, Lincoln NK. Expanding the suite of Cultural Ecosystem Services to include ingenuity, perspective, and life teaching. *Ecosystem Services* 2017; **25**: 117–27.

13Schultz PW. Inclusion with nature: The psychology of human-nature relations. In: Psychology of sustainable development. Springer, 2002: 61–78.

14Braun V, Clarke V. Using thematic analysis in psychology. *Qualitative research in psychology* 2006; **3**: 77–101.

15Vaismoradi M, Turunen H, Bondas T. Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & health sciences* 2013; **15**: 398–405.

16Kruse E, Chancellor J, Ruberton PM, Lyubomirsky S. An Upward Spiral Between Gratitude and Humility. *Social Psychological and Personality Science* 2014; **5**: 805–14.

17Cladder-Micus MB, Becker ES, Spijker J, Speckens AEM, Vrijsen JN. Effects of Mindfulness-Based Cognitive Therapy on a Behavioural Measure of Rumination in Patients with Chronic, Treatment-Resistant Depression. *Cognitive Therapy and Research* 2019; **43**: 666–78.

18Watkins E. Adaptive and maladaptive ruminative self-focus during emotional processing. *Behaviour Research and Therapy* 2004; **42**: 1037–52.

19Feldhaus CG, Jacobs RH, Watkins ER, Peters AT, Bessette KL, Langenecker SA. Rumination-Focused Cognitive Behavioral Therapy Decreases Anxiety and Increases Behavioral Activation Among Remitted Adolescents. *J Child Fam Stud* 2020; **29**: 1982–91.

20Michl LC, McLaughlin KA, Shepherd K, Nolen-Hoeksema S. Rumination as a mechanism linking stressful life events to symptoms of depression and anxiety: Longitudinal evidence in early adolescents and adults. *Journal of Abnormal Psychology* 2013; **122**: 339–52.

21Lee J, Park B-J, Tsunetsugu Y, Ohira T, Kagawa T, Miyazaki Y. Effect of forest bathing on physiological and psychological responses in young Japanese male subjects. *Public Health* 2011; **125**: 93–100.

22Park BJ, Tsunetsugu Y, Kasetani T, Kagawa T, Miyazaki Y. The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine* 2009; **15**: 18.

23Shin WS, Shin CS, Yeoun PS, Kim JJ. The influence of interaction with forest on cognitive function. *null* 2011; **26**: 595–8.

24Henrich J, Heine SJ, Norenzayan A. The weirdest people in the world? *Behavioral and Brain Sciences* 2010; **33**: 61–83.

25Muthukrishna M, Bell AV, Henrich J, *et al.* Beyond western, educated, industrial, rich, and democratic (WEIRD) psychology: measuring and mapping scales of cultural and psychological distance. *Psychological Science* 2020; : 0956797620916782.

26Agyeman J, Spooner R. Ethnicity and the rural environment. In: Cloke P, Little J, eds. Contested countryside cultures: Otherness, marginalisation, and rurality. London: Routledge, 1997: 197–210.

27Finney C. Black Faces, White Spaces. Chapel Hill, NC: The University of North Carolina Press, 2014 https://www.uncpress.org/book/9781469614489/black-faces-white-spaces (accessed Oct 28, 2018).

28Kendi IX. Stamped from the beginning: The definitive history of racist ideas in America. Random House, 2017.

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**Ethics Committee Approval**

This research was certified as “Exempt” and approved by the University of Vermont’s Instituitonal Review Board.