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# Transdisciplinary Environmental Work: An Evaluation of Transdisciplinarity in the Field of Environmental Science and its Relevance to South Carolina Conservation Efforts in Lake Wateree and the Catawba Indian Reservation

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# Transdisciplinary Environmental Work: An Evaluation of Transdisciplinarity in the Field of Environmental Science and its Relevance to South Carolina Conservation Efforts in Lake Wateree and the Catawba Indian Reservation

By

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## Abstract

Transdisciplinarity describes the integration of knowledge and exchange of ideas across diverse academic disciplines, public stakeholders, and decision-makers. In this paper, I discuss the relevance of transdisciplinarity to the environmental field and offer ways in which its principles could be employed to enhance current South Carolina Conservation efforts. I advocate for transdisciplinary work through analyzing existing discourse on the value of transdisciplinary research to the environmental field, and I present some of the challenges associated with this mass integration of knowledge. Finally, I describe three models of transdisciplinary research that have been proposed by scholars to address some of these challenges. Next, I investigate current conservation efforts in Lake Wateree and at the Catawba River near the Catawba Indian Nation, synthesizing knowledge gained from my review of transdisciplinarity to suggest improvements for these works. With respect to Lake Wateree, I recommend that ongoing university investigations and collaborations with stakeholders act as a sort of case study for environmental transdisciplinary work. With respect to Catawba, I recommend that academic institutions like USC become more involved in existing conservation efforts between community stakeholders to establish a similar transdisciplinary network to that of Lake Wateree. From my investigation, I conclude that individuals and institutions need to adapt to accommodate a transdisciplinary mode of knowledge production so that the full potential of conservation can be reached, which will be crucial in addressing growing environmental concerns associated with anthropogenic climate change and resource management.

# Introduction

Since the start of the Industrial Revolution, humans have emitted large amounts of carbon dioxide and other greenhouse gases leading to several adverse effects on the environment including rising global temperatures, ocean acidification, severe weather patterns, and more (IPCC, 2019). This human impact on Earth's climate is referred to as *anthropogenic climate change*, distinguishing these effects from those associated with the Earth's natural variability. Additionally, the overconsumption of natural resources and land usage associated with agriculture and urbanization are contributing to a decline in the health of ecosystems and presenting harmful consequences on human health (IPCC, 2019). These environmental stressors and their potential risk to human life have led to a growing demand for environmental research investigating the effects of anthropogenic climate change, potential mitigation strategies, and how best to protect and conserve natural resources.

In order to best address these concerns, experts state that a wide variety of approaches involving many societal sectors will need to be taken (Yates et al., 2015). In the public sphere, individuals will need to take actions to reduce the amount of greenhouse gases they produce and resources they consume, such as utilizing renewable energy, reducing consumption of meat, conserving power, and so on. Politically, regulations are needed to limit the amount of greenhouse gases emitted and to conserve natural resources. Within academia, research needs to be conducted involving multiple different disciplinary spheres to identify the strategies of anthropogenic climate change mitigation and conservation that are most effective, cost-efficient, and accessible to a wide range of people. Because each of these domains is crucial to the protection of Earth's environments, it is important that conservation efforts engage members of the public, policymakers, and academic researchers from a wide variety of disciplines. In other words, conservation efforts require transdisciplinarity.

Here, I use the term *transdisciplinarity* to describe the integration of knowledge and exchange of ideas between academic researchers across many different disciplines, the general public, public stakeholders, and/or policymakers. In this paper, I argue that a transdisciplinary approach to environmental research and conservation is necessary to address some of the most pertinent ecological issues, and applying transdisciplinarity to environmental issues in South Carolina reveals ways in which current conservation efforts can be improved. The central questions surrounding this investigation are: what is transdisciplinarity, how did transdisciplinarity emerge, what is its role within environmental research, and how could it be employed in South Carolina? Specifically, I will investigate the transdisciplinary efforts to investigate and monitor harmful algal blooms in Lake Wateree and water quality issues within the Catawba Indian Reservation. I aim to compare these ongoing situations to related transdisciplinary environmental work, and I will synthesize my conclusions from my evaluation of transdisciplinarity and these specific environmental issues to propose suggestions for how conservation efforts should proceed in the future. In these ways, I hope to meaningfully contribute to the field of conservation in South Carolina.

# A Review of Transdisciplinarity

## Introduction

In this section, I will define and distinguish disciplinarity, interdisciplinarity, and transdisciplinarity. Next, I will discuss the progression of how science was conducted in the industrialized West and the modes of knowledge production associated with each period. I will then discuss the emergence of transdisciplinarity in science as a whole before focusing on its place within environmental science. By the end of this section, I hope to answer why transdisciplinary research is crucial to the field of environmental science, what challenges transdisciplinary research presents, and how transdisciplinary research is conducted to overcome these challenges.

## Disciplinarity, Interdisciplinarity, and Transdisciplinarity

In understanding transdisciplinary environmental work, it is first important to clearly define the concept of disciplinarity, interdisciplinarity, and transdisciplinarity. German mathematician Roland Scholz, one of the pioneers of transdisciplinarity theory, distinguishes transdisciplinarity from disciplinarity and interdisciplinarity. Scholz defines *disciplines* as fields that are "characterized by objects and (core) methods by which certain problems are approached," (Scholz 2013). These are independent areas of study which have unique methods of investigation, such as mathematics, biology, sociology, and so on.

Each discipline is guided by a set of norms that dictate how research should be carried out and evaluated for quality control. For example, a biologist performing an assessment on the fauna present in marine environments is going to have a much different experimental procedure and quality assurance method than an analytical chemist measuring properties of seawater due to the nature of their disciplines. The chemist can easily collect several seawater samples and analyze them using a specific instrument associated with a certain precision and calibration, all of which gives the data a known reliability. However, the biologist cannot use an instrument to precisely calculate the concentration or diversity of marine animals in certain area. Instead, they must rely on different observational and sampling methods which are typically associated with greater uncertainty than the chemist's instruments. Thus, a level of uncertainty that is acceptable for the biologist might be unacceptable for the chemist. The goals and scope of a discipline dictate its experimental and quality assurance procedures, and for these reasons each discipline is distinct from each other.

Scholz continues and establishes *interdisciplinarity* as the "fusion of concepts from different disciplines," (Scholz 2013). Unlike disciplines, interdisciplinary research has no consistent set of procedures, and it must rely on the integration of knowledge across different disciplines. Much of environmental research could be considered interdisciplinary. Many projects often involve scientists or other academics specialized in different disciplines. Oceanographic research teams can have individuals specialized in physical, chemical, biological, or geological oceanography, each of which is its own discipline. When academics from different fields collaborate on a project, they must combine elements of their respective disciplines to address the research question, and the relative contribution of each discipline may vary depending on the research goal.

Imagine a team of oceanographers (biological, chemical, physical, and geological) responsible for studying how changing physiochemical oceanic conditions impact marine life. The team has two research objectives: first, to investigate the impact of ocean acidification, and second, to investigate the impact of El Niño and La Niña events. In the first research objective, the chemical oceanographer would have more predominant role than they would in the second research objective because the first objective investigates a chemical change and the second investigates a physical change. Similarly, the physical oceanographer would have a more predominant role in the second research objective than they would in the first. All of this is to say that there is no standardized set of norms with which an interdisciplinary question can be answered and is therefore distinct from disciplinarity.

It is worth noting that fields that start off as interdisciplinary may become their own disciplines as they start to develop their own sets of norms surrounding experimental procedures, quality control, and so on. Take, for example, biochemistry. When biochemistry was emerging as an area of study around the late 19th century, it was using a combination of methodologies from different disciplines such as physiology, chemistry, and enzymology (Vennesland and Stotz, 2020). However, as the field progressed, key knowledge was produced that distinguished the field from other disciplines—the concept of an enzyme, components of nucleotides, the process of the Citric Acid Cycle, and so on. Additionally, new experimental procedures were developed to investigate these topics, and these procedures became commonplace among biochemists. Thus, biochemistry evolved from an interdisciplinary field constructed from the procedures and knowledge of other disciplines to a discipline in its own right.

Interdisciplinarity is sometimes used interchangeably with transdisciplinarity, but there are key distinctions between the two. Scholz writes that *transdisciplinarity* “organizes mutual learning among science and society that can generate socially robust knowledge,” and he emphasizes the collaboration between the scientific community and “decision-makers, stakeholders, or the public at large,” (Scholz 2013). Herein lies the distinction from interdisciplinarity. Whereas an interdisciplinary project could involve a team of researchers or academics from across disciplines, transdisciplinary work requires the involvement public stakeholders or policymakers, a different sector of the community. Take, for example, the case of harmful algal blooms in Lake Wateree, SC. There is currently a joint effort between the University of South Carolina, members of the Lake Wateree community, and public stakeholders like Duke Energy to investigate and monitor the severity of harmful algal blooms. Each year, representatives from each of these sectors (i.e., academic, stakeholder, and the general public) meet to exchange information regarding the harmful algal blooms. Lake Wateree collaborative efforts will be discussed at length later in this thesis, but I introduce it now to illustrate an example of transdisciplinary environmental work that is currently ongoing in South Carolina.

Scholz goes on to define transdisciplinary process and transdisciplinary research. According to Scholz, a *transdisciplinary process* is a joint, power-balanced effort to integrate knowledge between the scientific community, public stakeholders, and/or decision-makers (Scholz 2013). Usually, transdisciplinary processes emerge from the shared interest of the scientific community and decision-makers in a complex, societally relevant issue that both parties agree would be best addressed by integrating knowledge across their respective fields. Common examples of these complex problems include how communities respond to climate change or the overexploitation of natural resources. After scientists and decision-makers define the scope of their problem, members of the public who feel concerned about the outcome of this joint effort may participate in the transdisciplinary process. The aforementioned Lake Wateree annual meeting between academic researchers, public stakeholders, and members of the community is one example of a transdisciplinary process.

In contrast, *transdisciplinary research* occurs before, during, or after a transdisciplinary process to offer preparatory, support, or follow-up information and is strictly controlled by scientists. For example, brief surveys are often conducted in the Lake Wateree community to evaluate the effectiveness of education campaigns, information exchange through the annual meeting, and joint-monitoring efforts of harmful algal blooms. These would be considered transdisciplinary research because they help promote the transdisciplinary process of community, stakeholder, and academic collaboration. Throughout this paper, unless otherwise specified, I will use Scholz's definitions for transdisciplinarity, transdisciplinary process, and transdisciplinary research when referring to these concepts, and I will use the term *transdisciplinary work* to refer to any research, process, project, or effort which exhibits principles of transdisciplinarity.

Scholz's definition of transdisciplinarity is commonly applied to transdisciplinary projects in Europe (Bennich et al., 2020). In the United States, however, transdisciplinary tends to most closely match Scholz's definition of interdisciplinary. Here, scientists often define transdisciplinary as the collaboration between the social and natural sciences (Yates et al., 2015). I choose not to employ this definition for two reasons. Firstly, the United States application of the term does not clearly distinguish itself from interdisciplinarity because it doesn't clearly define where the boundary between social and physical science is. Take, for example, a research team consisting of a psychologist, who uses overlapping elements of biological and social science, and a biologist. Would this count as a transdisciplinary project, or are the fields too closely related and instead considered interdisciplinary? What about a team of a psychologist and a sociologist? Physical and social sciences lie on a sort of spectrum, and the boundary between the two is not so clearly defined. Second, for reasons I will discuss at length later in this paper, the inclusion of different societal sectors in Scholz's definition for transdisciplinarity enables this form of knowledge co-production to address complex environmental issues more effectively. For these reasons, I maintain that the classification of transdisciplinarity cannot and should not depend on the boundary between physical and social sciences.

**The Evolving Relationship between Science, Disciplines, and Knowledge Production**

Transdisciplinary research was not always a common practice. Traditionally (i.e., before World War II), scientific research and knowledge production was confined within the disciplines. This period of research is best characterized by the Mertonian norms commonly abbreviated to CUDOS. The acronym *CUDOS* was first coined by American sociologist Robert Merton in 1942 in his interpretation of the ideal ethos of science (Kellogg, 2006). Each letter represents a core principle that research projects should incorporate, namely communalism, universalism, disinterestedness, and organized skepticism. *Communalism* refers to the idea that all scientists should have shared ownership of the intellectual property produced by research with collective collaboration as the goal. *Universalism* describes the idea that one's race, ethnicity, gender, religion, or any other difference does not preclude one from performing science, and everyone's claims should be scrutinized equally. *Disinterestedness* reflects the belief that research should be motivated by the benefit of a common scientific goal rather than the personal gain of investigators. *Organized skepticism* is the value which states that scientific claims should be subject to intense, well-established scrutiny before being accepted, both within the methodology of the project and within the institution in which the research is performed.

The Mertonian norms are reliant on a method of knowledge production known as *Mode 1*. Mode 1 knowledge production is based off the assumption that science can be broken down and understood in discrete disciplines. As previously mentioned, disciplines are independent fields of study that have distinct investigative methods, such as mathematics, biology, sociology, and so on (Scholz, 2013). Mode 1 research is disciplinary and investigator-driven, meaning that it originates solely from the interests of the research community within a single discipline (Gibbons, 1994). Because of these academic confinements, there is generally very limited agency collaboration in Mode 1 investigations. Additionally, researchers are judged and held accountable by their peers, usually of the same discipline. Within these disciplines, there are well-defined norms which can ensure the quality of data produced. A general example of Mode 1 knowledge production involves a researcher or team within a single discipline pursuing a related scientific inquiry motivated by their own curiosity, like a biologist investigating the structure of cellular components or a physicist investigating subatomic particles for no other reason than to contribute to the general understanding and aims of their respective disciplines.

The alternative to Mode 1 knowledge production is *Mode 2*. In contrast to CUDOS and the Mertonian norms, the acronym PLACE has been offered by New Zealand physicist John Ziman (1996) as a description of how Mode 2 knowledge production is conducted. Ziman introduces the term *academic science* to describe the period of research characterized by Merton's norms and Mode 1 knowledge production. Ziman argues that science has since shifted to *post-academic science* which is best described with his acronym *PLACE*, standing for proprietary, local, authoritarian, commissioned, and expert. Ziman offers that modern science is partly *proprietary* instead of communal, reflecting how institutions and individuals have ownership over the intellectual property produced by research. Ziman continues that research is focused on *local*, technical problems rather than a general inquiry. He also writes that researchers are overseen by *authoritarian* managerial figures as opposed to acting as autonomous individuals. Research is *commissioned* to address some practical problem as opposed to being solely motivated by general scientific curiosity. Finally, investigators are seen as *experts* in their fields as opposed to individuals requiring intense scrutiny.

Mode 2 knowledge production relies on the collaboration between disciplines to investigate complex issues. As such, political scientist Michael Gibbons defines Mode 2 as transdisciplinary, or going beyond the framework of any one discipline (Gibbons, 1994). Here, Gibbons does not employ Scholz's definition of transdisciplinarity as collaborations between different societal sectors and instead uses it to mean across different disciplines. Transdisciplinary research is usually driven by a need to answer some question of economic, social, or political relevance, such as strategies to mitigate the spread of COVID-19 or the impacts of anthropogenic climate change. Heterogeneity of skills in researchers is needed to provide a transdisciplinary investigative approach. Additionally, because Mode 2 research typically involves a higher number and diversity of organizations than Mode 1, there is less hierarchical structure in Mode 2 research programs. Mode 2 research is more socially accountable and reflexive than Mode 1, and unlike Mode 1, methods of quality control cannot be confined within one set of disciplinary norms.

Much of environmental science, especially as it relates to climate change, relies on Mode 2 knowledge production. There is a recent interest in the environmental community to investigate methods of carbon dioxide removal (CDR) from the atmosphere to slow some effects of climate change. These researchers are tasked with determining cost-effective methods that will remove the most carbon dioxide with minimal impact on the surrounding environment. Typical research projects involve computer scientists who develop complex models simulating CDR conditions, a team of physical, biological, and chemical environmental scientists to interpret these models' impact on the surrounding ecosystem, and economists to determine the financial feasibility of these projects, all across different governmental and academic agencies. The aim and execution of these types of research projects is a characteristic example of Mode 2 science.

The transition between Modes 1 and Mode 2 is largely due to the evolution of scientific research to incorporate more collaborations between a variety of disciplines and organizations. In the 1990's, Gibbons and a team of researchers published *The New Production of Knowledge*, in which they noted general trends in the way science is conducted in the industrialized West. These trends have led to new discourse within the scientific community and given rise to new theories of knowledge production, which is relevant in the context of understanding transdisciplinarity. Gibbons identifies these trends as the increasing urge to 'steer' research priorities, the commercialization of research, and the public accountability of science (Gibbons, 1994).

The steering of research priorities describes the tendency of affiliates external to research programs to influence the activity of that program (Gibbons, 1994). This steering can occur on a national or international level, as organizations have been developed to shape research needs and cater to societal issues. One such international organization is the World Health Organization, which has responded to many international public health crises since its founding in 1948. Most notably, it has directed research and implemented vaccine programs contributing to the eradication of smallpox, near eradication of polio, and most recently combatting the COVID-19 pandemic (WHO 2021).

In the United States, government agencies are a large source of funding for scientific research (e.g., National Science Foundation, the National Institute of Health, etc.) and research and development. *Research and development* is a general term for the production of scientific knowledge for both commercial and non-commercial interests, potentially leading to the production or enhancement of products, methods, processes, systems, and so on (NSF R&D 2018). Research and development is comprised of three main categories: basic research, applied research, and experimental development. Here, the term *basic research* refers to the pursuit of new scientific knowledge without an immediate commercial interest, though there may be commercial interest in the specific research field. *Applied research* utilizes the findings of basic research or other information to produce new scientific knowledge with specific commercial objectives. *Experimental development* is defined as the systematic use of knowledge from research or practical experience towards the manufacturing or improvement of various products, materials, services, processes, etc. It is estimated that government agencies are responsible for funding 44% of basic research and 10% of all research and development in the United States.

Geoengineering, or the manipulation of environmental processes to help counteract the effects of anthropogenic climate change, is one such field that relies heavily on all types of research and development. To illustrate the differences between basic research, applied research, and experimental development with a practical example of geoengineering, I will briefly discuss projects related to ocean alkalinization. Oceanic alkalinization is the process of increasing the basicity of the ocean to promote the uptake of carbon dioxide of the atmosphere. Basic research of this topic would consist of seeking fundamental knowledge, such as a study investigating the interactions between the physiochemical conditions and ecology of ocean alkalinization sites. Applied research for this subject could be simulating ocean alkalinization at a specific site of commercial interest. Experimental development could involve the development and enhancement of chemical processes that produce hydroxide ions to increase the basicity of alkalinization sites.

The establishment of the National Science Foundation (NSF) marks a major shift in government's role in research and the steering of research in the United States. The NSF was created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense...” (NSF, 2022). These goals reflect the defining societal issue of the time—the Cold War. Motivated by the desire to outpace the Soviet Union in scientific advancement and arms development, Congress began allocating money for basic research aimed at the advancement of science and national security. After it was clear to Congress that funding basic research was essential to ‘winning’ the Cold War, they began allocating even more money to the NSF. To this day, the NSF is one of the largest contributors to governmental funding of basic research. The establishment of the NSF is a key moment in the United States’ trajectory in governmental influence of research, and the circumstances surrounding its founding illustrate how societally relevant issues direct the steering of research.

The second trend in the changing research environment as described by Gibbons is the commercialization of research. This commercialization manifests itself in two ways (Gibbons, 1994). First, with public funding of research less able to fulfill researchers’ needs, investigators turn to alternative sources of funding. Private and governmental organizations funding research often attempt to align public interests or market priorities with research policy, effectively creating a commercial partnership between the funding agency and the research program. For example, the development of drugs and vaccines in the United States are often results of collaborations between the National Institute of Health, academia, and pharmaceutical companies. Second, research institutions are more aware of the commercial value of the knowledge generated by their research. Institutions seeking to exploit the value of this intellectual property raise into question the true ‘ownership’ of the research material (that is, belonging to the research team, the research community, or the institution), which in turns raises questions of organizational and structural nature of the institution.

Finally, the third component of Gibbons' observations is the change in the public accountability of science, or the efforts by which the effectiveness and the quality of research is evaluated (Gibbons, 1994). Gibbons describe that, while accountability was deeply internalized in research teams, programs, and institutions, the accountability of science is beginning to include more governmental and private funding agencies. This extends the accountability of science from a professional domain to include a more managerial domain and alters the verification process of scientific research. For example, the National Institute of Health (NIH) has their own set of quality assurance guidelines that their clinical projects must meet, extending the quality control process beyond the disciplinary specifications (NIH, 2022).

The three trends in the evolution of scientific research noted by Gibbons are interrelated. Organizations seek to steer research programs to fit their own needs, usually relating to some broad, societally important issue, which highlights the commercialization of research and presents a need for these organizations to be included in the scientific verification process. For example, in 2020, the National Institute of Health funded approximately $8.3 billion in public health research in infectious diseases (NIH, 2021). This was a $2 billion increase from their 2019 allocation of $6.3 billion, and this increase is likely due to the COVID-19 pandemic. Because of the extreme societal impact of the pandemic, there was a growing demand and commercial interest in researching the virus and different products to slow the spread or reduce the severity of the symptoms, such as the development of vaccines and the manufacturing of personal protective equipment. The NIH funded many projects towards clinical research, all of which had to meet the NIH's standards for quality assurance.

These changes call attention to fundamental questions regarding the production of scientific knowledge. What drives a given research project? What entities are involved in the production of this knowledge, and how is this knowledge produced? Who is responsible for ensuring accountability and quality of the knowledge produced? Ultimately, the changes in these fundamental components of scientific research led Gibbons to propose that research was transitioning from a disciplinary, specific, structurally confined method of knowledge production (i.e., Mode 1) to a cross-disciplinary, broad, and structurally transient modes of knowledge production known as Mode 2. Here, I use the phrase *cross-disciplinary* to express knowledge produced across different disciplines which could be inter- or transdisciplinary. The key differences between Mode 1 and Mode 2 knowledge production as summarized by Gibbons (1994) are: 1) the context of the discovery, 2) the role of the disciplines, 3) the variety of researchers in terms of skills and organizations, 4) social accountability and reflexivity of the researchers, and 5) quality control.

The contrast of Mertonian ideals (CUDOS) and those denoted by Gibbons (PLACE) reflect not only changes in modes of knowledge production but attitudes towards researchers. CUDOS contributes to the myth of the researcher as a lone agent working tirelessly, producing knowledge for knowledge's sake and for the betterment of their field. Ziman's PLACE dispels this myth, but on its own could be a cynical view of the researcher as a self-interested agent under managerial control producing knowledge to fulfill an order rather than to satisfy their own intellectual curiosity. Perhaps a combination of Mertonian and Ziman characteristics of scientific research could be ideal in addressing some of the world's pertinent problems. Research aimed at practical applications is not necessarily a fault—especially when taking into consideration the threat of anthropogenic climate change and COVID-19. Incorporating Mertonian ideals into the kind of science that is practiced today could enhance environmental work aimed at improving ecosystems and people impacted by these environments.

**Advocating for and Identifying Challenges with Transdisciplinary Research**

For this next section, I will explore why transdisciplinary work, as defined by Scholz, is crucial for climate change mitigation and other conservation efforts. Before discussing transdisciplinarity, however, I will first establish the significance and difficulties associated with interdisciplinarity, all of which apply to transdisciplinarity.

With the growing threat of anthropogenic climate change, there is an extreme interest within the academic community to investigate how ecosystems and natural resources can be best protected. To this end, environmental scholars across disciplines have identified key research questions within their fields, many of which require interdisciplinarity. Climate change researchers acknowledge that solutions to the climate crisis will require an array of expertise across diverse academic disciplines, spanning physical sciences, social sciences, humanities, and engineering (Middleton, 2011). Geoengineering is a prime example of this. While large-scale manipulations of the Earth's environments to promote the removal of atmospheric carbon dioxide excite some engineers and scientists, others are wary of unintended consequences of these interventions. Because of the extensive, potentially irreversible effects of geoengineering, experts assert that any ethical climate solution would require the collaboration between natural and social scientists, engineers, and philosophers.

While scientists accept that meaningful solutions to ongoing ecological concerns require the collaboration of many academic disciplines, some of these disciplines, particularly the social sciences and humanities, go understudied. Philosophers of science Francesca Pongiglione and Jan Cherlet (2015) describe how social sciences are largely ignored within climate science. They point out that social sciences only made up 12% of the citations from the IPCC's Third Assessment Report, an already small portion which was further biased towards economics. They also draw attention to the United States Global Change Research Program (USGCRP), a federal program to coordinate the federal research and investments regarding climate change. In the years 2009 and 2010, this program dedicated less than 1% of its research funding to basic social and behavioral research (Pongigioine and Cherlet, 2015). In attempts to counteract this imbalance, the USGCRP established the Social Sciences Coordinating Committee (SSCC) in 2014 to facilitate the integration of social, behavioral, and economic sciences into research approaches and other USGCRP activities.

In 2017, the SSCC hosted a workshop for federal and academic scientists to discuss ways to better investigate and characterize human-environment interactions, communities that are highly vulnerable to climate change, and social science perspectives on anthropogenic climate change (USGCRP, 2017). During this workshop, some speakers presented on the difficulties of incorporating social science research into the larger domain of climate change research. Cultural anthropologist Rob Winthrop spoke on the challenges associated with investigating the interactions between the physical and social dimensions of climate change. He described the social sciences field as pre-paradigmatic, referencing philosopher Thomas Kuhn's theory on scientific progression (Kuhn, 1970). Kuhn asserts that science is characterized by different periods: a pre-paradigmatic state in which there is no consensus on fundamental theories, methodologies, and observational basis (i.e., a *paradigm*), a period of 'normal' science where a paradigm has been reached, a crisis leading to a paradigm shift and threatening the validity of the former paradigm, and a revolutionary period in which a new paradigm is selected. Physical sciences have had long-established paradigms and many paradigms shifts throughout the history of their discipline. For example, Isaac Newton's laws of motion and gravity dominated the study of physics for hundreds of years until Albert Einstein developed his theory of relativity which explained inconsistencies in physical observations that Newton's laws couldn't.

It is clear to see how the presence or lack of a paradigm might present a barrier to collaborations between pre-paradigmatic and paradigmatic sciences. Paradigms are revered by paradigmatic scientists almost to the point of pride, as if their disciplinary consensus on fundamental theories and methodologies renders them closer to seeking truth and objectivity than their non-paradigmatic peers. Modern physical scientists are less likely to accept the absence of agreed-upon fundamental principles because they have always worked within paradigms. They might also have negative implicit biases about those who work outside the confounds clearly established theories. A 2015 study on the motivations and barriers to interdisciplinary climate change research found that nearly half of all 559 surveyed interdisciplinary climate change researchers agreed that their peers did not view interdisciplinary work as theoretically rigorous as working within one's discipline (Milman et al., 2017). This lack of peer support reflects a feeling of academic superiority held by disciplinary scientists, likely motivated in part by the lack of a paradigm within interdisciplinary climate change studies. Thus, the pre-paradigmatic status of inter- and transdisciplinary research present challenges with getting them recognized and regarded within the larger scientific community.

Additionally, the integration of knowledge across academic disciplines and social backgrounds presents many inherent, institutional, and geopolitical complications. A 2016 study followed the work of an Australian transdisciplinary environmental research team comprised of physical scientists, social scientists, and sustainability and policy specialists (Gaziulusoy et al., 2016). The goal of the investigation was to identify large-scale issues faced by the transdisciplinary research team and to develop strategies to address them. After 15 months, the investigators identified 21 distinct challenges with the team's transdisciplinary work and characterized them by type (emergent, inherent, institutional, or teamwork) and by category (political environment, funding, stakeholder engagement, knowledge integration, project management, team development, or career development).

Most of the challenges faced by the Australian research team were inherent to transdisciplinary research: limitations of expertise within the group, insufficient funding and support for outreach and stakeholder engagement, low deliverability of academic publications, to list a few (Gaziulusoy et al., 2016). Because contributors are coming from a variety of disciplines, researchers within a cross-disciplinary team are not going to have as clear an understanding of the others' work as those within a disciplinary research team. Also, because transdisciplinary research requires a greater level of involvement from non-academics than disciplinary or interdisciplinary research, it requires more funding and support for this engagement. Finally, owing to their complexity, transdisciplinary projects take much more time to yield results, and once they do, these results do not have a clear method of quality control. These factors can be major deterrents for journals to publish and for academics to engage in transdisciplinary research, especially early-career professionals who rely heavily on producing publications and are still becoming familiar with their own discipline (Bennich et al., 2020).

Knowledge integration was a major contributor to the inherent problems identified by the transdisciplinary team, making up over one-third of the identified challenges faced by the researchers (Gaziulusoy et al., 2016). One such challenge denoted by the leaders of the study were that the Australian research group had differing assumptions on what counted as research and data. Disagreeing on something so central to the investigative process highlights the limitations of collaborations across disciplines. Because each discipline has their own set of methodological norms, investigators within one discipline may not recognize those from other disciplines as fitting their notions on what data and research should be, or they may incorrectly assume that everyone shares their position on these key concepts.

Emergent challenges are those which impede research progress in a top-down manner (i.e., from a higher level of disciplinary or organizational complexity to a lower level). One emergent challenge presented in the study was the political environment of the local and federal Australian government which led to disruptions in climate change research networks. Political interferences of environmental research and policy initiatives is hardly unique to Australia. In the United States, ideological polarization with regards to anthropogenic climate change has increased drastically over the past 20 years, contributing to public skepticism towards environmental sciences and policy gridlock (Farrell, 2015). This has led to inconsistent participation in international efforts to mitigate climate change, such as the 2020 withdrawal of the United States from the 2015 Paris climate agreement followed by a quick re-entry after the change of presidential administrations (Blinken, 2021). On smaller scales, state and local legislatures often compete for authority on dictating conservation efforts. For example, many coastal cities around South Carolina have issued single-use plastic bans to reduce the amount of plastic waste that ends up in waterways, but the state legislature has attempted to undo and prohibit these bans (Cedzo, 2022). Thus, political environments often hinder cross-disciplinary environmental research.

Up to this point, my discussion on the importance of transdisciplinary work in the environmental field has centered around the importance of knowledge integration across the physical sciences, social sciences, and humanities, and the challenges associated with these. However, the careful reader might recall that these benefits and challenges are not unique to transdisciplinarity. As mentioned in previous sections, interdisciplinary work also requires multiple disciplinary perspectives, but transdisciplinary work goes even further to include the public, stakeholders, and policymakers into the process of knowledge production. Why is it, then, that this inclusion of different societal sectors enables transdisciplinary work to better address environmental concerns?

Scholz asserts that the mutual learning between academia, stakeholders, policymakers, and the public is what allows transdisciplinary work to generate more socially robust knowledge than interdisciplinary studies (Scholz, 2013). This mutual learning occurs during the problem definition, problem representation, and problem transition stages of transdisciplinary project. At the problem definition stage, all collaborators can jointly determine the target of the transdisciplinary approach (or the problem that the transdisciplinary work will aim to 'solve'). Diverging views on this problem can be accounted for, integrated into the problem definition, and eventually agreed upon by all participants. During the problem representation stage, all sectors represented can take part in developing a language that adequately describes the project target. Finally, during the problem transition stage, the collaborators cooperatively decide on and initiate a problem-solving strategy that fits all their needs.

This sort of approach is particularly important with broader, more complex societal issues such as anthropogenic climate change. There are many ways in which the problem of climate change could be defined – environmentally by threatening the fate of ecosystems, economically by threatening industries reliant on certain organisms or vulnerable areas, socially by threatening food and water security in certain regions, and so on. Moreover, the problem definition will change based on the context under which is being defined. For example, citizens in coastal areas might be most concerned about rising sea levels impact on local properties and economies, whereas those in drought-ridden regions might worry for their immediate future in water security. The definition of the problem directly impacts the representation of it and how the problem will best be solved.

Because the success of this problem-solving will likely be contingent upon the joint efforts of the public, policymakers, and stakeholders, it's important that they are involved in the determination of these problem-solving methods so that it fits their interests as much as possible and has the greatest chance of being adopted. Similar to problem definitions, different sectors will likely have different qualities they look for in a problem-solving strategy. Academic researchers might seek the strategy that is most scientifically sound whereas legislators might seek the one most likely to gain them political favor. For any transdisciplinary work to be most effective, the problem definition, representation, and transition needs to align with the most pressing issue felt by the target community, and the best way to ensure that it does to include them in the mutual learning process.

Of course, including more segments of the community inherently complicates the knowledge production process. Knowledge integration poses enough of a problem just across academic disciplines, and involving sectors completely outside academia can only be expected to increase this difficulty. Additionally, some of the main barriers to environmental protection exist within the public, private, and governmental sectors. As mentioned previously, public uncertainty in the environmental field and ideological polarization are emergent challenges with transdisciplinary environmental work. Since the mid- to late-2000's, many private corporations have contributed to the funding of climate contrarian campaigns (i.e., those denying the existence or severity of human-caused climate change) further reinforcing political polarization (Farrell, 2015). Yet, the only way to gain the most knowledge that can be used to overcome these challenges is to include the agents that are responsible for them; we will never learn as much from the outside looking in as we will from listening to those on the inside.

Climate solutions and effective conservation measures are reliant on the active participation of the public, policymakers, and stakeholders—who also happen to make up some immediate barriers to any remedial action. It stands to reason that the most effective method of knowledge production in addressing these issues requires the involvement of these sectors. Even if some individuals or groups are unwilling to contribute to the mutual learning process, that unwillingness must be acknowledged and accounted for in future processes of problem definition, representation, and problem-solving. A variety of disciplinary perspectives is crucial in exploring the social, economic, and ethical complexities of climate solutions and related environmental issues. However, only by incorporating these different societal sectors can the full potential of knowledge acquisition be reached. If barriers to meaningful environmental policies lie within the public, political, and private sectors, then these sectors need to be involved in the knowledge production about how to overcome these barriers.

**Models of Transdisciplinary Environmental Research**

Now, I will focus on current efforts to study models of transdisciplinary research starting with a broad overlook on the transdisciplinary research process. Environmental scientists Nicole Klenk and Katie Meehan have identified many overlapping characteristics of transdisciplinary environmental research (Klenk and Meehan, 2015). After reviewing 60 papers on transdisciplinary research, they noted 14 shared structural, compositional, and cognitive and relational factors. Structurally, they write that transdisciplinary projects can be influenced and enhanced by the following elements: (1) clear, cooperative institutional policies that enable the exchange and integration of transdisciplinary knowledge; (2) targeting problems of a manageable geographical magnitude and timescale; (3) the continuous receival of funding and any other necessary resources; (4) the spatial proximity of the project being close enough to facilitate face-to-face dialogue and interactive research processes; (5) reward structures, such as the potential for promotion or tenure and the sufficient compensation of labor; (6) the clear identification of shared goals during problem structuring.

Klenk and Meehan also note various compositional factors which can influence the practice of transdisciplinary research: (7) the engagement and selection of stakeholders; (8) the researchers' familiarity or past experiences with transdisciplinary research; (9) active management of the research project; (10) the standardization of research methods and data, including intellectual rights and security; (11) the social, disciplinary, and functional diversity of the research team. Finally, Klenk and Meehan discussed the cognitive and relational influences in transdisciplinary research: (12) the credibility and trust between research members and stakeholders; (13) frequent and effective communication between collaborators; (14) flexibility and adaptability with respect to social learning. For a transdisciplinary research model to be most effective, it would need to include or address the aforementioned factors.

Klenk and Meehan continue to discuss the traditional integration model of transdisciplinary research. *Integration* relies on the idea that different forms of knowledge can be combined to produce a homogenized set of standards and theories, which can then be used to arrive at a 'solution' to the target research problem (Klenk and Meehan, 2015). In an ideal integrated transdisciplinary research project, collaborators share their expertise and disciplinary perspectives with the goal of arriving at an agreed-upon research methodology that incorporates aspects from each discipline. Specific disciplinary theories and techniques are adjusted to be more digestible for the larger team. When disagreements on theory, methods, or findings occur, they are discussed and investigated, and knowledge production and exchange continue until a commonality can be reached (Mouffe, 2005). If these disagreements are irreconcilable, a new object of study or question is posed that can fully integrate knowledge amongst its collaborators. Some transdisciplinary scholars suggest that this kind of knowledge synthesis stems from a belief that “a new integrated perspective can be found on a singular object, if only the right object can be identified,” (Donaldson et al., 2010).

Critics of the integrative approach to transdisciplinary argue that integration is inherently exclusive to certain kinds of knowledge, undermining its perceived inclusivity and incorporation of different ideas, methods, and so on. Klenk and Meehan write that “the process of producing knowledge to solve societal problems…involves mechanisms of inclusion/exclusion as scientists and non-scientists frame climate change adaptation according to what matters to them,” (Klenk and Meehan, 2015). They offer the IPCC as an example, driven by the desire to integrate knowledge around anthropogenic climate change. Disagreements within the IPCC are almost inevitable due to the sheer number and diversity of organizations involved, and Klenk and Meehan note how this has led to alliances, competitions, and conflict between various research agents. Ultimately, this necessitates a differentiation on what information is and is not accounted for in the larger assessments of the IPCC so that a consensus among collaborators can be reached. Klenk and Meehan warn against this, writing that this imposition of a “consensus on knowledge integration” could obscure the “necessary political work of composing a common world” (i.e., one in which the problem of anthropogenic climate change is agreed upon and in solutions are worked towards by all members) and hinder “different pathways of societal development.”

Instead, Klenk and Meehan advocate for alternative transdisciplinary research models, namely triangulation, the multiple evidence-base approach, and scenario building. Policy analyst Emery Roe describes how, for environmental science to lead to effective policy, research should use a plurality of theoretical and methodological approaches (Roe, 1998). In the *triangulation* model, researchers engage in case-by-case analysis, prioritization of research problems, and decision-making under consistent uncertainty (Klenk and Meehan, 2015). Moreover, decision-making is guided experimentally with the testing of competing approaches and the development of experiential knowledge (Roe, 1998). In this way, triangulation allows for a variety of methodologies to be incorporated into research as opposed to a single integrative approach, and it allows for different types of knowledge production.

The second transdisciplinary research model discussed by Klenk and Meehan is the multiple evidence-based approach (MEBA). They write: "MEBA suggests that quality and validity of research results are assessed within each knowledge system [i.e., discipline, organization, or societal sector] with a view to developing complementarity and synergy," (Klenk and Meehan, 2015). In other words, instead of establishing a consensus on a research approach or testing competing methodologies, MEBA offers a separate, concurrent evaluation of knowledge through the framework of each entity involved in the transdisciplinary work. MEBA allows for contradictory knowledge and relies on the acceptance that "there is some knowledge and information that will remain incompatible." (Tengo et al., 2014). Contradiction is viewed as productive in the generation of new understandings or research questions, as opposed to the integrative approach of contradiction requiring compromise. For these reasons, MEBA is better equipped to deal with incompatible knowledge originating from different disciplinary or societal backgrounds, which will be key in the future of climate change research.

Finally, Klenk and Meehan describe a third alternative transdisciplinary research model—scenario building. Within scenario building, investigators imagine specific situations and conditions that could lead to the most severe outcomes of whatever the research entails. With respect to climate change research, this would be widespread food and water insecurity, strong and persistent natural disasters, the complete destruction of ecosystems, loss of human life, all resulting in an uninhabitable planet. The goals of this scenario building are to develop ways to assess when and how these conditions emerge so that their effects can be mitigated and potentially stopped or transformed as soon as possible. Klenk and Meehan note that this approach is more challenging than the previous ones because it seeks knowledge that is "disquieting, uncomfortable, and potentially disruptive" in order to "prepare for the unexpected consequences of our current practices and anthropogenic trajectories," (Klenk and Meehan, 2015). This method encourages many ways of thinking and sources of knowledge to establish as many comprehensive scenarios as possible. Ultimately, this research model enhances the foresight and potential forecasting of future research efforts, which may be uncomfortable, but is necessary in assessing growing environmental threats.

The integrative model of transdisciplinary research is commonly employed as an attempt to reach a compromised, shared understanding of some complex societal issue requiring the input of many different disciplines and stakeholders. However, the inclusion and exclusion of certain knowledge inherent to this method is a shortcoming that can be addressed by utilizing alternative transdisciplinary research models. Triangulation, MEBA, and scenario building are three approaches that can lead to the production of different types of knowledge that will be useful in addressing current and future environmental crises. If transdisciplinary work is to combat these crises, it needs to account for a variety of different, and at times, contradictory perspectives and reflect these contradictions in the process in knowledge production. In the words of Klenk and Meehan, “Transdisciplinarity, in short, cannot be a precursor for integration; instead, transdisciplinary environmental science must recognize and value difference as much as it strives to produce policy-relevant knowledge,” (Klenk and Meehan, 2015).

**Concluding Remarks on Transdisciplinarity**

Transdisciplinarity, especially with respect to environmental research, is a relatively new concept. Transdisciplinary science in general is largely pre-paradigmatic; it does not share the disciplinary luxuries of consistent research methodologies, a consensus on fundamental principles, or standardized quality assurance procedures. It is inherently more complicated than disciplinary and interdisciplinary studies, and it faces a larger number of institutional and political barriers. It is also more disregarded by the scientific community, owing to its lack of paradigms, quality assurance, and the general neglect of the social sciences and humanities. Yet, to generate societally robust knowledge that is best equipped to address complex issues such as that of anthropogenic climate change, a variety of perspectives is needed across different societal sectors, disciplines, and ideologies. Only through transdisciplinary work can we fully begin to understand and address pressing environmental issues. Throughout the remainder of this thesis, I will focus on specific ways transdisciplinarity can be applied to ongoing environmental efforts in Lake Wateree, SC, and the Catawba Indian Reservation and offer recommendations to enhance these projects. For now, I’d like to conclude with a general recommendation of reflexivity across all disciplines and societal sectors, especially with respect to how knowledge within these domains is produced, methods of knowledge production or sources of knowledge that may be neglected, and ways in which these gaps could be filled.

# Collaborative Efforts to Mitigate Harmful Algal Blooms in Lake Wateree

## Introduction

This chapter will focus on the collaborative efforts between the University of South Carolina, the Lake Wateree community, and Duke Energy on the monitoring and management of harmful algal blooms in Lake Wateree, SC. First, I will give a general overview on Lake Wateree, the history and severity of its harmful algal blooms, and the various impacts (e.g., economic, health, etc.) of the harmful algal blooms on the community. Next, I will describe current collaborations between the University of South Carolina, Duke Energy, Lake Wateree residents, and other stakeholders to monitor and investigate these environmental impacts, and I will describe ongoing research in this area. I will compare these efforts to other transdisciplinary projects and synthesize knowledge from my investigation of Lake Wateree and my previous review of transdisciplinarity to offer recommendations for the future of this project.

## Lake Wateree and Harmful Algal Blooms

Lake Wateree is found in central South Carolina between Fairfield, Kershaw, and Lancaster counties. Located within the Catawba-Wateree River Basin, it is the most eutrophic (i.e., receives the most nutrient inputs) major reservoir in South Carolina (Tufford et al., 1999). It is the oldest lake in South Carolina, created in 1920 by Duke Energy for the operation of a hydroelectric station (SCDNR, 2014). Within its area of over 13,000 acres and its shoreline of 216 miles (348 km) is the site of state recreation areas, a bird refuge, and an air force base recreation center. Currently, Lake Wateree is owned and managed by Duke Energy, while the South Carolina Department of Natural Resources (SCDNR) manages recreational fishing activities.

According to the South Carolina Department of Health and Environmental Control (SCDHEC), Lake Wateree experiences high nutrient loading originating from the Charlotte, NC metropolitan area (SCDHEC, 2019). Because of the increased input of limiting nutrients, Lake Wateree is a hotbed for primary production. This can lead to harmful algal blooms (HABs), or the extreme growth of microscopic plant-like organisms within the lake which can produce toxic or harmful effects to humans or aquatic life (SCDHEC, 2019). In order for HABs to grow, they need sunlight, slow-moving water, limiting nutrients (nitrogen and phosphorus), and warm temperatures (SCDHEC 2019). Thus, HABs are most prevalent in the late spring to early fall when temperatures are more conducive to bloom growth.

Lake Wateree is prone to blooms of *Lyngbya wollei*, a species of cyanobacteria, which presents itself in the form of thick, green algal mats on the surface of the lake (SCDHEC, 2019). These HABs have been associated with the toxins cylindrospermopsin and microcystin; it is still debated whether harmful effects are caused via skin contact, ingestion, or inhalation. Skin irritation has been reported in humans in contact with the blooms along with feelings of sickness and nausea, so it is advised by SCDHEC to avoid the algal mats. Pets can experience more severe symptoms after contact with the HABs, including hypersalivation, weakness, labored breathing, seizures, low blood sugar, low protein, and in extreme cases, death (SCDHEC, 2019). Toxins can also accumulate in fish which can then spread to humans via ingestion. Currently, SCDHEC has issued fish consumption advisories on six types of fish in Lake Wateree due to the presence of probable human carcinogens; however, these accumulations are associated with pollution outside of HABs (SCDHEC, 2019).

In addition to the threats on ecosystem, human, and animal health, Lake Wateree HABs have negative impacts on the local economy. The lake attracts fisherman with its high supply of bass, catfish, and bream, and its recreation areas offer lakeside campgrounds, hiking trails, and boat ramps for recreational lake access (Kershaw County Chamber of Commerce, 2022). With a rise in anthropogenic nutrient input due to the rapid growth of the Charlotte metropolitan area, HABs in Lake Wateree are expected to worsen and deter recreational use of the lake (Powell, 2010). Real estate is a major source of income in Lake Wateree, having a total estimated market value of $17 million (Lake Homes Realty, 2022). On average, about 50 lake homes and 90 lots of land are listed for sale at any time in Lake Wateree, and the average list price for a house is around $350,000 (Lake Homes Realty, 2022). These property values are projected to decrease due to the lowering water quality of the lake from pollution and HABs.

**Collaboration Between Universities, Public Stakeholders, and Community**

Because of the direct impact on human health, ecosystem health, and the local economy, there is a vested interest in monitoring the water quality and HABs in Lake Wateree. This monitoring occurs at the academic and stakeholder level. In 1993, a community-led monitoring group in Lake Wateree called Water Watch was formed using funds from the federal judgement of an industrial pollution court case occurring upstream (Powell, 2010). Members mostly came from local housing associations, namely the Lake Wateree Association (LWA) of Kershaw County and the Wateree Homeowners Association (WHOA) of Fairfield County (Water Watch, 2016). For years, the group operated successful water quality monitoring programs, but in 2003, a lack of funding and decreased interest led to the termination of its monitoring efforts. However, in 2008, concerned citizens restarted the monitoring project again with funding from LWA and WHOA along with the assistance of the University of South Carolina (USC). Today, Water Watch volunteers cooperate with USC personnel to provide bi-monthly assessments of water quality across 20 sites in Lake Wateree, and a report summarizing these findings is sent to SCDHEC after each sampling.

USC faculty have conducted many investigations surrounding the water quality and HABs at Lake Wateree. Past research projects include the study of community monitoring efforts (Powell, 2010), the role of nutrient limitation on phytoplankton growth (Clyburn, 2019) and the effects of different physiochemical conditions on the toxins present in Lake Wateree HABs (Smith, 2013). However, not much transdisciplinary research (i.e., involving non-academic stakeholders) has been conducted by USC with respect to Lake Wateree. Sara Powell conducted a transdisciplinary project which, along with investigating issues of Lake Wateree water quality, involved the development of a website where stakeholders could easily access monitoring results, modifying the website with input from the community. This website is still operational and consistently updated with new reports, most recently as of March 2022.

Despite not conducting much transdisciplinary research on Lake Wateree, USC participates in ongoing transdisciplinary processes in its communication with those involved in monitoring efforts. USC regularly attends the LWA Annual Meeting, in which representatives from different stakeholders discuss upcoming projects for the year or recent investigative efforts. The most recent meeting occurred in March 2022 during which Duke Energy, LWA and Water Watch, and USC faculty presented on projects related to the enhancement of Lake Wateree habitats. Representatives from Duke Energy spoke of a partnership with SCDNR to artificially enhance habitats of largemouth bass, crappie, and catfish populations (LWA, 2022). They also detailed a dam-modification project in which they enlisted the help of the LWA to minimize the impact of the construction on the Lake Wateree community and resources. The LWA presented on administrative changes and funding for the upcoming year, while Water Watch focused on its most recent water quality monitoring efforts and future plans. USC faculty presented on different projects related to water quality and HAB monitoring, such as methods for HAB monitoring improvements, details on *Lyngbya wollei* blooms, and HAB toxicity in fish.

Overall, the joint efforts between the Lake Wateree community, Water Watch, Duke Energy, SCDNR, SCDHEC, and USC have led to enhancements in the monitoring of HABs and water quality in Lake Wateree. Collaborations between USC, SCDHEC, and Water Watch have led to high-quality, long-term measurements of biological, chemical, and physical water parameters of regular spatial and temporal resolution. Additionally, SCDNR and Duke Energy have partnered to develop methods of enhancing the Lake Wateree habitats for local wildlife. The LWA Annual Meeting has provided a regular source of information exchange between these stakeholders and societal sectors, exemplifying Scholz's definition of a transdisciplinary process.

**Recommendations for Enhancing Transdisciplinarity in Lake Wateree**

Next, I will recommend ways in which future transdisciplinary research should be conducted for the enhancement of current environmental monitoring and communication in Lake Wateree, drawing from elements of similar transdisciplinary projects. In offering these recommendations, I would first like to recall the case study of the Australian transdisciplinary environmental research team that I discussed at length in the previous chapter. As mentioned earlier, a 2016 study followed the work of an Australian transdisciplinary environmental research team comprised of physical scientists, social scientists, and sustainability and policy specialists (Gaziulusoy et al., 2016). The goal of the investigation was to identify large-scale issues faced by the team and to develop strategies to address them. The methods employed by those conducting the study could be applied to Lake Wateree collaborations to offer a sort of case study on transdisciplinary work in South Carolina, providing greater insight not only to the Lake Wateree research efforts, but also broader conservation efforts.

To assess the challenges faced by the research team in question, Gaziulusoy et al. (2016) used a participatory action research methodology characterized by sets of action research cycles. An action research cycle (ARC) consists of four stages—planning, action, observation and reflection. During the planning stage, a specific problem and method of approach is developed. Afterwards, the plan is carried out in the action stage and analyzed during the observation stage. The initial plan is then re-evaluated and potential improvements to the problem identification or research method are suggested, after which a new plan is developed and the cycle repeats. As such, participatory action research is iterative and continuously offers suggestions on how a desired research outcome can best be reached.

The specific methods used by the investigators of this transdisciplinary case study involve three simultaneous phases of ARCs. These three phases as described by Gaziulusoy et al. were: "1) Project kick-off and exploratory research; 2) Planning for and execution of two visioning workshops with participation of stakeholders and follow-up meeting with partners; 3) Analysing and making sense of data generated during the first two phases, reframing project scope and methodology, and planning for the further research and engagement activities," (Gaziulusoy et al., 2016). The first phase refers to the research regularly conducted by the transdisciplinary research team in question. The second phase deals with reflective workshops and stakeholder meetings held by the transdisciplinary research team about the research they conduct in the first phase, and these ARCs are shorter and more frequent than those in phase 1. The third phase involves the journal entries of one member of the transdisciplinary research team about phases 1 and 2, and these ARCs are even shorter and more frequent than those in phase 2.

Each workshop, meeting minutes, and journal reflection were reviewed and analyzed qualitatively to identify 21 distinct challenges faced by the research team and offer recommendations to these challenges. Because the transdisciplinary network within Lake Wateree is already well-established, a similar kind of participatory action technique could be easily implemented into current investigations and transdisciplinary processes. This approach would require more active participation from project stakeholders, but the value of the information it would provide would be well worth the effort. A similar case study in the Lake Wateree region would offer an understanding of the specific challenges hindering effective water quality monitoring, communication between stakeholders, and more, which would allow these challenges to be addressed and accounted for in future work. Moreover, these findings could be extended to inform other similar conservation efforts, thereby contributing to the larger field of environmental science and transdisciplinarity. Overall, I believe that USC should take a more active role in transdisciplinary research and begin to assess Lake Wateree, not just as a source of HABs and water quality issues, but as a potential case study of transdisciplinary environmental work.

# Understudy of Air and Water Quality Effects in Catawba Indian Nation

## Introduction

For this next section, I will focus on air and water quality issues associated with the Catawba Indian Reservation. Like the previous chapter on Lake Wateree, I will first examine the history of air and water quality issues with this region and its effects on the local community. Next, I will discuss any existing efforts to study or manage this issue before presenting related transdisciplinary research to offer recommendations of how research and conservation efforts should continue in this area.

## Catawba Indian Reservation, Air and Water Quality

The Catawba Indian Reservation is a 600-acre land tract in York County, SC, located around the banks of the Catawba River. Of the 573 federally recognized tribes in the United States, the Catawba Nation is the only one located in SC. Currently, the nation has over 3300 enrolled members (Catawba Indian Nation, 2022). The Nation within 10 miles of Rock Hill, SC, a suburb of the Charlotte metropolitan area, a prime location for growth and development but also for environmental issues associated with urbanization.

The Catawba River is located within the Catawba-Wateree basin, upstream from the Wateree River. It receives runoff input from major areas of urban development, such as the Charlotte metropolitan area and Rock Hill, SC. Additionally, over 2 million people live within the Catawba-Wateree basin, which has placed a strain on water resources. Hydroelectric and textile dams within the river pose risks to flow management, polluted runoff, and industrial waste, all threatening the health of the river and the communities around it. For these reasons, the Catawba River was named one of America’s Most Endangered Rivers by American Rivers in

2008, and the Southern Environmental Law Center identified the Catawba-Wateree basin as one of the top 10 endangered places in the Southeast in 2010 (American Rivers, 2021).

One major historical pollutant of the river was coal ash, a byproduct of power generation. In 2009, the Environmental Protection Agency stated that four of the 44 most hazardous coal ash ponds were located along the Catawba-Wateree basin. Coal ash regularly threatened the river and local water supply (EPA, 2009); to address this, the North Carolina Department of Environmental Quality (NCDEQ) approved a number of plans for the excavation of this ash from the river in 2020 (NCDEQ, 2021). Other water quality issues include harmful bacteria and chemical elements from homes, stormwater runoff, and sewage spills.

Recently, the development of the New Indy Containerboard paper mill in Catawba, SC, has led to air quality issues in the Catawba region. The mill produces sulfur-containing compounds which can release strong, unpleasant odors often compared to that of rotten eggs. Very low concentrations of sulfur-containing compounds can be detected by the human sense of smell, and while these concentrations are often lower than concentrations associated with being harmful to human health, the odors can trigger headaches and nausea (SCDHEC, 2022). To monitor odors and air quality conditions, SCDHEC records daily measurements of these sulfur-containing compounds in the Catawba region and encourages community members to report any instances of odor they come across, and this data is made readily available through the SCDHEC webpage.

SCDHEC monitoring has shown that hydrogen sulfide, one sulfur-containing compound, has exceeded the acute Minimal Risk Level (MRL) established by the Center for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry (ATSDR). The MRL, or the estimate of the daily human exposure to a hazardous substance that has no appreciable risk to cause adverse health effects, for hydrogen sulfide is 70 parts per billion (ppb). To date, SCDHEC has not observed any exceedances of this threshold over a daily period. There have been brief periods (~1 hour) where concentration exceed the daily MRL, but the effects of exposure of harmful substances on human health are dependent on the concentration of the substance and the duration of the exposure; in other words, they need to fulfill the concentration and the time requirements of harmful exposure to surpass the MRL, and this has not yet been the case for hydrogen sulfide around the Catawba area. Still, residents do report high volumes of strong, unpleasant odors leading to nausea and headaches in some cases, negatively impacting the quality of life in this region (SCDHEC, 2022).

**Management and Academic Understudy of Air and Water Quality Issues**

While there have been many local, state, and federal attempts to address the water and air quality issues around the Catawba region, not much academic research has been conducted on these overall impacts on ecosystem and human health or how these environmental hazards are communicated to local communities. An investigation of an institutional repository at USC revealed that academic investigations on water quality of the Catawba River have focused on the specific effects on the Wateree community downstream, likely due to the existing networks between USC and Lake Wateree stakeholders and the closer proximity of Lake Wateree to USC.

In comparison to the Lake Wateree community, the Catawba Indian Nation has much less involvement from academic institutions in their communication and outreach of environmental issues. Per the Catawba Nation's website, the Catawba Nation Environmental Services office offers updates to their community through their Facebook webpage and community portal, which all Catawba Nation citizens are given access to when they register within the Nation. While the community portal is inaccessible to outsiders, the Environmental Services Facebook page was available to those outside the community. Contrasted with the Lake Wateree website for water quality monitoring, the Facebook webpage is much harder to navigate and offers less information. Also, whereas the Catawba Facebook webpage primarily lists advisories from SCDHEC and NCDEQ, Wateree has the additional feedback, resources, and research of USC accessible from its website. Finally, there seems to be no analog to the LWA Annual Meeting in the Catawba community, all of which hinders the communication of environmental health information.

Still, there have been joint efforts between local, state, and federal governments as well as community stakeholders to protect the Catawba River. Federally, the EPA has issued orders to control the odors associated with the New Indy paper mill and is in the process of issuing new environmental regulations for this situation (SCDHEC, 2022). On a more local level, between 2010-2011, The Catawba Scenic River Advisory Council (CSRAC) partnered with SCDNR to host workshops and community meetings about the conservation of the Catawba Scenic River, a 30-mile stretch of the Catawba River that attracts many recreational visitors (CSRAC, 2011). The CSRAC is a community-based organization comprised of Catawba residents concerned with the preservation of the Catawba Scenic River. Within the meetings, representatives from state environmental agencies such as NCDEQ and SCDHEC, county governments from North and South Carolina, tribal representatives from the Catawba Indian Reservation, and public stakeholders such as Duke Energy and CSRAC discussed how best to manage the Catawba Scenic River. However, there was no involvement of any academic or tribal organization during these series of meetings.

The academic understudy of environmental health concerns in areas of lower socioeconomic status is a known and cited problem within the larger environmental research community (Egger, 2013). This disparity is even more pronounced when considering issues impacting indigenous communities. While a detailed overview into the history of environmental racism and academic neglect of certain minority communities is beyond the scope of this project, I mention it now to offer how a cross-disciplinary perspective involving the natural sciences, sociology, and humanities can enhance environmental research. Whereas natural scientists with no humanities or historical background may be unfamiliar of issues surrounding environmental racism, their more-informed counterparts would be better aware of these issues and more equipped to address them.

**Recommendations for Enhancing Transdisciplinarity in Catawba Indian Reservation**

I will now discuss on ways in which transdisciplinary work could be executed in the Catawba community, focusing on how the needs of the Catawba Nation and academic institutions could be more involved in future efforts. In offering these recommendations, I will draw from the 2010-2011 workshops on the preservation of the Catawba Scenic River and a transdisciplinary research project investigating the environmental needs of tribal leaders across 15 Nations. In evaluating these projects with respect to ongoing conservation efforts in the Catawba community, I will advocate for the increased participation of academic institutions like USC in research surrounding the Catawba community and for tribal representatives to have an increased role in community gatherings centered around conservation.

My first recommendation for transdisciplinary work in the Catawba region is more involvement from academic researchers in monitoring and investigating environmental conditions and the communication of these findings. The collaboration in Lake Wateree demonstrates that USC can do this sort of work, and USC researchers have substantially enhanced Lake Wateree monitoring and the distribution of this information to stakeholders

(Powell, 2010). Similarly, USC representatives could begin to investigate similar issues in the Catawba area. This, of course, presents more difficulties than Lake Wateree because USC does not yet have a transdisciplinary network in Catawba, and it would require more resources to travel to and from the location. Also, lack of trust towards academic and community stakeholders is a much larger issue in the indigenous community due to a long history of environmental racism (Egger, 2013). In accounting for this challenge, researchers would need to approach engagements with the Catawba Nation from a cross-disciplinary perspective, one that will incorporate the sociological and historical elements necessary for most effectively working with indigenous communities. As some environmental scholars point out, this sort of perspective tends to be quite difficult for natural scientists (Klenk and Meehan, 2015). Still, it is necessary for the successful collaboration between indigenous communities and academic and public stakeholders.

In conducting research related to environmental health issues in the Catawba community, investigators could incorporate elements from existing transdisciplinary works related to conservation in indigenous communities and past collaborations between Catawba stakeholders. In 1998, an investigation on the environmental services and training needs of indigenous tribal leaders was conducted with the goal of improving the quality of environmental services on reservations (Saxena, 1998). Eighteen tribal officials across 15 Nations were surveyed in this study, during which they ranked 28 statements on environmental responsibilities related to the management of drinking water, wastewater, and solid waste on their relative importance (scale of 1-5, 1 being low importance and 5 being high importance important) and their own performance abilities with respect to these areas (scale of 1-5, 1 being low ability/confidence and 5 being high ability/confidence). It was found that tribal officials struggled most in the areas of solid waste management, collaborating with federal or state governments in the enforcement of environmental regulations, drinking water management, training for environmental staff, and wastewater management.

Tribal officials also discussed their preferences for environmental training methods during phone interviews. Common training preferences included instructors who were "knowledgeable about the subject matter and tribal culture" as well as "problems and issues related to environmental management," and "to receive relevant information from different sources," (Saxena, 1998). These results highlight the importance of transdisciplinary approaches to conservation as a variety of academic disciplinary perspectives are preferred by indigenous environmental service officials, and the request of different sources of information could be fulfilled by academic involvement in conservation efforts around indigenous communities.

Similar research involving methods of surveying and interviews could be conducted in the Catawba Nation to best identify the needs of this community. In the meantime, the Catawba region has the frameworks of a transdisciplinary network, only lacking university participation in its study and monitoring of environmental health conditions. Institutions like USC should also seek out community collaborations such as the 2010-2011 workshops hosted by CSRAC and SCDNR to establish a similar transdisciplinary network to the one in Lake Wateree. University resources have been instrumental in the communication and investigation of environmental hazards in Lake Wateree, and they could also be utilized in the Catawba community to the same effect. These efforts should especially focus on the involvement of the Catawba Indian Reservation which has been overlooked in past Catawba community conservation collaborations. Finally, academic researchers should consider the sociological and historical factors which may be unknowingly contributing to their areas of study to identify topics that may go understudied or neglected.

## Conclusions

In this paper, I have discussed the concept of transdisciplinarity and its relation to the field of conservation and environmental science. I explored disciplinarity and the evolving relationships between disciplines and modes of knowledge production. I discussed transdisciplinary environmental research and the value of multiple disciplinary perspectives and the exchange of ideas across the societal sectors of academia, policymakers, and other public stakeholders. I then discussed general models of transdisciplinary research to highlight the importance of accepting different types of knowledge and not just seeking to find a compromise between them. Finally, I presented the environmental hazard monitoring of Lake Wateree and the Catawba community to offer recommendations for how transdisciplinary work should proceed in these regions. With respect to Lake Wateree, I recommended that ongoing university investigations and collaborations with stakeholders act as a sort of case study for environmental transdisciplinary work. With respect to Catawba, I recommended that academic institutions like USC become more involved in existing conservation efforts between community stakeholders to establish a similar transdisciplinary network to that of Lake Wateree.

Both strategies in Lake Wateree and Catawba require the self-reflexivity of researchers and organizations and the cooperation of Mode 1 and Mode 2 processes. Academic institutions incentivize researchers to stay within the confines of their disciplines and present many boundaries to those looking to engage in cross-disciplinary work. In many ways, these institutions overlook the value of inter- and transdisciplinary studies. Similarly, non-academic organizations present their own challenges to transdisciplinary researchers. The challenges associated with transdisciplinary work stem from the current inability to jointly accommodate Mode 1 and Mode 2 knowledge production. In the coming decades, academics and non-academics alike will need to recognize the importance of the mutual exchange of information across disciplines, societal sectors, and modes of knowledge production.

Transdisciplinary scholars have already begun to identify major challenges associated with this kind of work as well as potential solutions. The burden now lies with academic institutions, external organizations, and the environmental community to enact some of these necessary changes. Only then can the full potential of climate change mitigation and conservation be reached.

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