UNIVERSIDADE CATÓLICA PORTUGUESA

APPROACHING THE ENVIRONMENTAL THREAT IN ART, CULTURE AND SCIENCE. A TRANSDISCIPLINARY DIALOGUE IN A BIO-ACOUSTIC SOUND EXPERIMENT AND LINE OF BEAUTY.

Dissertation submitted to Universidade Católica Portuguesa to obtain a Master's Degree in Culture Studies (Management of Arts and Culture)

By

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ABSTRACT

The new geological era, the Anthropocene, is characterized by humanity being the prevailing geological force. With its activity, humankind is influencing the Earth System by changing natural processes and being responsible for the consequences of climate change.

The uniqueness of this historical moment manifests itself in the witnessing of the becoming of an era, while still having the possibility to influence the outcome of the environmental crisis, which currently reached a tipping point. The encounter between the disciplines of art and science could represent a possibility of closing the knowledge gap concerning the influence of humankind over the Earth System. Therefore, transdisciplinary collaborations between art and science will be presented to illustrate through a different approach what the Earth System is and how it functions. A thorough investigation of the various narratives concerning the history of life, the understanding of nature, wilderness, the natural as well as the transdisciplinary practice and the Earth System is necessary.

Furthermore, cutting across disciplines allows the possibility of taking action. The thesis analyzes to what extend transdisciplinarity between these two domains might be able to solve current environmental threats and influence the Earth System in the Anthropocene.

Projects such as the bio-acoustic sound experiment between Dunn and Crutchfield and *Line of Beauty* between Lorenz and Pflugmacher, will illustrate the interaction. Dunn and Crutchfield experimented with sound to influence the behavior of bark beetles, which were infesting California´s forests. Susanne Lorenz explores together with biologist Stephan Pflugmacher the possibility of cleaning the river water of the Seseke through an installation. Both projects will be discussed as transdisciplinary attempts between art and science to come to terms with environmental threats.

KEYWORDS

Anthropocene—Transdisciplinarity—Geological Force—Environmental Threats—Earth System—Ecological Logic—Action—Countervisuality

ABSTRACT

O Antropoceno, a nova era geológica, é caracterizado por a humanidade se assumir como a força geológica predominante que pela sua atividade está a influenciar o Sistema Terra, alterando os processos naturais e sendo responsável pelas consequências das alterações climáticas.

A singularidade deste momento histórico encontra-se na observação da afirmação de uma época que embora ainda tem a possibilidade de influenciar o desfecho da crise ambiental que está a atingir um ponto de inflexão. O encontro entre as disciplinas da arte das ciências pode representar uma possibilidade de colmatar a lacuna de conhecimentos sobre a influência da humanidade no Sistema Terra. Assim sendo, as colaborações transdisciplinares entre a arte e a ciência serão apresentadas para ilustrar, com uma abordagem diferente, o funcionamento do Sistema Terra. Para tal è necessárias uma investigação.

O encontro entre as disciplinas da arte e da ciência poderia representar uma possibilidade de colmatar a lacuna de conhecimentos sobre a influência da humanidade sobre o Sistema Terra. Por conseguinte, colaborações transdisciplinares entre arte e ciência serão apresentadas para ilustrar através de uma abordagem diferente o que é e como funciona o Sistema Terra. É necessária uma investigação aprofundada das várias narrativas relativas à história da vida, à compreensão da natureza, da natureza selvagem, da prática tanto natural como transdisciplinar assim como do Sistema Terra.

O corte transversal de disciplinas permite a possibilidade de tomar medidas. A tese analisa até que ponto a transdisciplinaridade entre estes dois domínios poderá ser capaz de resolver as atuais ameaças ambientais e influenciar o Sistema Terra no Antropoceno.

Esta interação entre as duas disciplinas será ilustrada através de dois projetos: a experiência sonora bio-acústica entre Dunn e Crutchfield e a Linha de Beleza entre Lorenz e Pflugmacher. Dunn e Crutchfield experimentaram usar som para influenciar o comportamento dos *bark beetles* que estavam a infestar as florestas da Califórnia. Susanne Lorenz explora juntamente com o biólogo Stephan Pflugmacher a possibilidade de limpar a água do rio Seseke através de uma instalação. Ambos os projetos serão discutidos com o objetivo de apresentar uma abordagem transdisciplinar entre a arte e a ciência para enfrentar as ameaças ambientais.

PALAVRAS-CHAVE

Antropocena — Transdisciplinaridade — Força Geológica — Ameaças Ambientais — Sistema Terra — Lógica de Acção — Contravisualidade

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Carlotta Brandizzi

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1 Introduction

The environmental crisis is one of the biggest challenges in our century and it will shape the years to come. The desire to dedicate the research of this dissertation to the understanding and studying of the environmental crisis and its threats started from the desire to connect the fragmented and great amount of knowledge available. The extensive flow of information concerning environmental issues, their high complexity and description through scientific language created a passivity in society to take action in solving them. Patience and time are needed in order to analyze what is happening, which nowadays are scarce goods. Looking for a way to actually understand what is going on when talking about environmental crisis and how to take action by solving its issues inspired the development of my research to the point of adventuring myself into complex scientific dynamics. The failure of governmental and political bodies to understand environmental issues and to solve them from an angle that requires the inclusion of the social, political, cultural and political area and their neglect to act, motivated the research in taking a different angle where objectivity and subjectivity meet, entangle and intertwine. Therefore, the transdisciplinary has been a great source for developing a certain understanding in this matter and direct the research into a different mental space.

In order to situate the discourse around the environmental crisis in our epoch the illustration of historic, social and cultural context is necessary. Ruptures are characterizing the time we are living in such as ruptures in the Earth System, ruptures in disciplines, rupture with the past epoch the Holocene, rupture with ideas concerning nature and ruptures in mentality to mention some. They are accompanying the development of the times to come and the discourse concerning the environment.

According to Klingan et al. systemic and historical ruptures allow us to grasp textures. “For geologists, whose profession trains them to listen to the Earth, a rupture appears as an unconformity between different strata, different deposits – the changing composition of rock, silt, clay, organic material, and fossil traces – and thus, a discontinuity between different ages, denoting the end of a period in the Earth’s dynastic succession and another one’s beginning, or its chronostratigraphy” (2015, 14). Hence ruptures concerning the Earth System are showing us the end of an epoch the one of the Holocene and designating the start of the epoch of the Anthropocene, which humanity characterizes as in being a decisive geological force.

The Anthropocene denotes the becoming of a paradigm shift, where the basic assumption underpinning the discipline of science is being changed in a revolutionary way. It marks a rupture with the common understanding of science according to Jill Bennett (professor of Experimental Arts and founding director of National Institute of Experimental Arts (NIEA) in Sydney) and underlines the fact that "climate science" is not taken into consideration by politics because it attacks the freedom of the individual and of the market. Especially it threatens a "way of life" we are used to, characterized by commodities and a certain pattern of how life is being lived (Bennett 2012a). A rupture with how our everyday and domestic sphere is experienced should change drastically if certain objectives concerning the battle against climate change and the impact of humanity on the Earth System want to be met. Since humanity has become a geological force, meaning that its impact on the Earth System with its activity is changing the climate and ecosystems in a rapid and irreversible way, it is humankind's responsibility to act. But how is it possible to induce a shift in a mindset which not only has to happen on an individual way, but collectively and in various areas such as the social, cultural, political and economic one?

A decisive step was the one taken by the atmospheric chemist and Nobel laureate Paul Crutzen when in 2002 he identified the epoch we are living in officially as the Anthropocene. Though in the past decades several scientists already recognized the "anthropozoic" character of the epoch, no effort has been taken especially from politics to reveal and consider available insights concerning pollution and emissions. However, after Crutzen's declaration several debates regarding the assertion of the Anthropocene have started and the attention towards humanity as being an impacting force rose. Yet not many initiatives have been taken to stop certain activities such as the burning of fossil fuels, the usage of waters as wastewater canals or the deforestation for cattle-land even though the negative impact was known. As Crutzen states in his paper about the Anthropocene the catastrophic situation concerning the ozone hole could have developed in a completely different way and did not more by luck than by wisdom. "Unless there is a global catastrophe – a meteorite impact, a world war or a pandemic – mankind will remain a major environmental force for many millennia" he recognized in 2002. Hence can the COVID-19 pandemic be seen as an opportunity to actively work for a new paradigm were humanity's impact on the Earth System is mitigated and reduced until restoring certain dynamics which are necessary for the survival of the planet and therefore also for humanity?

A short-term benefit has been detected during the pandemic: forcing the globe or at least many countries with active industries, tourism and a frequent individual movement between cars and planes, to stop. It showed clearing waters and returning especially of aquatic ecosystems to a state they have not been seen for a long time. Yet, it was a short-term effect, which with the necessary restarting of the economy already is fading. Interestingly, in this year 2020 the alarm concerning various catastrophes rose, such as the wildfires in California (since July over 1 million acres have been registered as burned according to the LA times), wildfires in the arctic region and in Siberia are breaking records of temperatures, the deforestation ravaging in the Amazon forest (8.4 million soccer fields in the past decade)[1] and the plan of the Trump administration to drill in Arctic National Wildlife Refuge are just some to mention.

It can be a moment of reinvention and shift that operates on different levels and in various areas in order to create knowledge and to act for solving these global environmental threats. Bennett argues that a "transdisciplinary revolution" is necessary, which works globally and invests in new social ecological systems, a new governance and management paradigm in 200 countries. Therefore, also disciplines will find themselves challenged by configuring their practice to meet the challenges of living in the Anthropocene. The shape of future collaborative practices, specifically as the one between art and science that I propose in this paper, need to be imagined, researched and most importantly experimented with. An ecological logic which "rocks the ground beneath disciplines" and where "art practice will be configured beyond contemporary institutional boundaries" (Bennett 2012a, 11) are key aspects in the Anthropocene. The transdisciplinary "concerns the dynamics engendered by the action of several levels of reality at once" and aims at "joint problem solving" (Nicolescu 2006, 6; Nicolescu 2005, 7). Therefore, offers an innovative way of approaching issues concerning the environmental realm.

The complexity of environmental problems in the Anthropocene lies in the fact that they can become or already are global issues and connected to various areas such as the social, economic, politic and cultural one. For example, the issue of the bacteria Xylella in the south of Italy in Apulia stands for a problem tied to the economic, cultural and social realm. Xylella fastidiosa came through Dutch imported decoration plants from Costa Rica

[1] The Royal Statistical Society 2019

and already ravages since some years in the olive tree fields affecting 21 million of the 60 million present trees in the region. It inserts itself in the xylem, the nutritive path of the olive tree which brings water and other nutrients to the leaves and profits from the tree's food. In this way it starves the tree from the inside and destroys the harvest of the olives. Yet, the greater threat is that Xylella fastidiosa is one of the most dangerous bacterias worldwide because it can affect 563 different plants such as almond-, cherry-, peach-trees and vines, rosemary, lavender and more. Additionally, to the fact that Xylella can present a global threat, the issues is that the bacteria likes warmth, hence the increasing temperatures due to climate change are facilitating the propagation of Xylella fastidiosa. Fighting against the bacteria means currently to cut the trees and to burn them afterword to avoid the spreading of the bacteria (Aisslinger 2019). Since the culture of olive tree fields is fundamental in the region of Apulia because most of the fields today belong to the families since many generations and some of the trees are about 1000 years old, Xylella is a threat to culture. Moreover, it affects greatly the economy of the region and the people inhabiting it by destroying their harvest and lowering their social abilities. Additionally, olive trees are also an important element for CO_2 retention and absorption in the region of Apulia since they cover a great part of the land.

This issue shows the interconnection between various areas which experience problems tied to the threat of Xylella. The issues are at different levels, but somehow linked to each other. A disciplinary approach can open up new ways and paths in order to research and act in such complicated and complex issues tied to the environment and climate change. Art and science as being challenged by this complexity can face it and contribute to the production of knowledge and action in regard of intricated environmental issues. Therefore, the two chosen case studies develop and analyze the mode of practice, the collaboration between the two disciplines and the result of the cooperation.

As argued by French philosopher and psychoanalyst Felix Guattari in such a context given by the Anthropocene and the threats tied to the environment "(…) it appears crucial (…) that we rid ourselves of all scientific references and metaphors in order to forge new paradigms that are instead ethico-aesthetic in inspiration" (2008, 25). A different mental space is demanded were domains can act outside of their boundaries in order to address and possibly solve environmental issues that we are facing today. This paper proposes an attempt to reach the understanding of these complex epoch and its elements and most importantly

wants to raise awareness and action in the reader may he or she be artist, academic, scholar, farmer, scientist or just involved in the supporting of the planet.

Research Question

Therefore, the main goal of the research in the framework of this dissertation is to identify how successful and beneficial the collaboration between art and science can be. Since the two domains are very different in approach and modality it will be interesting to discover in what way they can collaborate and if their collaboration can come to a useful outcome for the addressed environmental problem. Additionally, it is central to the research to establish if through a transdisciplinary approach environmental threats can be mitigated or even solved. The core aspect of the collaboration between the domains of art and science is to depict if they are able with their capacities to analyze the tackled issue and to make it understandable to the public. Moreover, it is central to identify if the transdisciplinary project can actually reach to a solution which is applicable in reality on a global scale and which has the ability to solve the threat from a social, economic, cultural and environmental point of view.

The research concerning the fruitfulness of transdisciplinary projects in regard of complex environmental threats aspires at finding a new path, where the combination of not yet thought elements can be possible. This research wants to inform about the possibility of using the techno-scientific resources available to humanity for approaching and solving environmental threats. In combination with creative thought the opening up of innovative methods wants to be an opportunity in the fight against global warming and will be researched as such.

Methodology

In the framework of the dissertation the transdisciplinary approach between the domains of culture, art and science is the core methodology used, because of the highly complex and interdependent issues dealt within the case studies. The transdisciplinary has the ability to investigate what is across disciplines and hence reveal the undiscovered. It is important to adopt this methodology to find new and innovative ways to tackle, understand and solve environmental threats. Moreover, the epoch of the Anthropocene with its

fragmented knowledge and the connection of ecology with the social, economic, political and cultural sphere demands the transdisciplinary approach.

In order to face the challenging fragmentation of knowledge a systematic literature review was adopted in order to critically research the necessary information concerning the Anthropocene, the dialogue between art and science, transdisciplinarity, the Earth System science and the necessary information for the various case studies. Different authors have therefore provided indispensable knowledge and have been chosen in order to depict the variety, vastity and duality of information concerning the above-mentioned fields. A reflection about humanity being an impacting geological force through the literature of Chakrabarty (2009), Crutzen (2002), Bennett (2012a), the dialogue between art and science with Latour (2014), Mirzoeff (2014), Wilson (2017) and the analysis of the transdisciplinary through Latour (1993), Nicolescu (2006), Bennett (2012b; 2012c), Damm (2000) have contributed to fundamental insight.

The domains of culture studies, science and art are lastly united under the transdisciplinary methodology. Culture studies is responsible in the development of the methodology to render the contextual background and to facilitate the dialogue in the intersection of the disciplines (Santos 2018). It is an important element to connect and operate in between the exchange of art and science in the discussion and operation of environmental threats. Experimentation is also an important element in the assessment of the methodology since it characterizes the collaboration between art and science. The domain of science will focus on the area concerning climate science and nature. The research is focused on the environment and on the way, science is coping with the threat of climate change.

The exemplification of the theoretical analysis under the transdisciplinary approach will happen through two case studies, which will be analyzed for their outcome. This to also potentially address the usefulness of the research to a diverse audience between artists, scientists, environmentalists, the individual and society as a whole.

Structure

The dissertation is structured into three main chapters representing the body of the work. Chapter 2 deals with the analysis and critical research of the conceptual framework in three fields namely the Anthropocene, the dialogue between Art and Science and

Transdisciplinarity. The conceptual framework depicts the fragmented knowledge in the epoch of the Anthropocene, the position of the domains of art and science in the Anthropocene and the transdisciplinary approach as in the necessary methodology to face the challenges of this epoch. Hence it represents the theoretical base for the further development, understanding and analysis of the two case studies. The chapter concludes by stating that art can be an opportunity to render together with science, nature again visible and understood by humanity through a transdisciplinary approach. Important therefore is to understand what the environmental threats are and which dynamics they entail, since they belong to a system humankind is inhabiting but not entirely belonging to.

Chapter 3 will explain the realm of the Earth System science, a science dedicated to picture the various dynamics belong to the earth. It is fundamental to understand them in order to develop a feeling for how ecology and its various ecosystems work, to at best use the gained knowledge to solve the threats. Furthermore, in the second subchapter of chapter 3 the ecosystem of the forest and of the river which will later serve for the understanding of the case studies, will be developed. The comprehension of the various elements interplaying and interconnecting in the two ecosystems is a critical part of the development of the case studies and the linkage to global warming.

The chapter 4 *A new ecological paradigm: "Ecological logic"* develops the two chosen case studies on a descriptive and conceptual level. First the addressed case studies will be explained to illustrate the reader the connection between various elements concerning the ecosystem in question and the contribution of the collaboration between art and science. In the next step the outcome is analyzed regarding how beneficial the transdisciplinary experimentation between art and science has been for the addressing and solving of the environmental threat in question. The bio-acoustic sound experiment between the sound artist David Dunn and the physicist and chaos theorist James P. Crutchfield will investigate the threat of the bark beetles in California and reveal humanity by using its inventiveness and tools at disposal to find a solution. On the other hand, the artist Susanne Lorenz and the biologist Stephen Pflugmacher open up the possibility of intervening in an ecosystem with their installation *Line of Beauty* between science and art to regenerate it.

2 Conceptual Framework

2.1 Anthropocene

2.1.1 Humanity as a geological force

Humankind is counted today as the predominant force on planet earth, with the ability of influencing nature. This theory has become, according to Bennett a defining aspect of the new geological era, the Anthropocene, since not nature is mostly responsible for changes in the Earth System, but human activity now has driven change at a planetary level (2012, 4).

The term Anthropocene has been coined by Crutzen, who in 2002 argued that "For the past three centuries, the effects of humans on the global environment have escalated. Because of these anthropogenic emissions of carbon dioxide, global climate may depart significantly from natural behavior for many millennia to come. It seems appropriate to assign the term 'Anthropocene' to the present, in many ways human-dominated, geological epoch." Crutzen underlines the fundamental role of humankind in geology and ecology in this new geological epoch. The term Anthropocene suggests, that the Earth is moving away from the Holocene, which is it's natural and previous geological epoch. The Earth finds itself in "planetary terra incognita", where it is "(..) rapidly moving into a less biologically diverse, less forested, much warmer, and probably wetter and stormier state." (Steffen, Crutzen and McNeill 2007, 614).

However, Crutzen was not the first to acknowledge the shift humankind was and still is responsible for on a planetary level. Various scientists and researchers recognized in early years important processes which are connected to global warming and responsible today for the over-heating of the atmosphere. Already in 1873, Antonio Stoppani an Italian geologist, understood the influence of humans on the environment by stating that the power of humanity is comparable to the bigger forces of the earth. He described the era he was living in as "Anthropozoic era" (Crutzen 2002). Joseph Fourier (a french natural philosopher in 1824) and Claude Pouillet (a French physicist in1873) recognized, that the atmosphere and the temperature at the earth's surface were strongly connected. Their research came to the conclusion that the atmosphere worked as an "absorbing layer" for the radiation coming from earth and leaving to space. This was influencing the temperature at the earth's surface which with more radiation was getting higher (Bolin 2007, 3).

Fourier and Pouillet identified already the theory of the atmosphere functioning "like the glass in the frame of a hotbed" (Bolin 2007, 5-6). Their findings regarding the

relationship between the sun's heat, the earth's surface and the atmosphere show that already in 1896 important knowledge, for what determines the rise of temperature, was discovered. Both identified the transparency of the air as a fundamental determinant for how much heat radiation would reach the earth's surface. The transparency of the air on the other hand depends on fine suspended particles in the air, which block the entrance of sun's heat. Moreover, the clouds reflect also a great part of the sun's heat which tries to trespass them. "And these substances have the peculiarity that to a great extent they absorb the heat radiated by the earth's surface, while they have little effect on the incoming heat from the sun" (Bolin 2007, 5-6). In1957, Charles David Keeling (an American scientist) developed a method to measure the amount of carbon dioxide in the atmosphere and discovered that increase of emission could be caused by human activity of burning fossil fuels. The social concern for these phenomena did not exist at that time, hence scientists, politicians and industrialists did not worry about the consequences of the warming of the atmosphere (Bolin 2007, 8). Until the 2000s the term Anthropocene and the consequences for the environment were not of political and economic interest, because they did not affect in an extreme way the life of humans. The awareness regarding to consequences due to climate change in the "Western World" and some developed countries changed, when first signs started to involve it. Australia was hit by devastating fires, which affected large part of the country. Signs such as drought, cyclones and failure of crop in different parts of the world "became politically and economically inescapable" according to the Indian historian Dipesh Chakrabarty (2009, 199).

The development of the Anthropocene terminology shows that since 1896 there has been attention and a certain understanding for processes which were important for the heating of the Earth System. The question arises then, why no concrete measurements were taken, when already in 1896, the system of heating of the earth's surface and its determinants were known.

In order to understand the neglect for acknowledging the danger coming from human activity, the history of life (the historical development of humanity) and different narratives such as those of capitalism, industrialism and globalization have to be taken into account. All of them characterize in their way the beginning and the development of the Anthropocene.

The beginning of the Anthropocene is still unclear today, is it the climate change, the biodiversity loss, the uncovering of archeological remains, the usage of radio nuclide later, the great acceleration or the traceable process of rapidly accumulating anthropogenic impacts within the Earth System (Klingan et al. 2014, 24). Within the scientific community various directions are being followed and supported, showing the difficulty of assessing the beginning of this new geological epoch. According to Crutzen the Anthropocene might have started in the second part of the eighteenth century. In this period, first discoveries concerning "growing global concentration of carbon dioxide and methane" were met, by analyzing air trapped in polar ice. The design of the steam engine in 1784 by Watts happens to coincide with the same period and is a defining aspect for the start of the industrial revolution (Crutzen 2002).

The scientists of the Anthropocene Working Group[1] (AWG) very much differ in their opinions. Some assert that the "great acceleration" is the marking beginning of the new era. Others state that the Anthropocene should only be defined with a "unique stratigraphic unit that is characterized by unambiguous, widespread and essentially permanent anthropogenic signatures in rock, glacial ice or marine sediments" (Zalasiewicz 2015). The difficulty lies in the fact, that "For the first time in geological history, humanity has been able to observe and be part of the processes that potentially may signal such a change from the preceding to succeeding epoch" (Waters 2014). Humanity is experiencing unprecedently in history the emergence of a geological epoch, which is unique, as the past "cenes" have been acknowledged retrospectively with signs that are dated in millions of years. This reveals another great difference to the past eras: in the Anthropocene humanity has the power to influence the process of reaction which can be decisive for the next generation (Waters 2014). The past historical epochs could not have been influenced, but only analyzed and dated in the past. Moreover, past geological eras are characterized by way longer phases on the geological timescale, such as the Pleistocene dating 1.8 million years. Compared to this, the last geological era, the Holocene, is very short dating between 10.000 and 12.000 years (it is still not defined how long the Holocene lasted).

According to Chakrabarty (2009) the history of life is a fundamental aspect in the understanding of the Anthropocene, which is characterized by the gaining of freedom and independence through the advance of agriculture and the industrial revolution.

"In no discussion of freedom in the period since the Enlightenment was there ever any awareness of the geological agency that human beings were acquiring at the same time as and through the processes closely linked to their acquisition of freedom." (Chakrabarty 2009, 208). Chakrabarty argues that there is a correlation between geological time and the chronology of human history, which before climate change was being seen as unrelated. The question of freedom concerned itself with the issue of freeing oppressed from their oppressor, of giving minorities a voice and ending injustice. The means of gaining this freedom were never questioned, weather they were influencing the environment or causing damage to nature. Through agriculture and industrialization many countries freed themselves from poverty and reached a higher standard of life. But these practices were and still are connected to energy-intensive processes such as the burning of fossil fuels, which are highly damaging for nature and the planet (Chakrabarty 2009, 208). The problem is that our economy is based on these practices and on the acceptable exploitation of natural resources without measure (Wilson 2000, 17-18). "It seems true that the narrative of climate change has been necessitated by the high-energy-consuming models of society that capitalist industrialization has created and promoted (…)." (Chakrabarty 2009, 217). The specific period of time when this shift happened is approximately from 1750 on, as in that time humans changed renewable fuels such as wood and others to fossil fuels such as coal, oil and gas, which were used on a large scale (Chakrabarty 2009, 208). Hence without the history of industrialization, globalization and the one of capital the theory of the Anthropocene would not have been possible.

"So has the period from 1750 to now been one of freedom or that of the Anthropocene? Is the Anthropocene a critique of the narratives of freedom? Is the geological agency of humans the price we pay for the pursuit of freedom?" (Chakrabarty 2009, 210). The answer to these questions is quite complex since climate actions attack in the eyes of politics the freedom of the individual and of the market. They especially threaten "a way of life", which is not given up willingly by the people (Bennett 2012, 7). There is resistance to change habits as they stand for each's individual independence, which nowadays in most countries is an unquestioned right. People are not willing to change in such a short time and drastic way their behavior and "way of life", which is required by the application of climate actions (Bennett 2012, 7). "We are in a moment of history when Western democracies who thought of themselves as the cutting edge of freedom are seeing their values eroding, their freedoms

put into question, their humanism getting lost, all this because their awareness that their power is diminishing on the world scene is creating in them sheer panic" (Adnan 2012, 6-7). The outbreak of the COVID-19 pandemic in the beginning of 2020 is a great example for this, since it is a disease coming from animals and it is hitting in a decisive way humankind on a global level. The pandemic has brought onto their knees many countries in the whole world, forcing people to stay home and to follow strict guidelines which saw them deprived of their freedom of movement, social interaction and decision-making in daily life. The outbreak of the pandemic created panic and for many it was difficult to give up their freedom and personal will for the greater good. The result of people escaping from the northern regions of Italy to the south, when the government decided to close the northern regions in order to contain the Covid-19 spread, is a great example of this behavior.

Even though the Anthropocene sees humankind as the protagonist of this new epoch, the discourse concerning the human induced climate change is not exclusively human centered. According to Chakrabarty a distinction has to be made between the planetary and the global, being the planetary "a perspective to which humans are incidental" and the global "a singular human history" (2014, 23). It can be argued that for example the agricultural revolution was not solely a man-made inventiveness. It was also possible to grow certain crop because of a warmer climate which appeared, because of a change of the amount of carbon dioxide in the atmosphere, a stabilization of the climate and the entering of a new, warmer epoch, the Holocene, after the colder Ice-Age (Chakrabarty 2009, 217). This climatic development was out of human hands and could not be controlled by them, especially in the period when it happened.

Hence the development of the crisis of climate change "(..) has brought into view certain other conditions of the existence of life in the human form that have no intrinsic connection to the logics of capitalist, nationalist, or socialist identities. They are rather connected to the history of life on this planet, the way different life-forms connect to one another, and the way the mass extinction of one species could spell danger for another. Without such history of life, the crisis of climate change has no human "meaning" (Chakrabarty 2009, 217). These other conditions such as shifts in the Earth-system concerning the temperature for example, also play an important role in the becoming of the status quo. The capitalist-industrialization is an important aspect which plays a significant role in the whole crisis and certainly contributed to a high degree to what the Earth-system

has to face in the 21st century. “Our current warming is an instance of planetary warming that has happened both on this planet and on other planets, humans or no humans, and with different consequences. It just so happens that the current warming of the earth is of human doing. The “global” of globalization literature, on the other hand, cannot be though without humans directly and is necessarily placed at the very center of the narrative.” (Chakrabarty 2014, 23).

To summarize the climate change crisis is complex and defined by various narratives, processes of the Earth-system and by humanity as being a predominant force. Various aspects are intertwined on different levels such as climate shifts concerning the deep history and the capitalist-industrialization characterizing the history of life. The Earth-system is not easily grasped and existed already way before humans entered this world, hence some elements are characterized by thousands of years of development and adjustment. Gayatri Chakravorty Spivak (Indian scholar, literary theorist, feminist critic) explains this arguing that “The planet is in the species of alterity, belonging to another system; and yet we inhabit it” (2012, 338). She accurately describes that humankind has to acknowledge retrospectively, that the planet will continue to exist, since it is an own system working independently from humankind. But since, in order to survive, humankind depends on the planet to live, it has become its task to understand the necessities of the planet and not the ones of humankind.

2.1.2 Wilderness in the Anthropocene

Spivak's words highlight in a particular way the relationship humankind has with the planet, on which it is living, and it also pictures the dynamic between nature and humans. The planet is part of a system, which we are trying to understand, but also to domain and to exploit by using the resources of nature for our own survival in an excessive way. Hence it is necessary to reflect on the dynamics which characterize our planet and to define one of the most complex and manifold ideas, which is nature. Hence what does nature mean and how is wilderness defined? "(…) When we say nature, do we include ourselves?" (Williams 1980, 67). Has nature and the natural changed in the epoch of the Anthropocene? What is humankind's place in nature? These are just some of the questions which will be attempted to answer in the framework of this chapter.

According to Raymond Williams "We need and are perhaps beginning to find different ideas, different feelings, if we are to know nature as varied and variable nature, as the changing conditions of a human world." (1980, 85). Nature and its aspects such as wilderness, are composed of different ideas which have to be revealed, since they have changed in time and mutated to different ones according to the historical and societal circumstances. Hence, also the definition of nature has to be determined in the light of the Anthropocene as the historical and societal context are part of a different setting. For the further development of the terms concerning nature, the context is an important factor to take into account. Following the line of thought of Spivak, the ecologist Fern Wickson asserts that "(…) we are just another species intimately intertwined in the complex web of biological systems on this planet" and "(…) I consider humans to be embedded in nature rather than separate from it. (…) For example, the food you eat, the paper you read and the energy you consume are all product of multiple interacting organisms and ecosystem services." (2008, 29). In other words, Wickson argues that everything humankind is producing and using in a certain way is coming from nature, may it be by applying natural resources or ideas of nature.

Generally speaking, a common idea of nature in modern times is that it "exists where people do not. Nature lies outside the urban and agricultural realms, in regions of Earth where natural processes are unimpeded. Nature is where fallen logs rot and acorns grow, wildfires turn woodlands into meadows, and battier islands shift with the currents—all without human interference. By extension, this definition suggests that nature is best

protected by keeping humans far away, so that it can continue to run itself." (Nature 2008, 263). Here human interference is the defining aspect of what characterizes nature, hence an untouched environment without human interference would be counted as truly belonging to nature. However, "(…) the idea of nature contains (…) and extraordinary amount of human history" as well (Williams 1980, 67). It is important to note nature considerably developed alongside humankind especially from the industrial revolution on, until today. Secondly the variety in currents of thought in different contexts shows, that nature cannot be reduced to one thought.

"Like some other fundamental ideas which express mankind´s vision of itself and its place in the world, 'nature' has a nominal continuity, over many centuries but can be seen, in analysis, to be both complicated and changing, as other ideas and experiences change" (Williams 1980, 67). Nature as a living organism has antecedents in ancient systems of thoughts, which formed the prevailing thought in the sixteenth century. Central to the organic theory was the "identification with nature, especially the earth, with a nurturing mother" as Carolyn Merchant (ecofeminist philosopher and historian of science) states (1993, 269-270). The opposing image to the "nurturing mother" was the "wild and uncontrollable nature that could render violence, storms, droughts, and general chaos." Both were human projections of their perceptions regarding the external world and they were tied to the female sex (Merchant 1993, 269-270).

After the Scientific Revolution two very important images of nature developed from the understanding of "nature as disorder". Power over nature became central and gave space to the ideas "of mechanism and of the domination and mastery over nature (…)", which became central concepts of the modern world (Merchant 1993, 270). The patenting of living organisms shows clearly the evolution of the commodification of nature through the scientific and industrial revolution as described by Merchant. Genetic engineering gave the space for a way of "reductionist science" as described by the Indian scholar and environmental activist Vandana Shiva (2011, 8) and redefined living organisms and biodiversity as "man-made" phenomena. She highlights that "reductionist science", "allowed nature to be declared dead, inert, and valueless. Hence, it allowed for the exploitation and domination of nature, in total disregard of the social and ecological consequences" (Shiva 2011, 8). The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) by the World Trade Organization (WTO) issued in 2012 an

international law about "patenting life". Shiva's analysis argues that this regulation was imposed by Western transnational corporations "on the diverse societies and cultures of the world" whose only concern is to follow their interests (2011, 9). It clearly shows the appropriation of living organisms belonging to another system. With this law living things were tried to be made controllable by humankind and mechanicalized, in order to serve for a purpose and use of maximizing a living being.

"However, "nature" is not such an easy word, and it actually fits the definition of an abstract *concept*, hence a mental construction rather than a concrete notion, which is situated both historically and geographically, and needs definition in context" (Ellen 1996, 105). The various definitions throughout time show the complexity and variety in understanding nature, making it impossible to reduce it to one only concept.

In contemporary western literature four main definitions of nature can be identified according to the ecologist Frédéric Ducarme and the professor Denis Couvet (2020, 4).

The four definitions are exclusive of each other, because of different parameters. One of those parameters is the exclusion of mankind from the definition of nature, which can be identified in the first definition belonging to the post-romantic philosophy or in the Christian tradition. This understanding defines as being part of nature "the whole of material reality, considered as independent of human activity and history" (Ducarme and Couvet 2020, 4). Especially inclusive are the ideas of nature belonging to the second definition of nature in Stoicism and Aristotle on one side and the third definition belonging to Heraclitus, Hegel and Darwin on the other. In their explanation of what nature is, they identify the whole of reality. Another parameter which characterizes these definitions is the idea of "protecting nature". It rarely uses the most inclusive of definitions of nature, which sees the whole universe as its place, "(…) as the universe itself is not under threat (and is beyond man's protection), and physical properties of material things are not changing" (Ducarme and Couvet 2020, 4). On the other hand, the fourth western definition attributing to nature "the essence, inner quality and character, the whole of specific physical properties of an object, live or inert" (Ducarme and Couvet 2020, 4), follows a very fundamental idea of protection, that is against any denaturation and distortion.

The issue with these currents in western literature, is that all four of them involve very different understandings of nature which, when individually taken, exclude some important aspects. Moreover, the conservation policies vary from one definition to the other and it is

not possible to merge them, because of their fundamental different character. “When the aim is conserving nature as a non-human natural heritage, there is need to limit as much as possible human intervention, such intervention being done mostly in order to remove previous human disturbance (…). At the opposite, when the aim is conserving processes, human intervention can be needed for ensuring their good functioning (…), including sometimes affirmative action such as species translocations, or ecosystem engineering (…)” (Ducarme and Couvet 2020, 4). In other words, if one was to follow a specific view this would mean that some aspects were not to be considered and left out. Moreover, since the definitions come from specific literary currents, it can be assumed that they lose their validity in a different historical and geographical context.

The most striking concepts in the discussion of defining nature are the one of the natural and wilderness. Both terms often entail paradoxical views, which make it difficult to define them. In the eighteenth century (the idea of nature developed into a philosophical principle of order and right reason) a “form of popular modern idea of nature” is the “considerable part of what we call natural landscape (…) is the product of human design and human labour, and in admiring it as natural it matters very much whether we suppress that fact of labour or acknowledge it” (Williams 1980, 78). Interestingly man-made landscapes are being contemplated as natural, such as the Tuscan vineyards, which occupy a great area of the venetian region. They are a creation of human labor in collaboration with nature. It is difficult to state at this point if those vineyards are natural or not and in literature concerning nature and the natural its property is often not being pointed out clearly.

Moreover, the concept of wilderness propagated intensively the idea that true nature is where humans are not and that if nature was to be entered by humans, it would die. The paradox of wilderness, named by the environmental historian William Cronon, that “(…) if nature dies because we enter it, then the only way to save nature is to kill ourselves” (1995, 83) is quite difficult to follow, but thematized by many currents of thought. In contrast to this paradox wilderness in the 19th century became a recreational place, it “(…) suddenly emerged as the landscape of choice for elite tourists, who brought with them strikingly urban ideas of the countryside through which they traveled” (Cronon 1995, 78). Generally, it can be argued that nature has order and laws by which it functions, “This is why “nature” is not a synonym of wild, wildness or wilderness: it is initially not a state, but a spontaneous process.” (Ducarme and Couvet 2020, 2).

The "wilderness dualism" as discussed by Cronon "(…) tends to cast any use as abuse, and thereby denies us a middle ground in which responsible use and non-use might attain some kind of balanced, sustainable relationship" (1995, 85). A middle ground is a very difficult territory to discover and to affirm, since it is a grey area, avoided by many. Additionally, the discussion of nature, "natural" and wilderness entails many paradoxical and conflicting views. Nevertheless, as Cronon states to establish an environmental ethic, which considers as well using nature as not using it is paramount (Cronon 1995, 85).

Significantly is what Cronon continues to argue:

> "On the one hand one of my own most important environmental ethics is that people should always to be conscious that they are part of the natural world, inextricably tied to the ecological systems that sustain their lives. Any way to look at nature that encourages us to believe that we are separate from nature—as wilderness tends to do—is likely to reinforce environmentally irresponsible behaviour. On the other hand, I also think it no less crucial for us to recognise and honour non-human nature as a world we did not create, a world with its own independent, nonhuman reasons for being as it is. The autonomy of nonhuman nature seems to me an indispensable corrective to human arrogance. Any way of looking at nature that helps us remember—as wilderness also tends to do—that the interests of people are not necessarily identical to those of every other creature or of the earth itself is likely to foster responsible behaviour." (Cronon 1995, 87).

I argue that this approach might be a good one to follow in the context of the Anthropocene in understanding, cooperating and respecting nature. There still are, as Williams calls them, "(…) some true wilderness, some essential untouched places" (1980, 77), where man's intervention is not present yet. It is fundamental to understand that nature belongs to the planet and works by systems and processes of which humankind is not part of. Considering this, it is humankinds' responsibility to understand these processes and systems in order to mitigate its impact as a geological force. We have to acknowledge that "Out of the ways we have interacted with the physical world we have made (…) human nature and an altered natural order (…)" (Williams 1980, 84).

To summarize different definitions of nature, exist nowadays, which have developed form various domains according to their contexts. Hence it is impossible to reduce the term of nature to one and only definition, as there do not exist wrong explanations of nature. Indeed, the variety of interpretations offers a wide range of inclusion to what is part of nature

and may compose and determine it. As Williams argued as varied and variable are the "changing conditions of a human world" (1980, 85) so are the ones of nature and it is our task to identify and understand them since we are part of the planet.

Human history cannot be thought separated from the one of nature, since "We have mixed our labor with the earth, our forces with its forces too deeply to be able to draw back and separate either out" (Williams 1980, 83). In other words, humankind is entangled with natural processes, because of using nature's resources to survive and to develop. Therefore, a separation for humankind with nature is not possible. Yet, nature can separate itself from humanity, since it already existed before and most probably will so if humanity no longer exists.

"Learning to honor the wild—learning to remember and acknowledge the autonomy of the other—means striving for critical self-consciousness in all of our actions. It means that deep reflection and respect must accompany each act of use and means too that we must always consider the possibility of non-use." (Cronon 1995, 89). Hence, it is paramount to establish an understanding of the environment aspiring to an environmental ethic, which aims at putting into perspective all this knowledge and conceptions of nature, the natural and wilderness.

2.2 Dialogue Between Art and Science

2.2.1 The domains in the Anthropocene

The future of the Anthropocene, which is already our present, demands reinvention in various aspects. The current situation of climate change and of emergencies such as the COVID pandemic urge us to invest in a new paradigm, which according to many scientists and researchers has to happen at a global level.

Bennett argues that disciplines and domains which are confronted with the Anthropocene are facing the challenge of self-organization (2012a, 10). She urges to imagine the shape of future collaborative practices such as interdisciplinary, academic, governmental, industrial and managerial ones in order to face the present and future of the Anthropocene (Bennett 2012a, 10). Art and science are two important domains which are addressing the complexity of the Anthropocene and therefore face the challenge of self-organization. Contemporary art shares a long history of engagement with the STEM (Science, Technology, Engineering, Mathematics) sector (Bennett 2012b). Therefore, their dialogue and contribute in the environmental crisis is central and hence has to be developed in order to understand, develop and foster the issues of the Anthropocene.

In order to analyze the dialogue between art and science, it is fundamental to depict the agency of the respective domains in the light of the Anthropocene. Significant is to capture all the various facets of the encounter of, especially, art and science with the natural world and the development as a domain. Furthermore, the dialogue between art and science is crucial, since it showcases the terrain for a new transdisciplinary, experimental practice, which will be analyzed deeper in the following chapter 2.3 *Transdisciplinarity*.

According to the visual activist Nicholas Mirzoeff it is paramount to learn "to think anthropocentrically" which means "letting go of both the divisions of time and space that define research and the myth of the solitary intellectual. Crowd-sourced collective and horizontal practice is not just desirable but necessary (…)" (2014, 215). Dealing with environmental issues means to work in between various domains as they address different aspects such as geology, anthropology, management, economics, etc. This further suggests that thinking anthropocentrically demands acting outside the respective disciplines since the climatic crisis is characterized by many different domains. That is the reason why different actors from the scientific and artistic field collaborate in the research of the climatic issue

(Borries et al. 2011, 4). They have the potentiality to experiment in a horizontal and collective way in the addressing, solving and dealing with environmental issues.

Several authors in the field of art and ecology see art as a medium of aesthesis in order to understand the Anthropocene, "to think with and feel through it" (Davis and Turpin 2015, 2). The relation between the Anthropocene and art can be found in the fact that the Anthropocene is a "sensorial phenomenon", which is characterized by an accelerating diminishing and toxic world. Factors such as noise, smog and smells in cities are coming from the advent of the expanding human influence and affecting of the natural world. Moreover, the experience of the Anthropocene has been mostly visual because of data visualization, climate models and actual signs of consequences of the climate crisis on the planet, such as rise of the temperature, acidification of the sea, droughts and wildfires. Additionally, art is a field of experimentation, free of confinement and rules, which presents an opportunity of different tools ranging from "discursive, visual and sensual strategies" (Davis and Turpin 2015, 2-3), in order to approach the issues concerning the Anthropocene.

Aesthetics has been an important theory in the human visualization and understanding of beauty and art throughout time. According to Mirzoeff "Visualizing was and is a hierarchical, indeed autocratic, means of imagining the social as permanent conflict" (Mirzoeff 2011, 123-54) with nature. Since the beginning of the industrial revolution and hence the advance of the Anthropocene, the planet was visualized in the West as "an enemy to be subdued" and defined the call for the "conquest of nature". Mirzoeff calls it the "Western imperial project", characterized by the idea that the war against nature is right. It determined greatly the Anthropocene visuality and affected every living being (Mirzoeff 2014, 217). Hence, the "conquest of nature" has been from the beginning of the Anthropocene a dominating image and colonized, according to Mirzoeff, the power to imagine (2014, 219). Rather an impulse to conflict was fostered, then an action based on common understanding.

Additionally, the imperial aesthetics thematizes the image of conquest of nature as being responsible to anaesthetizes the perception of modern industrial pollution and making the conquest of nature seem beautiful and natural (Mirzoeff 2014, 220). The ambivalence of the Anthropocene is here again present as it aestheticizes the conquest of nature, which results in a loss of the perception of the modern industrial pollution.

The anaesthetics is present in various examples in artworks from the beginning of the industrial period, which shows that the transformation of the biosphere was a known phenomenon also in the domain of art. Monet repeatedly aestheticizes in his works the anthropogenic environmental destruction. *Impression: Sun Rising (1873)* for instance depicts "the circulation of capital and the modern visible and sayable as Anthropocene (an)aesthetics. Whereas the material smog was a dangerous by-product, this modern aesthetic countered it by transforming the very perception of its difference into a sign of human superiority and the continuing conquest of nature" (Mirzoeff 2014, 222). The anesthetics of the Anthropocene affected human senses in a way that living in a modern city was very desirable. Smog and pollution were already a big part of the image of big cities such as London and revealed itself through smells, dirt and low standards of life.

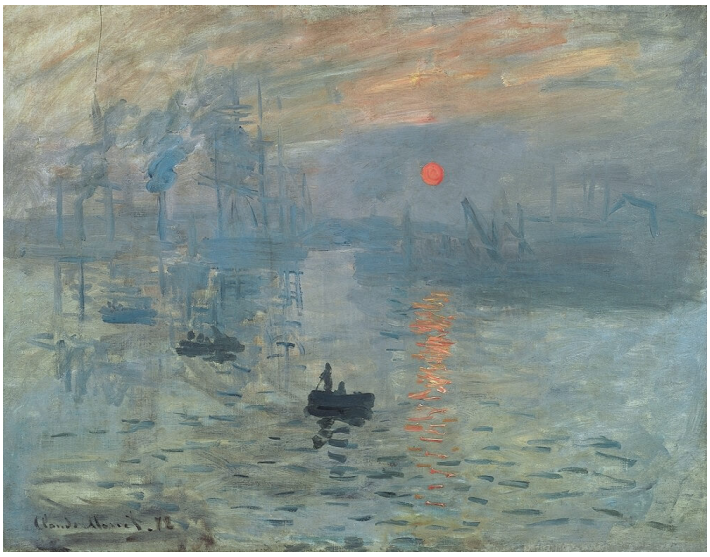

Figure 1 | Impression: Sun Rising by Claude Monet (claude-monet.com 2010)

Mirzoeff proposes a countervisuality as an alternative, which should "create a mental space for action that can link the visible and the sayable. In relation to Anthropocene visuality, a move out of one's place would be the end of the de facto hierarchy of humanity that continues to affect global populations long after anthropologists and other scientists abandoned the formal attempt to classify the human." (2014, 226). The creation of a new mental space could be an opportunity to understand environmental issues from a different perspective, a less abstract one. Art could be the tool, which experimental approach permits to "test social boundaries and conventions" (Bennett 2012b) and to question, transgress and reinvent methods to explore through art the problems coming with the Anthropocene.

Aesthetics should help in the visualization but not impose a specific image as Robert Pfaller (Austrian Professor of Philosophy and Culture of Theory), referring to the artist Barnett Newman, mentions. Aesthetics is for art what Ornithology is for the birds. Ornithology talks about birds and hence discusses problems of the domain of Ornithology, but actually does not help birds to fly. The philosophy of aesthetics talks about art and deals with problems that concern the philosophy of aesthetics, but it does not help art to fly (2019).

Since the Anthropocene fostered the impulse of conflict, anaestheticized the image of pollution and human interreference and is determined by many contradictory elements, art as a space can allow to overcome those conflicts and contradictions. Carolyn Christov-Bakargiev (Italian American writer, art historian and curator) argues that "art is a striated space, and it allows one to hover and remain in the realm of ambiguity and contradictions, in the space of opacity" (2012, 9). Therefore, art is the space, where complex and seemingly unresolvable conflicts can be understood and engaged with. "That is where the sphere of art, which is poised on the edge of the private and of history, becomes a location in which one can experiment with experience on the edge of the anthropocentric, where the rubble lies, and can build an imaginative society where the human is not at the center of our cosmology, but only one element within an accord of all the makers of the world, animate and inanimate, including traumatized people and objects" (Christov-Bakargiev 2012, 9). Art has the potential to test different approaches and to see problems from a variety of angles. Moreover, its approach departs form conflict and desires a common and collective access to the Anthropocene, aiming at a global alliance.

Sciences stand at a different point with nature compared to art. They understand and analyze the dynamics between humankind and nature. Their research in phenomena such as the heating of the atmosphere, droughts and cyclones give scientific evidence about what is happening with the Earth-system (Grefe et. Al. 2020). Hence the importance of this domain lies in the fact of its objective analysis of the current developments and shifts in our environment. They represent a way of formulating knowledge such as in observing phenomena and in formulating natural laws for them (Klingan et al. 2015, 10).

The American biologist Edward Wilson on the other hand argues that in the age of STEM an extreme anthropocentrism is experienced, "Nothing, it seems, counts except on the impact on people" (2017, 67). He analyses the current moment as being trapped inside the "humanities bubble", which has many limitations and therefore also limits the

development of science. He acknowledges the scientific domain as being fundamental in facing the challenges which the Anthropocene brings, but sees at the moment the human condition in being the most dominant point of view. Wilson claims that humans are nearly blind and not able to perceive sounds and ways of communication used by animals and the earth, they can merely perceive this through technology. How is it possible to "detect Earth's magnetic field, used by some bird species to navigate during the yearly migration" (Wilson 2017, 67)? In addition, Bruno Latour (French philosopher, anthropologist and sociologist) also suggests that "(…) the very notion of objectivity has been totally subverted by the presence of the humans in the phenomena to be described (…)" (2014, 2). Hence the question arises, if science lost objectivity and does not possess the actual capability of understanding and researching phenomena concerning the Earth-system, how can they be understood?

Many in the scientific community debate whether or not the domain reached a limit in researching new phenomena and in finding different technological solutions. Nevertheless, in the discussion regarding the Anthropocene, science is a fundamental element in the dialogue between humankind and the natural world. "One cannot see, either in this century or the following ones, how it will be possible to maintain a knowledge-based society in a reasonable and sustainable manner without the participation of science. No, there is no end in sight for science: and it's the continued stimulation of its practice amongst the younger generations, year after year, that represents our best insurance against the uncertainties of the future." (Caraça 2008, 148)

Today science is composed by a broad group of different activities, which range from "(…) research, applications, management, learning and dissemination of knowledge, attitudes and scientific expectations" (Caraça 2008, 147). Moreover, science is divided into many specialized disciplines, which are not so isolated from each other anymore as in the past. In the domain itself multidisciplinarity can be detected for various reasons. "First, the problems which scientists are trying to solve are increasingly multidisciplinary. For example, the understanding of climate change requires experts in meteorology, oceanography, glaciology, ecology, cloud physics and atmospheric chemistry to talk to one another and understand each other's jargon. Once you learn to speak another person's jargon, it is not difficult to jump over the fence and become a member of his team" (Dyson 2008, 155). In this case Dyson speaks out of personal experience since he is a physicist by training

and through a research project, he got interested in forest ecology and he acknowledged that it is a crucial discipline in order to understand climate change.

To summarize understanding and researching phenomena concerning the environment and specifically the threats present in the Anthropocene, requires an approach which sees different disciplines dialoguing together. Science has a history of researching and formulating natural laws, but in this new setting, where humankind is dominant, the objectivity of its findings is suppressed by its human centeredness. For instance, the City of Sydney recognized, while assessing their plan for meeting its 2030 emissions reduction targets, that the only use of the technologies at their disposal would not have been sufficient. They acknowledge that other approaches are necessary to induce social and behavioral change in the population (Bennett 2012b, 3). A different angle, which sees the insight of domains such as the one of science exchanging insight within its domain (since science is becoming more multidisciplinary) and with completely opposite domains such as art to approach environmental phenomena is necessary. Not alone for understanding environmental threats, but also to visualize them, as in the countervisuality proposed by Mirzoeff. This means to leave the present mental state dominated by humans and enter a different one, where the dialogue between art and science is fostered to visualize environmental threats. Art can be the opportunity which makes Nature visible and audible and reveal the different layers of its lifeworld in order to not anaesthetize it and unveil Nature for what it is.

2.2.2 A collaborative Practice

It can be argued that the environmental crisis and all the phenomena concerning climate change are difficult to understand or at least to expose to the public, since they are explained in scientific terms. In the news often the reader is confronted with headlines like the following: "The amount of CO_2 in the air is the highest it has been for more than 2.5 million years—the threshold of 400 ppm of CO_2, the main agent of global warming, is going to be crossed this year" (Le Monde 2013). If the reader is not particularly interested in climate change and does not have the adequate knowledge to understand this information, he or she will continue to ignore this warning. Nowadays the wider public is much more informed about what climate change is and what the scientific findings mean in terms of consequences. Apart from this, researchers in the environmental field are acknowledging that simple scientific findings do not activate the public's awareness for climate change. It is important that knowledge about climate change moves towards understanding it (Grefe et al. 2020). That is where the importance of the dialogue between art and science lies, since the collaboration between these two domains can exactly lead to the result of understanding complex scientific findings of environmental issues.

Nevertheless, it is decisive to identify what the dialogue between art and science entails from the domains and if exploring horizontal research methods between them also presents some danger for the disciplines. For example, that science is being called less objective if in touch with a domain such as art and that art becomes functional.

Bennett points out that researchers of the NIEA, who worked on projects of experimentation from art and science not only advanced in art-based approaches but also in art-led multidisciplinary ones, which brought to a positive outcome of art and knowledge. "(…) Arts-led research maintains a commitment to fundamental 'discovery' in the arts, often developing its technological base by establishing its necessary connection to spheres of science and engineering" (Bennett 2012b, 2). According to Bennett art-led research offers the opportunity of exploring research-questions in a wider domain and moreover, it may lead to a critical approach (2012b, 2). In addition, this approach does not aim at instrumentalizing art "as a form of visualization or its subordination to an externally defined agenda" and it "asserts the research agenda of art itself" (Bennett 2012b, 2). Nevertheless, Bennett sees the danger in the possibility that the scientific approach in a collaboration with science may take the part as "enabling discipline for art" (2012b, 2). This would prioritize the scientific

domain over the artistic one and not foster an equilibrium in the dialogue between them, which actually Bennett does not see always as a "bad arrangement". But overall the danger lies in questioning "how art itself might be transformed" in the encounter with science (Bennett 2012b, 2). Bennett argues that the importance during art-led research lies in the clear assertation of "distinctive aesthetic (sensory and affective) methodologies that transform the nature of an experiment" (2012b, 2). Hence, for the further development of the dialogue between art and science it will be important to determine if there exists a middle ground where art and science can meet in the process of their research. The specificity of the various projects may also assert in which direction the cooperation can lead. Furthermore, it might also be that art in meeting with science can also add and enrich this domain, may it be in methodologies or different angles of approach towards research topics.

Guattari proposes a theory in line with the one of art-led research proposed by Bennett (2012b): in the context of the ecological crisis "(…) it appears crucial (…) that we rid ourselves of all scientistic references and metaphors in order to forge new paradigms that are instead ethics-aesthetic in inspiration" (2008, 25). Hence, the starting point should lie according to him in the artistic practice in order to aim at a reinvention of the spheres between humankind and nature, which are decisive for facing the environmental crisis. Furthermore, Guattari stresses the aspect of reinvention as he affirms that it is fundamental for avoiding repetition, which may result literally in a "deathly trap" (2008, 27).

Yet, the dialogue between art and science could also present threats for the autonomy of the domains and for what art and science are. Art, for instance, could lose—dealing with more political and scientific matters—its autonomy and be biased. Moreover, art in being a domain were subjectivity is an essential element and the freedom of making art is not tied to boundaries, intersecting with political and scientific spheres could bring to the foreground a misleading idea of intention in the artistic work. Science on the other hand could in the exchange with art, lose its claim for objectivity as it is collaborating with a domain were subjectivity and the emotional aspect are very important. That could contribute to a sceptic view of the scientific sector in the population, since they might not believe anymore in the objectivity of scientific findings regarding environmental issues (Grefe et al. 2020). Hence, subjectivity might interfere with the credibility of objective information concerning processes of climate change. If then the objectivity of the scientific element in a collaboration

between art and science results biased and fallacious it is questionable if the project can contribute to an understanding of environmental issues, even less to find solutions for them.

Nevertheless, "Science and technology offer the artist some attractive territory for open-minded exploration (…)" affirms Brook (2012, 4). Generally speaking, contemporary art has a tendency to test boundaries and conventions, especially social ones and the experimental practice is central to the testing of such boundaries. "(…) art's methods have long been experimental, hybrid and potentially transdisciplinary" (Bennett 2012b, 3). Experimenting with sciences offers an approach to transgress and question the limits of the domain of arts. Its engagement with science is also not a new phenomenon as already pointed out. What let emerge the dialogue between these two disciplines in the twenty-first century is its planetary politics, which offers the social, political and economic drivers for such a collaboration. "Experimental art today is increasingly concerned with the complex relationships involved in seeing, defining, framing and responding to pressing events. What is clearer today than in previous generations of research is that the aesthetic (in the fullest sense, encompassing the practical study of affect, sensation, perception, behavior, imagination) is fundamental to any understanding of the connections between lifeworlds, disciplinary procedures and given problems: the arts, in other words, are the core of the transdisciplinary experiment." (Bennett 2012b, 3).

The understanding of environmental issues also changed, as it is more acknowledged that an environmental problem is constituted by different intertwined issues. "Artists work with science and technology to get things done; to address big agendas, to transform public space or processes of consumption on a grander scale and in constant purposeful ways in the real world (Bennett 2012b, 3).

Henceforth, the tendency is towards an art-led multidisciplinary approach in understanding and visualizing environmental issues from a different mental space—as in Mirzoeff's analysis—which transgresses and questions social boundaries and conventions in the context of the Anthropocene. Art and science may work together as in understanding both, though in a different methodological way, the different lifeworlds and in constituting a connection between those and issues concerning the environmental crisis. How and in what methodological terms this encounter between the domains of art and science proceeds and works will be further analyzed and evaluated in the next chapter about transdisciplinarity constituting the theoretical framework of the present thesis.

2.3 Transdisciplinarity

2.3.1 Multi-, Inter-, Transdisciplinarity

The issues we are facing in the twenty-first century are in the majority not one sided but implicate the consideration of different aspects. Domains of various spheres meet and collaborate, because issues they are facing do not require just scientific knowledge but also the expertise of other specialists such as ecologists, architects, chemists, biologists etc. Latour already recognized a while ago while examining the content of newspaper articles, that they were mixing the content of different domains such as chemical and political one (1993, 1). They resulted in 'hybrid' articles that outline 'imbroglios' of science, politics, economy, law, religion, technology and fiction. His advice to humankind is to follow these 'imbroglios' instead of categorizing them as they would guide him/her towards a new paradigm (Latour 1993, 2).

As already mentioned in the previous chapters, mankind is being faced right now with a paradigm shift, which has been changing majorly in the twenty-first century various aspects of the global world we imagined to be. The different vision is necessitated by the shifts induced by the new epoch we are in, the Anthropocene. It challenges so many aspects of the global world, that it will be difficult to consider all of them. In the framework of this thesis I will especially consider the demand of reinvention in collaborative practices, precisely the reorganization of art and science required by the transdisciplinarity which they are faced with in the Anthropocene.

The transdisciplinary approach is a relative new one which can be attributed to the Swiss philosopher and psychologist Jean Piaget, who describes it as "(…) not (…) limited to recognize the interactions and or reciprocities between the specialized researchers, but which will locate these links inside a total system without stable boundaries between the disciplines" (1972, 144). He already recognized that this approach would lead to a crossing of the boundaries between domains and work on interaction between specializations. Basarab Nicolescu (Romanian honorary theoretical physicist) developed thoroughly the theory concerning transdisciplinarity and founded the International Centre for Transdisciplinary Research and Studies (CIRET). He argues in his analysis "(…) the prefix 'trans' indicates, transdisciplinarity concerns that which is at once between the disciplines, across the different disciplines, and beyond all disciplines" (Nicolescu 2002, 44). The goal

of transdisciplinarity according to Nicolescu "(…) is the understanding of the present world, of which one of the imperatives is the unity of knowledge" (2005, 7).

The area beyond disciplines is central, since it is an unexplored part, full of knowledge still to be discovered that could be useful in facing many of the current environmental threats. Nicolescu describes the space across disciplines as a space where "we meet the interplanetary and intergalactic vacuum(…) full of invisible matter and energy" (2006, 6). This intersection can offer an amplification for the elaboration of the knowledge needed in order to face environmental threats and all the various issues concerning them in different disciplinary fields.

Transdisciplinarity developed from Multidisciplinarity and Interdisciplinarity and is necessary in the Anthropocene for the development of collaborative practices due to the high increase of knowledge. Multidisciplinarity studies a research topic in several disciplines at the same time, overstepping disciplinary boundaries, yet leaving its goal to the enrichment of the starting discipline in question. Interdisciplinarity on the other hand, works in a similar way, by going over disciplinary boundaries but with the goal of transferring methods in between the disciplines. In contrast, transdisciplinarity goes between, across and beyond all disciplines, with the aim of a "joint problem solving" of that "interplanetary and intergalactic vacuum" (Nicolescu, 2006, 5).

Hence, how is this development towards a transdisciplinarity just being perceived so vividly today in the setting of the Anthropocene, since the domain of arts for instance as Bennett argued is exploring transversal, hybrid and experimental practices already for some time (2012b, 3). It can be argued that issues concerning the environmental crisis are characterized by being multidisciplinary as they ask the expertise of different specialists. Bennett states that in the present time of the Anthropocene "objects, images and ideas routinely range across different spheres" (2012c, 8), which is a challenge for the domains dealing with such elements. For instance, understanding climate change from just a scientific perspective involves experts in various scientific fields: an atmospheric problem can interdepend with forest ecology, rivers, soil and insects. That is why today's knowledge is fragmented and results in a philosophical chaos which shows the real world as a "Kunstprodukt der Gelehrten" (Wilson 2000, 15). Furthermore, Wilsons argues in his analysis that the key to understanding and picturing the interweaving and connections is consilience. In a time of synthesis when the biggest intellectual challenge is represented by

the testing of transdisciplinarity and interconnection, consilience between sciences and humanities is paramount (2000, 19).

This theory is in line with Guattari's analysis, since he argues that the Anthropocene calls for a connection and "transversal" thinking between nature and culture to understand "the interactions between ecosystems, the mechanosphere and the social and individual Universe of reference (…)" (2008, 29).

"Wicked problems" such as climate change are the ones which constitute nowadays a challenge, since they often cannot be solved with an optimal solution, but they can be addressed with responses which are better or worse. These problems are characterized by having "complex interdependent variables", which means "that any potential 'solution' exacerbates yet another raft of entrenched problems" (Bennett 2012b, 3). To exemplify roughly, the measures taken to mitigate the COVID pandemic forces nations on a global level to not travel, to stop transactions important for their economy and to simply not exercise all those movements with vehicles which pollute. This is having a great impact on the environment by reducing drastically the emissions over specific regions such as northern Italy for the period of lock down. Animals are coming back to the people-less city centers and for instance to the waters in and around Venice, which are not trafficked with gondolas or huge cruise ships. On the other hand, the economic impact on businesses and on the economy of the various affected nations is remarkable, to the point that unemployment is rising, homelessness as well, many big and small businesses have to close because the sustained costs during lockdown were too high (Chakraborty and Maity 2020). Hence it can be argued that "(…) the transdisciplinary is impelled by external conditions (…)" (Bennett 2012a, 11), which in the case of environmental threats demand a practice across various disciplines such as science and art. This not to only address or to find answers which only solve the threat from a multidisciplinary perspective, but from a transversal one, across all the domains involved in the particular issue.

A further element of transdisciplinary practices is "the conviction that disciplines do not have proprietary rights over their domains" (Bennett 2012a, 11) and therefore transversal links have the potential to go across institutionalized divisions. That is also the element which really determines to experiment transdisciplinarity. According to Bennett "the difference between a conventional application of the arts and a transdisciplinary experiment lies principally in the degree of latitude (…)" (2012b 2). The artist-researcher instead of

being only tied to the area of an art can assume also the position of being a planner and try "reconceptualizing public space in a way that inserts an artist's viewpoint into a set of pragmatic operations" (2012b, 3). Richard Goodwin, Australian artist between architecture, urban planning and arts, elaborated with his art-led transdisciplinary works various projects in the area of urban planning which aimed at expanding the use of public space. Reconceptualization through art, research and urban planning where just a few elements incorporated by Goodwin (Audisho 2013).

Therefore, it can be argued that this moment we are experiencing, is one of a radical shift. To live actively in the Anthropocene, an epoch we are experiencing while it is happening, means to live in the midst of a paradigm shift. The entire Earth-system—land, ocean and atmosphere—can be the expanded field of art and a place where it meets with science in order to address "the ramifications of a radical shift" (Bennett 2012b, 16).

> "In this highly unstable moment of planetary transition, is our transformation that of everyone, everywhere, everything? Does this transient situation propose a "TRANS-science", that is, a yet-to-be articulated science of the future that cuts across all the sciences, technologies, and epistemological cultures at hand? Or is it a "trans-cience", as opposed to "conscience", which is the capacity to evaluate and make judgments that penetrate against the grain; the ability to implement diagonal intentions, the cultivation of states of consciousness that occupy the in-between, or even the promise of same collective, ethical entanglement that leaves no singularity, no solitude, no objective removal from the situation in which we mere humans find ourselves." (Klingan et al. 2015, 20)

The articulation of these times where we experience a high fragmentation of knowledge, dealing with issues which are complex as they can be found in various domains and the necessity of those domains to collaborate is quite critical. What if climate change can be addressed and even solved through a transdisciplinary approach on a global level, asking politics to collaborate with science (in its whole multidisciplinarity), arts, philosophy, ethics, etc. It seems that we are in a moment of the history of life were a trans-domain is required in order to face the environmental crisis, which is in a great part human induced. It is necessary to save the planet humankind is living on, in order to continue to have the possibility to live on it. Humankind has the necessary tools to induce this movement to cut across sciences, technologies, epistemological cultures and politics and to use the knowledge and capabilities at disposal to act on a global level. At the base of this transdisciplinary

practice a “trans-cience” as described by Klingan et al. should form the capacity to evaluate and judge on a global level. This “trans-cience” aims at collectivity in an ethical concept which does not leave anyone or anything out, which is conscious and explores the neglected areas. Definitely it is a huge project, which challenges many beliefs and ways we live today of all the cultures in a different way (if looked at from a global point of view). Yet it may be an approach which can be made possible with the resources humankind has.

Cultural studies in the intersection of other disciplines “(…) is a discipline but also a facilitator of dialogue and exchange with people who work within other disciplinary contexts, showing an openness, to what the other disciplines might consider the blind spots of cultural studies” (Santos 2018, 22). Hence it is also an opportunity to enable innovation in this discipline, by opening up to the transversal practice and dealing with questions from the outside of its domain. In the research of this dissertation it is a discipline which with its methods and resources at disposal will facilitate the transversal exchange between art and science in not only finding answers but actual solutions. The objective is to explore the transdisciplinary approach, which aims at addressing and even solving environmental threats (further explained in Chapter 3) by working transversally between science and art.

2.3.2 "Environment as an ongoing experimental project"[2]

The earth will change independently from humankind´s development and if there is no reaction to the current environmental crisis, the change presented by the capacity of human technologies and knowledge is just misusing the opportunity to direct the current paradigm shift in a way that it is beneficial for the Earth System and for humanity as a species (Adnan 2012, 7). The problem is universal, it affects the globe and hence every nation, which is an ulterior complication. Hence, "the only true response to the ecological crisis is on a global scale, provided that it brings about an authentic political, social and cultural revolution reshaping the objectives of the production of both material and immaterial assets. Therefore, this revolution must not be exclusively concerned with visible relations of force on a grand scale but will also take into account "molecular domains of sensibility, intelligence and desire" (Guattari 2008, 20). Specifically, in the framework of this thesis the collaboration between art and science is of great importance. The new paradigm shift, given by the anthropocentric changes, asks for a transdisciplinary practice which "rocks the ground beneath established disciplines. Within an ecological paradigm art practice will be configured beyond contemporary institutional boundaries" (Bennett 2012a, 11). Yet not only art is experiencing and will go beyond its institutional boundaries, as well science is and still will experience a great shift. The ecologically informed artworks and projects which are discussed in the framework of the thesis will reveal "(…) fieldwork ranging across a boundless domain" (Bennett 2012a, 11) or better formulated across the domains of art and science.

The question arises, how the pattern of future transdisciplinary collaborations between art and science can be conceived. In the previous chapter I already described the collaborations as art-led, experimental and with the systematic approach of science. It is difficult to establish a specific method regarding the collaborations, since depending on the type of thread they are working on, the approach differs. Moreover, it can be argued that the encounter between art and science is an experiment during which different methodologies and practices can be established (Borries et al. 2011, 8).

In order to understand the dynamics of ecologically informed projects different collaborations will be discussed. It can be argued that the pattern of collaborations varies

[2] Bennett 2012a, 15

from project to project since they are mostly experiments which cannot be predicted in methodologies or outcome. According to Keane´s evaluation "the role of experimentation in the arts and embodied cognition as a material and adaptive engagement is crucial to our evaluation of what constitutes knowledge and the role of the creative research across the arts and sciences" (2012, 1). Central are the "constantly changing parameters that link art and science and art and life", which are united in the "experiences and capacities of the individual (body-environment, artist-scientist, researcher-practitioner, etc.)" (Keane 2012, 1). This setting offers the opportunity to reevaluate and recontextualize the different relations in order to introduce change for existing conditions, which might seemingly be difficult or impossible to move.

In the following, I will present two outstanding examples of ecologically informed works, which range from ecologically informed exhibition to active collaborations between art and science. This to indicate the range of possibility which environmental projects offer and especially the already since many years existing awareness in the domain of art to discuss and deal with environmental issues. Moreover, it is interesting to understand the capacity of ecologically informed projects and their various characteristics.

Joseph Beuys' (German artist) work *7000 oaks* is a work of great importance in the development of ecologically informed exhibitions which was conceptualized for documenta 7 (1982). For this project the German artist invited the citizens of Kassel to plant 7000 oak trees throughout the city to act against the ongoing urbanization of Kassel. A further element of the experimental project was composed by a pile of 7000 basalt stones on Friedrichsplatz in Kassel. Each stone symbolized the planting of a tree and the pile would shrink throughout the development of the project. In this way Beuys wanted to involve actively the citizens of Kassel to participate in his experimental project, in order to raise awareness towards social and environmental change (Public delivery 2020). Beuys' work extended over five years until completion and inspired similar projects all around the world. It shows "environment as an ongoing experimental project" (Bennett 2012a, 15), with the active participation of people in contributing to diminishing the ongoing urbanization and raising awareness towards a fundamental issue of our epoch, that of climate change and shrinking nature. This project set an important statement, that participation of the spectator is important in order to be able to realize the experiment.

Figure 2 | Joseph Beuys 7000 oaks in Ochsenallee, Kassel, Germany (Public delivery 2020)

Documenta showed during its various editions always a great number of artists interested in ecologically informed exhibitions and works. The 12th edition "essayed various strategies for tracing material connections and connotations across artworks, identifying the migration of form as an animating concept" (Bennett 2012a, 14). Material links offer a "new logic to the relationships that emerge within an exhibition" a logic that goes beyond the formal or thematic one (Bennett 2012a, 14). In the case of documenta 12 ecological thought was responsible for reevaluating the space for art and museum objects moving them into an external live world. Parameters and connections between artifacts, objects, thoughts and different things in the world experienced a reconceptualization and recontextualization allowing "that art moves freely into different registers, revealing patterns of connection and attuning to environmental dynamics" (Bennett 2012a, 15).

A contemporary example of environmentally informed exhibition with the participation of different elements such as the relationship between art and science and the relationship between the audience and the work itself is presented by the German artist and professor of the faculty of media at the university of Weimar Ursula Damm. For the development of her project Damm got inspired by the biologist Lynn Margulis and her

theory of endosymbiotic theory[3]. Moreover, the hydro-biologist Mechthild Schmitt-Jansen assisted Damm with the keeping of the water flees (Borries et al. 2011, 83).

Damm's installation *Treibhauskonverter (Venus V)*—also called greenhouse converter—displays the force-distribution between nature and humankind in an interactive way. The audience is the decisive element with the capability of influencing the balance of present ecological lifecycle of the installation. The central element is an aquarium which is connected through pumps to a fountain in form of a flat bowl. CO_2 is added to the water of the fountain which results into white fog. A lever in between the aquarium and the flat bowl can regulate the water flow from the bowl to the aquarium. When water is pumped from the flat bowl to the aquarium, a higher concentration of CO_2 can be experienced in the aquarium, which in turn is a source of nutrients for an algal culture in the aquarium. The water of the aquarium is populated by water flees, which attracted by the blue LED light inscription, *beloved*, feed on the algae covering the letters (Borries et al. 2011, 76).

Figure 3 | *Treibhauskonverter (Venus V)* by Ursula Damm (Damm 2010)

Already at this stage of the description of the installation a specific element of an ecological informed exhibition can be detected, namely that of an ecology or lifecycle, which is interdependent (Bennet 2012a, 14). When the water flees eat too much of the algal culture

[3] Margulis argues in her endosymbiotic theory that cells and their cell cores originate from endosymbiotic relationships in between various species of bacteria. The most interesting aspect consists in the mutual beneficial cooperation between the two organisms to survive and which Damm understands as a relationship of solidarity between them (Borries et al. 2011, 83).

covering the inscription *beloved* and multiply too much, the LED light can change slowly to red or to yellow which keeps the flees away and hence the algae can grow again undisturbed. It can also happen that the algae cover excessively the inscription, which can also tip the balance of the ecosystem. By reducing the LED light turning it to blue the flees are attracted again and will start to eat the algae. When the viewer can read *beloved* in a clear way, then the balance of the ecosystem is safe (Damm 2010, 7-8).

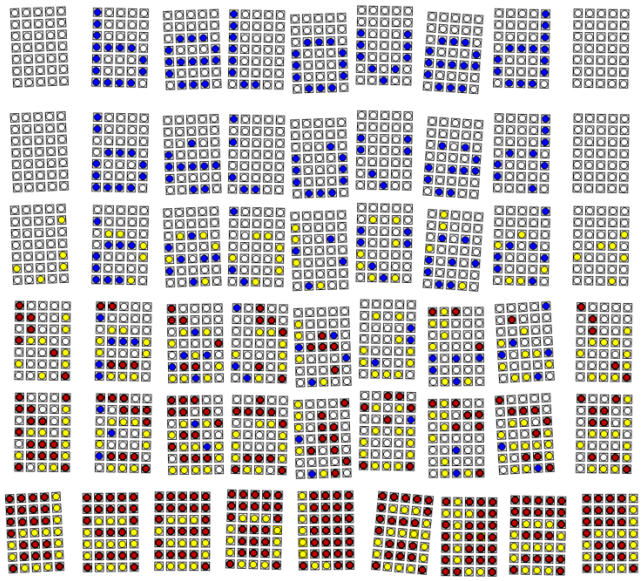

Figure 4 | The LED light *beloved* inscription (Damm 2010)

Yet, the decisive element, which can influence this ecology externally, is the lever, which can be operated by the audience from the outside. Pumping through the lever more CO_2-rich water from the fountain to the aquarium stimulates the algae to grow but can also tip over the ecological balance. If the algae grow too much, they cover the LED inscription and the light cannot attract the water flee. This action displays the desire of humankind to control nature with technology and also conveys the illusion to be in control from an external standpoint over an ecological system. Moreover, the lever is hard to handle, it requires a certain amount of force, which Damm states should create awareness in the audience of how difficult it is to bring under control the CO_2 emissions in the atmosphere (Borries et al. 2011, 82). Additionally, it stresses how sensitive and fragile an interdependence of biological systems is and how important self-regulation in a sense of cooperation is in living systems (Damm 2010, 6).

Damm's installation explains in an interactive way a very complex system to the audience, which's balance, depending on many connected elements, is constantly regulated

through feedback between the elements and self-regulation. The topics dealt with by Damm are highly scientifical, yet she managed through an art-led experiment to translate them into an understandable installation for the audience. She responded to an issue outside her domain, namely the fragility of ecosystems threatened by human intervention, and approached dealing with the issue in an experimental and transdisciplinary way.

Damm and Beuys address both in their projects the ramifications of a radical shift. According to Bennett it is central in projects concerning issues of the Anthropocene as it is not enough to insert an ecological work in a gallery and hence to green the image of gallery brands (2012a, 16-17). Ecological thought managed in both projects to connect art and museum objects with an external life world by revealing a link "to unlike things in the world as much as to like artifacts", permitting art to move freely into different areas (Bennett 2012a, 15). This enables the display of various patterns of connection with environmental patterns, opening up new paths. "Ecological thought is changing the way in which our practices might operate in future. Thinking ecologically means attuning, perceiving, and doing what we know how to do differently, in different spaces, dimensions, relationships" (Bennett 2012a, 17). Both Damm and Beuys addressed environmental issues and dynamics through elements outside their domains daring to explore different spaces, dimensions and relationships. In this way they not only inserted an ecological aspect but experimented with different aspects creating an ecologically informed exhibition.

It will be interesting to see how the disciplines of art and science will position themselves in the future of the Anthropocene. To live actively in the Anthropocene is according to Bennett how it is to live in the midst of a paradigm shift (2012a, 17). Hence when the domains encounter ecological issues and are really interested in dealing with them, they will be actively working on them. In this paradigm shift it is not necessary anymore to maintain experimentation and exploring inside its institutional practice. "(…) What if our institutions are simply not managing to frame a practice that is, of necessity, becoming increasingly distributed, extensive, and polymorphous; a practice whose dynamic points of connection escape the purview of the gallery exhibition?" (Bennett 2012a, 13-14).

Environmental issues are complex and demand the consideration of unlike aspects, since they tackle not only ecological issues, but also social and economic ones. Approaching them from just one domain is problematic, as solving the issue from that specific point of view might open up a raft of other questions to solve. That is the reason why addressing and

solving environmental threats requires a transdisciplinary approach of experimentation, free of disciplinary restrictions. Fundamental is to understand what these environmental threats are and where their position is in the present, which will be further analyzed in the chapter 3.2 dedicated to their examination.

3 The Threat of the Extinction of the Earth System

3.1 Earth-System Science

So far, in the development of this thesis we have acknowledged that humanity is a decisive force in the Anthropocene with a geological impact on earth. Nevertheless, staying focused on a solely human centric approach does not bring further the understanding of the epoch we are living in. Most importantly it does not change dynamics such as governmental processes, which are fundamental for a shift aiming at protecting the ground we are living on. As Joyeeta Gupta (professor of the environment and development in the global south t the Amsterdam Institute for Social Science Research) argued during a talk on the Anthropocene in the *Haus der Kulturen der Welt* it is important to acknowledge that we are overusing earth resources and that continuing to do so is endangering enormously the Earth System (Gupta 2014). We have to understand were action is needed, which processes are endangered and how they actually work, and to which extend they are influenceable. There is an urgency "to see humans in the context of planetary processes that have supported life in general for hundreds of millions of years" (Chakrabarty 2017, 41). For this a closer investigation of the planet and its interdependent processes is needed, which can be revealed by integrating the Earth System Science (ESS) in a framework comprising humankind and the domain of art.

The ESS is "a powerful tool for understanding how Earth operates as a single, complex, adaptive system, driven by the diverse interactions between energy, matter and organisms" (Steffen et al. 2020, 54). It conveys a "unified understanding of the Earth", which is indispensable "for studying global changes and their planetary-level impacts and risks, including phenomena such as climate change, biodiversity loss and nutrient loading" (Steffen et al. 2020, 54).

The term ESS indicates a series of "interacting physical, chemical and biological global-scale cycles and energy fluxes that provide the life-support system for life at the surface of the planet" (Oldfield and Steffen 2005, 7). The physical, chemical and biological processes are interlinked and they "cycle (transport and transform) materials and energy in complex dynamic ways within the System" (Oldfield and Steffen 2005, 7). This shows already the high degree of ramification and intricacy between the various processes and within the Earth System itself.

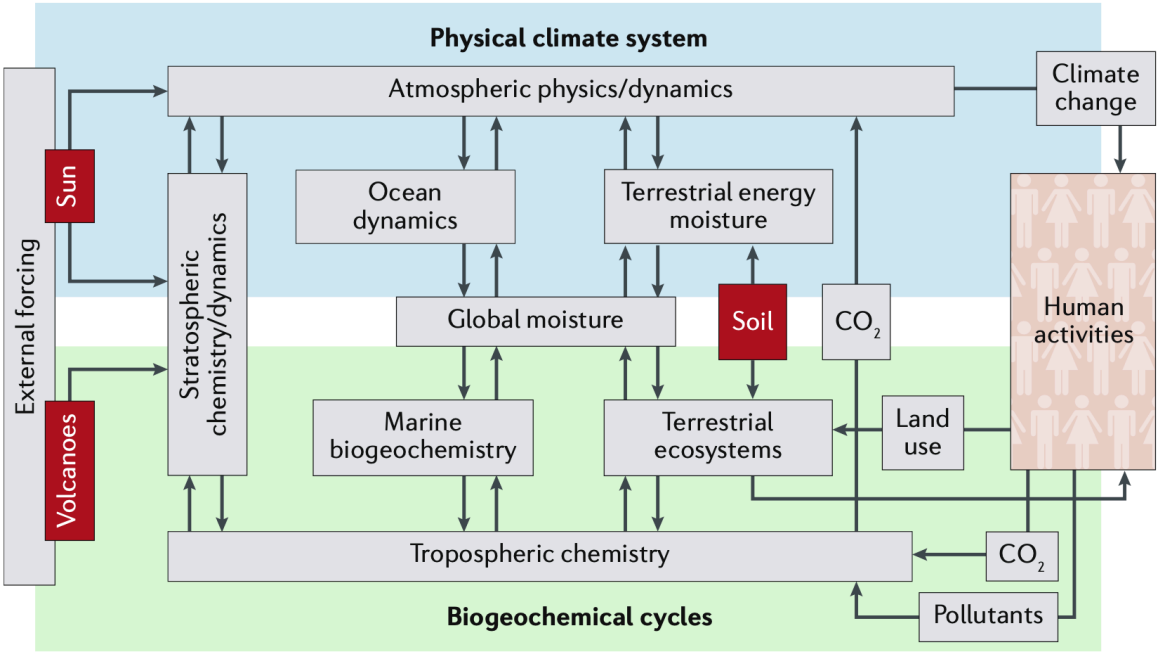

Figure 5 | The NASA Bretherton diagram of the Earth System. (Steffen et al. 2020, 56)

Another decisive aspect is that, because of this complexity of interwovenness the "forcings and feedbacks *within* the System are at least as important to the functioning of the System as are the external drivers" (Oldfield and Steffen 2005, 7). The feedbacks happen between physical, chemical and biological processes and are responsible of how the Earth might react to an encounter of these forcings and are displayed in the diagram of Figure 5. Human activities are presented as an external force affecting the displayed interactions between the geosphere and the biosphere (Steffen et al. 2020, 56).

The sun is as well an important element in the Earth System science as it is an essential external energy source which influences the materially closed system. In this setting biological/ecological processes (living organisms) are important and active participants in the functioning of the Earth System. Oldfield and Steffen also argue that "human beings, their societies and their activities are an integral component of the Earth System, and are not an outside force perturbing an otherwise natural system" (2005, 7). In the connection between different elements humans as organisms are an important part of cycles and systems in the environment (Steffen et al. 2020. They describe anthropogenically driven changes as a mode of natural variability and instabilities within the Earth System, hence "by definition, both types of variability are part of the dynamics of the Earth System. They are often impossible to separate completely, and they interact in complex and sometimes mutually reinforcing ways" (Oldfield and Steffen 2005, 7).

As well the component of time scales plays an important role and in ESS it changes depending on the questions being asked. A lot of global environmental change issues deal with time scales ranging from decades to a century or two, while the understanding of Earth System processes asks for an examination of longer periods. This is "to capture longer-term variability of the System, to understand the fundamental dynamics of the System, and to place into context the current suite of rapid global-scale changes occurring within the System" (Oldfield and Steffen 2005, 7). Yet time is a fundamental aspect in our epoch "The rapidity of change and the speed with which new situations are created follow the impetuous and heedless pace of man rather than the deliberate pace of nature" (Carson 1999, 6-7). Imagining that for certain impacts the earth would need time not in years, but in millennia to adjust is alarming. For example, the chemical substances, used by humankind, especially in industries such as industrial agriculture are synthetic and are not compatible with nature since they have no counterparts in it. "To adjust to these chemicals would require time on the scale that is nature's; it would require not merely the years of man's life but the life of generations" (Carson 1999, 7). It is not clear if the planet and humankind has that much time at disposal, since it would require a long process of readaptation.

The main tools and approaches of ESS are "observations of a changing Earth System, computer simulations of system dynamics into the future and high-level assessments and syntheses that initiate the development of new concepts" (Steffen et al. 2020, 58). All three of them are interrelated and characterize the development of the ESS. As already argued before the aspect of time is decisive in understanding the System and necessitates the consideration of past and contemporary changes. They need to be considered at a wide range of spatial and temporal scales, i.e. in top down and bottom up and forward-looking and backward-looking scales. This, if considered in a large-scale experiment, "can explore how parts of the Earth System may respond to future levels of human forcing or intervention" (Steffen et al. 2020, 58). Different studies have researched efficiency of iron fertilization to trigger oceanic drawdown of CO_2 from the atmosphere. They recognized it could be used as a potential strategy to mitigate the threat (Williamson et al. 2012).

To briefly summarize the knowledge gained through the development of the ESS permitted to understand better the dynamics and processes of the earth, which are very complex and intricated as shown previously. Hence it is an essential science to consider in a transdisciplinary dialogue between different domains which tackles environmental issues.

Furthermore, research in the ESS made it possible to introduce new theories such as the one of the Anthropocene, which has altered the understanding of the System by acknowledging the geological impact of humanity. As a matter of fact, the Anthropocene can be recognized as a unifying concept "that places climate change, biodiversity loss, pollution and other environmental issues, as well as social issues such as high consumption, growing inequalities and urbanization, within the same framework" (Steffen et al. 2020, 59). Various studies such as the one undertaken by Steffen et al 2015 and Malm and Hornborg 2014 illustrate the elements establishing the framework of the Anthropocene. This framework offers the opportunity to integrate natural sciences, social sciences and humanities in order to develop a sustainability science, which might be able to assert future trajectories of the Earth System and the impact of the Anthropocene (Steffen et al. 2020, 59).

Sustainability science is an important concept in connection to the ESS and the framework of the Anthropocene, since it also acts across different phenomena such as economic globalization and local farming practices. Basically, it aims at "meeting fundamental human needs while preserving the life-support systems of planet Earth (…)" (Kates et al. 2001, 641). Hence the focus is also on the interactions between nature and society and in how different actions between those two areas might create feedbacks and forcings. Kates continues to argue that in a research field such as climate change scientific exploration and practical application must happen at the same time, since they are often influencing each other by being entangled (Kates et al. 2001, 641). Therefore, the development of a sustainability science within the ESS can foster problem-driven and transdisciplinary research which aims at finding decisive knowledge concerning the System and transferable solutions to the addressed processes.

In the framework of the ESS another element is paramount which is the one of "tipping element" which "describe large-sake components of the Earth System that may pass a tipping point" (Lenton et al. 2008, 1786). Latter indicates "a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system" (Lenton et al 2008, 1786). The indicated thresholds can most of the times be determined by a critical value such as carbon dioxide concentration, which can increase the risk of crossing thresholds of other tipping elements. For example, the crossing of the threshold of water and land degradation can increase the risk of crossing the critical value in the climate system (Rockström 2009, 472). The relationship of these important elements of the Earth System

distinguish themselves by showing "(…) strongly nonlinear, sometimes irreversible, threshold-abrupt change behaviour" (Steffen et al. 2020, 59). Lentont et al. underwent a very thorough and precise investigation of the "tipping elements" concentrating on the ones induced by human activities and which are possibly relevant for future policies. Such elements can be important ecosystems for the Earth System such as the Amazon rainforest, the boreal forest, the melting of the Greenland Ice Sheet and the Loss of Arctic Sea-Ice.

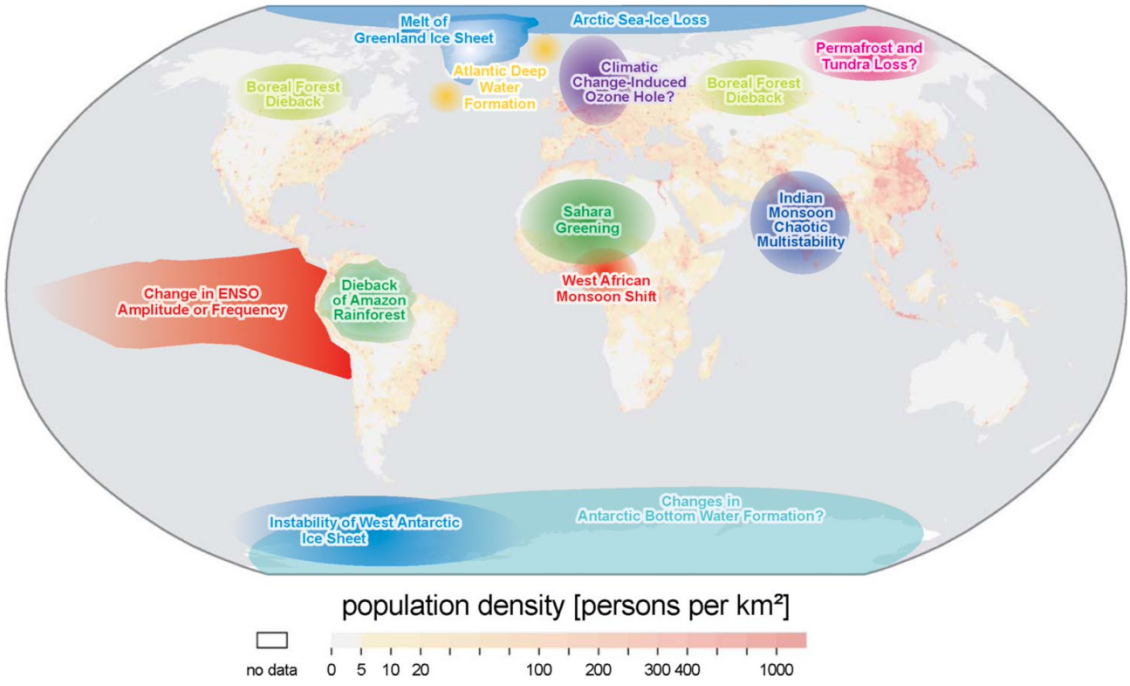

Figure 6 | Map of potential policy-relevant tipping elements in the climate system (Lenton et al. 2008, 1787)

For example, when looking closer at the circulation system concerning the Greenland ice sheet a reinforcing feedback can occur when the ice sheet melts and therefore the surface falls towards a warmer climate, which causes a higher melting rate. When the critical point of self-reinforcement, i.e. the point where the Greenland ice sheet cannot cope with the loss of its ice anymore, is reached it becomes an irreversible phenomenon. This highlights the risk of destabilization of the Earth System as a unified concept as well as of climate change and biosphere degradation (Lenton et al 2018, 1787; Steffen et al. 2020, 59-60).

Connected to the tipping elements another important concept arises from further research of ESS. It is the one of planetary boundaries, which associates the biophysical perception of the Earth in terms of states, fluxes, nonlinearities and tipping elements "to the policy and governance communities at the global level" (Steffen et al. 2020, 60). According to Rockström nine planetary boundaries can be recognized which are "climate change; rate of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus

cycles; stratospheric ozone depletion; ocean acidification; global fresh-water use; change in land use; chemical pollution; and atmospheric aerosol loading" (2009, 472). They delineate a safe space within which humanity can operate while respecting the Earth System and by maintaining a Holocene-like state. Furthermore, the planetary boundaries are interlinked with the planet´s bio-physical subsystems or processes, which are particularly sensitive when reaching a threshold level of certain variables. The subsystems can respond in a smooth way when thresholds are crossed, yet mostly their reaction is nonlinear and abrupt. The crossing of the threshold can cause important changes and shifts in the states of subsystems such as the monsoon one. Their overpassing is characterized by "a critical value for one or more control variables, such as carbon dioxide concentration". Though not every process or subsystem of the Earth can be attributed a critical value the issue is that human actions can undermine the resistance of these processes. Moreover, they increase the risk in other interdependent processes such as climate change (Rockström 2009, 472).

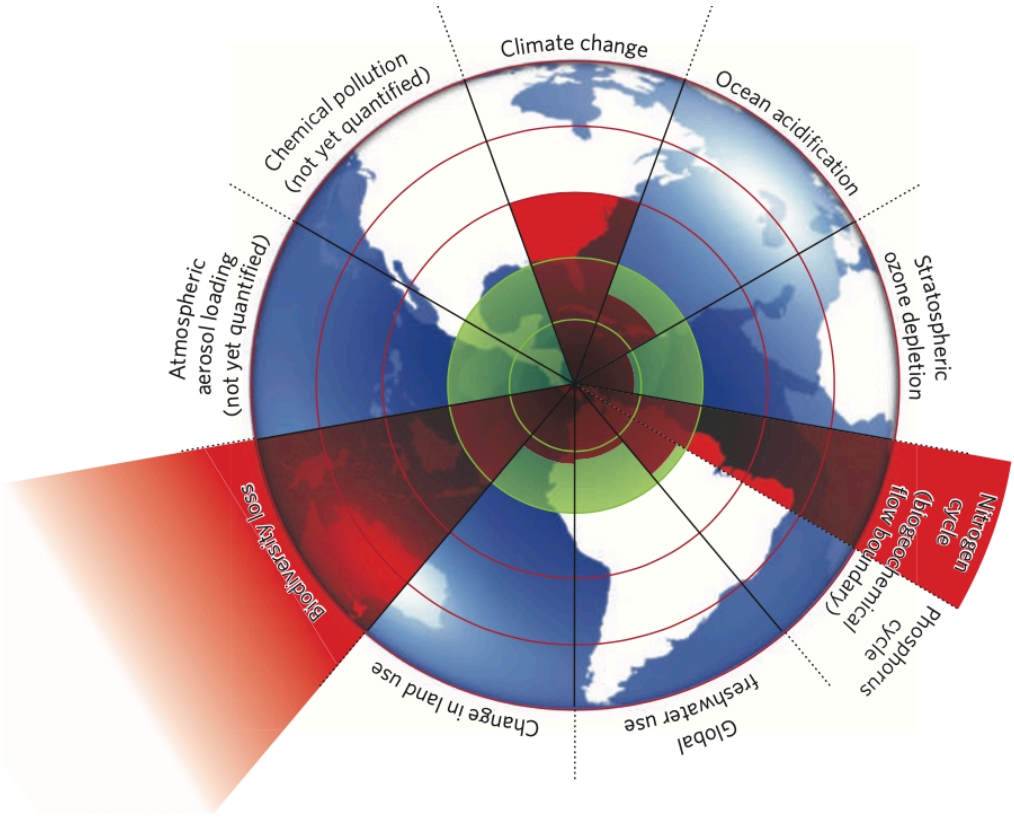

Figure 7 | Beyond the boundary (Rockström et al. 2009, 472)

Three of the planetary boundaries (rate of biodiversity loss, climate change and human interference with the nitrogen cycle) have already been exceeded according to Rockström, mainly caused by human activity through the great acceleration. Figure 2 displays all nine

of the planetary boundaries and proposes the inner green circle as the safe operating space for the systems. The red triangles show if the threshold of the various variables has already been overpassed. For example, though the extinction of species is also a natural process, the rate of biodiversity loss has accelerated heavily during the Anthropocene due to human activity. Moreover, the high extinction rate of species has an effect also on how the Earth System functions and influences as well other planetary boundaries: "(…) loss of biodiversity can increase the vulnerability of terrestrial and acquatic eco-systems to change in climate and ocean acidity, this reducing the safe boundary levels of these processes." (Rockström et al. 2009, 474). In the best case, a planetary boundary "should capture the role of biodiversity in regulating the resilience of systems on Earth." (Rockström et al. 2009, 474). Not only realizing and researching planetary boundaries can bring important knowledge within which space humans can operate, but they also show the interdependence between the various subsystems and how entangled they are with the Earth System.

As demonstrated above with the example of the rate of biodiversity loss it is not possible to concentrate while examining planetary boundaries only on one, since they are tightly connected to each other. For example, trespassing the nitrogen-phosphorus boundary "can erode the resilience of some marine ecosystems, potentially reducing their capacity to absorb CO2 and this affecting the climate boundary" (Rockström et al. 2009, 474). To develop this further a significant land-use change such as the deforestation in the Amazon could influence water resources even in Tibet. Hence, recognizing the interdependence and the mutual influenceability between the nine planetary boundaries, is important in order to be aware of the critical value of the control variables.

These are just some of the insights concerning the ESS, which as showcased is complicated and complex and always strongly coupled in between the Earth System and subsystems. The evidence so far also suggests uncertainties on how long it would take to "cause dangerous environmental change or to trigger other feedbacks that drastically reduce the ability of the Earth System, or important subsystems, to return to safe levels." (Rockström et al. 2009, 475). It is fundamental to bear in mind that regeneration is a central guiding principle for sustainability, which can direct sustainable societies, though the current modern industrial society does not see time and space for "living regeneratively" (Shiva 2016, 105).

Yet, it is still unclear how humans and their societies could live together with nature without misusing the processes and systems vital for the functioning of the planet we are living on. According to Steffen et al. "the big challenge is to fully integrate human dynamics, as embodied in the social sciences and humanities, with biophysical dynamics to build a truly unified ESS effort" (2009, 61). Figure 8 proposes such an adaptive system, which integrates also the Anthroposphere in the forcings and feedbacks with the Earth System.

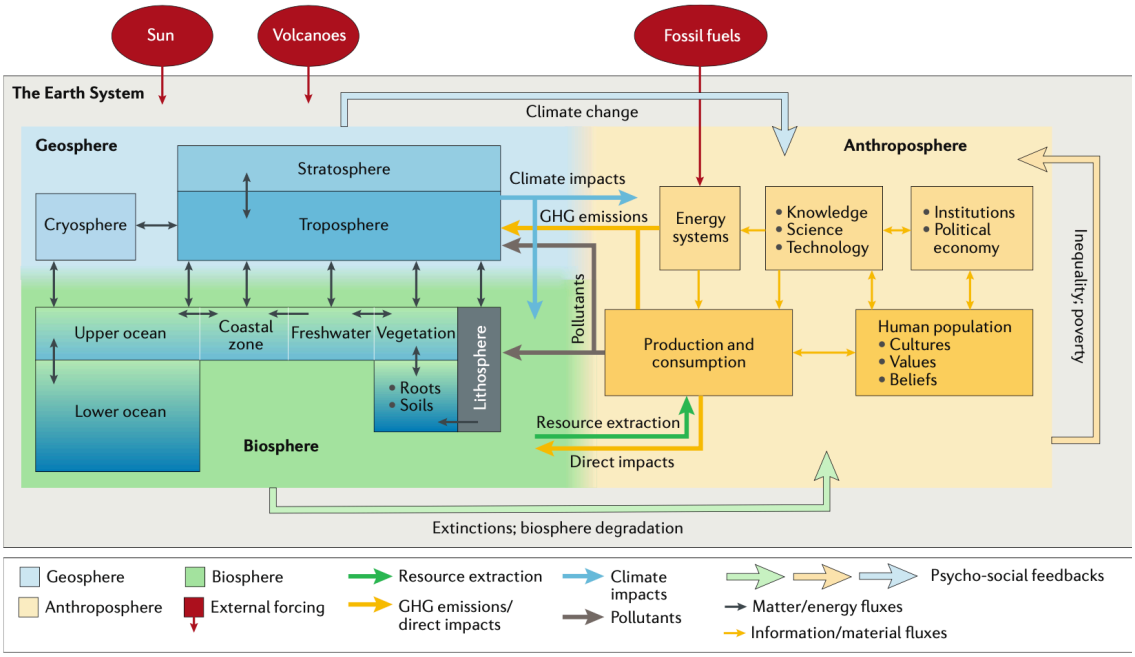

Figure 8 | Conceptual model of the Earth System (adapted version) (Steffen et al. 2020, 61)

It is not yet known how humans could interact with the Earth System as a fully integrative, interacting sphere. Exactly this knowledge gap is challenging future transdisciplinary collaborations in sustainability practices in order to find new ways of dialoguing and cooperating between the Earth System and the Anthroposphere. According to Steffen et al. technology and the concept of complex, adaptive systems[4] "(…) are decisive tools in order to foster the understanding and co-evolution of the biosphere and human cultures as social-ecological systems" (2009, 61). It is bringing decisive knowledge about the planet we are living on and about the Anthroposphere with its social and governance systems, its core values and aspirations (Rockström et al. 2009, 62).

[4] Complex adaptive systems are systems which connect people and nature, also known as social-ecological systems, such as coral reefs and grasslands. Essential features of these systems are "nonlinear feedbacks, strategic interactions, individual and spatial heterogeneity, and varying time scales". Hence, they are an integrative part for the further development of policies concerning social-ecological systems (Levin et al. 2013, 113).

Hence, it is paramount for humanity to recognize the role of being responsible of finding new perspectives which could lead the trajectory of the Earth System in a sustainable science. Therefore, an even deeper understanding is necessary of the environmental threats dealt with in the two selected case studies and which will be further explained in the following chapter 3.2.

3.2 Environmental threats

Environmental threats are—in the discourse of the ESS, climate change and the Anthropocene—important aspects which contribute to the intertwining between different elements. As already mentioned in Chapter 2.3.1 transdisciplinarity is impelled by external conditions such as climate change and in the framework of the Anthropocene climate change can be defined as a "wicked problem" since it is connected to other issues and elements. When one of these elements is trying to be addressed it possibly exacerbates another raft of problems. The same situation is displayed in the above given analysis of the Earth System which with its various subsystems, elements and variables reveal a high interconnectivity and complexity. "Many would argue that such problems, particularly in the environmental realm, are now engendering a paradigm shift, the effects of which are new ways of working, new economic models and systems of resource management, new allegiances" (Bennett 2012b, 3). Hence, tackling and addressing environmental issues which are connected to processes and systems of the Earth System, presents a great difficulty, yet it is necessary for facing the challenges of the Anthropocene. It demands to take into account various areas and elements, which therefore makes the transdisciplinary experimental practice an ideal approach.

In order to understand profoundly the environmental issues addressed and dealt with in the bioacoustics sound experiment between Dunn and Crutchfield and the installation *Line of Beauty* between Lorenz and Pflugmacher, it is necessary to analyze the ecosystems, processes and threats they are dealing with. In the following chapters the bark beetle threat addressed during the sound experiment and the ecosystem of the forest are explained. Moreover, the installation of Lorenz and Pflugmacher demands a closer look at river waters as an ecosystem and what other systems it influences in the surrounding area.

3.2.1 The forest ecosystem

The ecosystem of forests is constituted by a dynamic balance between different elements, that is of soil, insects, plants, animals and climate. This balance can be disrupted by various factors such as tree-eating insects, which on their turn react on climate, which controls precipitation. Forests are a very important example for dealing with solar energy since they represent "an important ground cover that absorbs, uses, and reradiates solar energy in various forms" (Dunn and Crutchfield 2008, 1). If seen from a wider perspective climate is compelled by absorbed solar energy and regulated by relative fractions of atmospheric gases. Ground and cloud cover determine in turn the amount of absorbed solar energy in the atmosphere. Moreover, forests are "key moderators of atmospheric gases" since they "exhaust oxygen and take up carbon dioxide in a process that sequesters in solid form carbon from the atmosphere" (Dunn and Crutchfield 2008, 1). That is the reason why forests are a fundamental element in the struggle against climate change and in the influencing of our atmosphere, since not only they determine ground cover and hence climate but also absorption and retention of carbon dioxide.

The Earth has three major forest ecosystems which are the tropical, temperate and boreal one. The three ecosystems vary from each other in vegetation and animals that inhabit them, given by conditions such as water, temperatures and varying of the seasons. The tropical ecosystem is the hottest one and with the most variation in plants and animal species, which makes them real biodiversity treasures. Compared to the tropical one the temperate and the boreal have colder climates and less biodiversity. Especially the boreal forests have frigid temperatures and cover vast expanses in Canada for example (Hancock 2019). All three forest ecosystems are of irreplaceable importance for their self-regulating balance, since their trees help to coordinate and determine the climate of the Earth. Moreover, they "provide essential timbre resources, and create a diversity of habitat and nutrients that support other forms of life, including millions of people" (Dunn and Crutchfield 2008, 2). Therefore, the forests play an important role in not only regulating the climate and retaining climate change, but they also are the home of a vast variety of living beings, including humanity for which they represent an important supplier of resources.

In spite of this irreplaceable role that trees have in regulating the climate of the Earth, the rate of mortality of trees rose drastically in recent years, especially in older trees, which have more capacity in regulating the climate and ecosystems. Between 1900 and 2015

(which is also when the great acceleration started) the world lost more than a third of its primal forests, the ones almost not contaminated by humanity. The mortality rate doubled in the last 40 years in older trees in Europe and North America, changing decisively the composition and structure of forests. McDowell et al. explain that theses continuous changes in "environmental drivers and disturbance regimes are consistently increasing mortality and forcing forests toward shorter-statured and younger stands, reducing potential carbon storage" (2020, 1). Younger forests have less capacity to retain and absorb carbon dioxide for which old trees play a decisive role. The loss of forest cover alters the equilibrium between species inhabiting it as well as reducing impressively biodiversity. According to McDowell the dynamic of forests is changing because of "anthropogenic-driven exacerbation of chronic drivers, such as rising temperature and CO_2, and increasing transient disturbances, including wildfires, drought, windthrow, biotic attack, and land-use change" (2020, 1). Hence human induced climate change and wildfires represent threats with the greatest impact on the change of the forest structure. The increasing of temperatures and the reduction of precipitation fosters wildfires like those that hit Australia and Siberia in 2019 (Crescente 2020).

Biotic disturbances from insects such as bark beetles are increasing in frequency, severity and extent since recent decades and are a great peril to the survival of the forests. They can contribute severely to the tree mortality since warmer climate fosters their reproduction and exhausts the capacity of trees to recover (McDowell et al. 2020, 5). Trees, insects and climate stand for a complicated system, which is characterized by cooperating and competing between various elements. It can be argued they overlap because the "phenomena and interactions they describe co-occur in space and time" (Dunn and Crutchfield 2008, 1). Figure 9 shows the connection between trees, insects and climate and how the actions of one of the elements influences a feedback from the other.

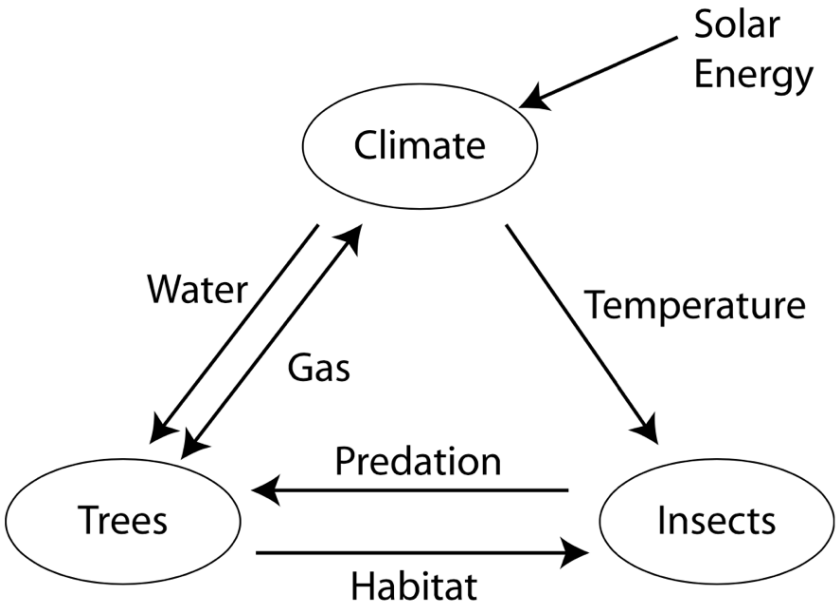

Figure 9 | The overlapping between climate, trees and insects

Bark beetles as a biotic agent have in this system a high capacity of adapting on time scales of years but can also cause effects on a large spatial scale during a short time such as deforestation. According to Dunn and Crutchfield this phenomenon can be determined as "entomogenic climate change" because of their capacity of influencing the advancing of the threat of climate change. Their procedure can be associated to a feedback loop which can be determined as a continuous affecting circle (figure 9): "insects reproduce by feeding on trees, forests affect regional solar energy uptake and atmospheric gas balance, and, finally, energy storage and atmospheric gases affect climate" (Dunn and Crutchfield 2008, 2). At the same time climate as a large-scale factor influences dynamics on a small scale: rising temperature favors the reproduction of insects and precipitation controls tree growth. "The feedback loop of insects, trees, and climate means that new kinds of behavior can appear—dynamics not due to any single player, but to their interactions." (Dunn and Crutchfield 2008, 2). Hence these feedback loops can maintain the stability of an ecosystem but also amplify through an instability small effects to a large scale. The interdependence between climate, insects and trees is clear and important for the stability of the climate of the Earth.

Figure 10 | Dying forest in California (2016) because of bark beetle infestation (Katz 2017; FOREST SERVICE)

When the first outbreaks of bark beetle infestation started in the western United States it was reported as a result of regional droughts that fostered bark beetles to reproduce. Yet, climate and forestry experts and biologists have observed that the bark beetle outbreaks are closely connected to the global climate change and hence an "inevitable consequence of a climatic shift of warmer temperatures" (Dunn and Crutchfield 2008, 3). Dying and dead trees from biotic attacks are a perfect ground for wildfires. Bark beetles foster with their behavior deforestation by eating and killing trees from the inside. Boreal deforestation is experiencing this pattern and a continental migration form the bark beetles to the great boreal forests of Canada is feared. To exemplify the risk, it is important to understand that not only the alpine forests of Canada are essential for the carbon dioxide absorption, but they are also important for a snow-fence effect. They "hold windrows of captured snow that are crucial to the conservation and distribution of water from the Rocky Mountains" (Dunn and Crutchfield 2008, 3), which is one of the primary water resources that supplies several major river systems in North America. If this would be put at risk through a bark beetle infestation given to warmer climates, which also increase the risk of wildfires, the boreal forest of Canada would be at high risk and as well the climate of the planet we are living in. It has been asserted that the boreal forests are very sensible to temperature shifts and have changed radically over millennia, which "suggests that the predicted warmer climate will cause their ecological niches to shift north faster than the forests can migrate" (Dunn and Crutchfield 2008, 3). In other words, these forests adapt to climate shifts at their own pace which is much

slower than the current drastic changes in climate. Most probably the ecological niches of these forest's tree species will not be able to adapt and hence migrate to a colder climate, necessary for their survival.

The correlation of threats such as bark beetles with the development of climate change and their huge impact on the survival of forests has just become in the last twenty years a recognized issue on a global scale. Their intrusion and outbalancing of forest ecosystems need to be recognized and researched since it affects a powerful tool in the battle against climate change. The conservation of ancient forests such as the ones in Eastern Europe for example or the boreal ones in Canada, which are threatened by deforestation are therefore fundamental.

3.2.2 The river ecosystem

As the forest ecosystem the one concerning waters, specifically the one of rivers is characterized by various interdependent elements, which together form a continuous, i.e. dynamic balance. Especially free-flowing rivers (FFRs) "(…) support diverse, complex and dynamic ecosystems globally, providing important societal and economic services" (Grill et al. 2019, 215). Their capacity of flowing freely is determined by the connectivity of pathways, which implement the movement and transfer of "water and of the organisms, sediments, organic matter, nutrients and energy that conveys throughout the riverine environment" (Grill et al. 2019, 215). Yet the development of infrastructures endangers the ecosystem processes, biodiversity and services support by these rivers. The main aspects restricting the connectivity of FFRs are "dams and reservoirs and their up- and downstream propagation of fragmentation and flow regulation" (Grill et al. 2019, 215). Therefore, "large continuous river networks with intact natural connectivity (CSI = 100%)", i.e. without any experienced human interference, can be found only in remote regions such as in the Arctic, in the Amazon Basin and in the Congo Basin (Grill et al. 2019, 216)[5].

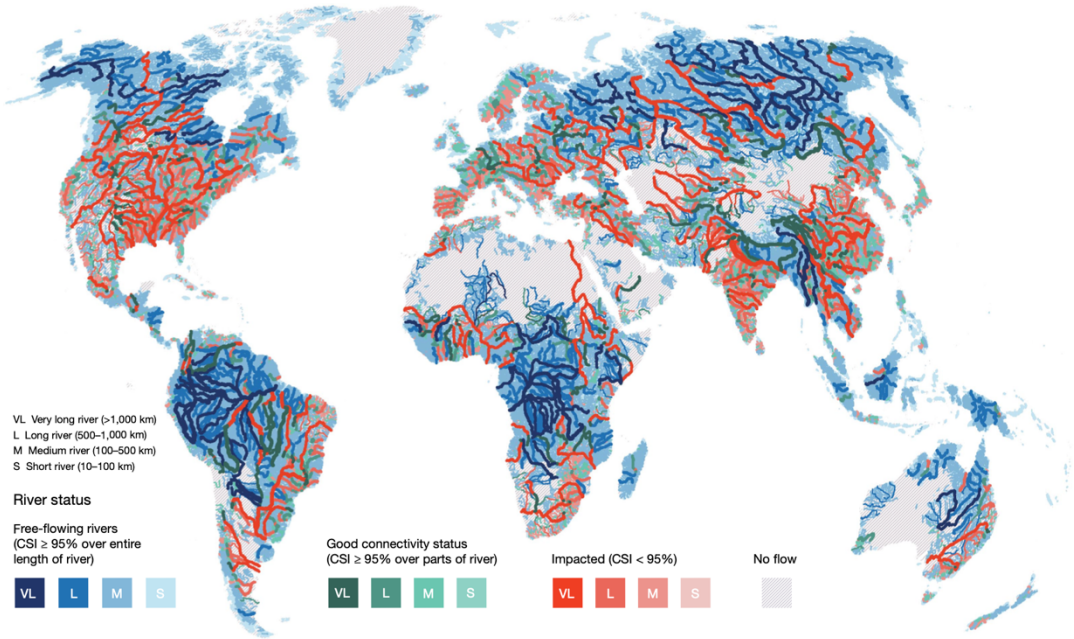

Figure 11 | Global map of the free-flowing rivers. Showed are rivers with good connectivity status and impacted ones with reduced connectivity (Grill et al. 2019, 219)

[5] The integrated connectivity status index (CSI) illustrates the degree of connectivity of the rivers, by classifying rivers with a CSI ≥95% as free-flowing rivers.

Rivers have always been an important source of environmental health, economic wealth and human well-being since they are an important resource as a "large natural course of flowing water", which "surface water moves down along the slopes due to the action of gravity" (Balasubramanian 2005, 1) (Grill et al. 2019, 215). It can be also considered as a powerful geological agent since rivers have the ability to erode, transport and deposit sediments, which can be defined as river alluvium. Different factors can determine velocity of the river's flow and force such as the nature of the bottom can be a defining factor of the habitat of a river course. On the other hand, elements and structures which can limit the ecosystem of a river are climatological factors such as changing temperatures of the atmosphere, humidity, hours of the sun, evapotranspiration and wind. Hence it can be argued that the connection between land and water and the one between water and air present a considerable role in influencing and controlling the environmental conditions of the surrounding area (Balasubramanian 2005, 2). Moreover, the advancement of society and the need for built infrastructure in order to transport and develop required the construction of "(…) an estimated of 2.8 million dams (…), regulating and creating over 500,000 km of rivers and canals for navigation and transport and building irrigation and water-diversion schemes" (Grill et al. 2019, 215). This led to several negative impacts affecting the river flows as for example exposure to continued pressure coming from fragmentation and loss of connectivity between rivers. As a result, the capacity to flow unimpeded is restrained and affects important processes and functions which are distinguishing of healthy rivers. Compromising the river reverses on the biodiversity causing rapid decline and on fundamental services of the ecosystem (Cardinale et al. 2012, 60).

The biodiversity of the river's waters is primary since it provides home for many different species ranging from water plants to insects, fish, birds and mammals. The pollution and interference in the ecosystem of rivers can cause severe declining of the biodiversity of rivers and impact negatively the ecosystem of freshwaters (Balasubramanian 2005, 5-6). Humans have altered directly and indirectly the natural river connectivity through the placement of structures into the water flow such as dams and levees or by altering the hydrological, thermal and sediment regimes of the river. Consequently, these activities have been linked to a decline of biodiversity of terrestrial and freshwater species. Additionally, the "(…) sediment caption through dams may cause the alteration of the geomorphic dynamics of rivers and the shrinking of river deltas worldwide" (Grill et al.

2019, 215). These changes will not only have damaging consequences for the ecosystems and human societies but will also be costly from a social and economic point of view (Palmer et al. 2008, 86). Rivers play a significant role as they are strategic points for many cities and represent an fundamental economic resource, but most importantly are one of the most fundamental resource on earth for every species, which is water.

The threat of global environmental change, i.e. of climate and land use change, is seen according to Grill et al. as a factor that will raise the "pressure on rivers and their connectivity through alterations in flow patterns and intermittency, modifications in the frequency, magnitude and timing of droughts or floods, and changes to water quality and biological communities" (2019, 220). A river can autonomously respond with adjustments such as "lateral migration of channels and dynamic interactions between the streambed, floodplain, and riparian zone"[6] (Palmer et al. 2008, 81) to modifications in the surrounding landscape and in developments in discharge. These natural and healthy river responses are important since they "allow rivers to absorb disturbances and buffer the ecosystem and surrounding land from the impacts of floods and anthropogenic effects" (Palmer et al. 2008, 81). Nevertheless, changes induced by urbanization, excessive water withdrawals or climate shifts which may cause droughts or even alluvions that happen rapidly and "lead to flows outside the natural range of variability" can impact decisively the ecosystem of the rivers and as well the people who depend on them (Palmer et al. 2008, 81; Poff et al. 2002).

Furthermore, Palmer et al. highlights the threat coming from the overlapping impacts of climate change the one's caused by dams and other human infrastructures, since they have not received enough attention. The stress coming from excessive water withdrawal and land development can be intensified by climate change and exacerbate issues such as biodiversity loss or severe flooding. According to him the identification and prioritization of actions that can fortify the resilience of riverine ecosystems against the threats and challenges they are facing, is paramount. As well proactive responses such as actions improving "the capacity of river systems to absorb disturbances while minimizing threats to the environment and human populations" as well as reactive responses "to problems as they are generated by repairing damage or by mitigating ongoing impacts" will be needed (Palmer et al. 2008, 82).

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[6] The riparian zone is the area between the river and its adjacent land, which host various plants, animals, insects. Hence it is important for the preservation of biodiversity, for soil conservation and the preservation of fauna and aquatic ecosystems.

The analysis undertaken by Palmer et al. suggests that within 50 years (from today on 40 years) greater changes in discharge and water stress will be experienced by rivers altered by dams or by extensive development. On the other hand, FFRs will have better chances to react naturally to climatic changes since they are unimpacted and free of human interventions. Proactive measures are additionally the actions with a higher capability of restoring the natural capacity of rivers to mitigate climate- change impacts. Their advantage is that they can also contribute to environmental benefits which can result in higher water quality and restored fish populations (Palmer et al. 2008, 88).

It is interesting to note at this point that also the river system is characterized by an interdependence of not only elements belonging to itself such as water, organisms, sediments, organic matter, nutrients and energy but also exterior aspects such as the climate, atmosphere, sun hours, humidity, evapotranspiration and wind. Additionally, the intervention of human activity through the construction of dams and other several interventions to benefit economic and social growth impacted greatly the natural free flow of rivers. As a result, the feedback dynamic between the river system and these elements is similarly to the forest ecosystem intertwined with many elements which can prevail on one side and hence cause biodiversity loss and the disappearing of rivers.

Taking as an example the Seseke river in Germany, which has been used for many decades as a wastewater canal, human intervention has interfered with its free-flowing course by forcing it to a straight concrete bed. As a result, the Seseke was deprived from developing vital ecosystems through its riparian zone and polluted since being used for discharging the wastewater of the whole region. The Seseke river results from different creeks and trenches in the area Werl-Holtum and Unna-Hemmerde and emerges southeast of Lünen. It is a side river which emerges from the left side of the Lippe in North Rhine-Westphalia, which on its turn results from the Rhein (Greule und Hackl-Rössler 2014, 496). Until the 19th century the Seseke river was a natural water, which changed during the start of industrialization and with mining, being practiced extensively in the Ruhr area. As a result, various issues such as flooding, and soil subsidence impacted the region and together with the need of a system of wastewater due to the developing urbanization of the area initiated several interventions on the present waters. The affected areas used as wastewater canals were the ones around the Emscher and rivers and creeks resulting from the Lippe. Converted into open canals the Seseke and its inflows were used for discharging for decades

the wastewater of the region until the end of the mining period in the 1980ies. Closed canals below ground were thought as feasible due to the possible damage from soil subsidence resulting from mining. In these times repairing such damages and the possible pollution of ground water were seen as a too high risk. Hence the open wastewater canal system was the easiest and most efficient solution and its side effects taken into account (Emscher Genossenschaft n.d.; Regionalverband Ruhr 2017).

Nevertheless, after the mining period finished in the 1980ies a renaturation program was initiated by the Lippeverband to clear the Seseke and its parallel waters from the long-lasting function as wastewater canals and to regenerate the ecosystem of the river and its adjacent landscape. Four different wastewater treatment projects were initiated between 1984 and 2014 in order to meet the aim of renaturation. Additionally, closed wastewater canals running below ground of about 73 Kilometers were built in the Seseke region to redirect the wastewater from the affected waters to the four different wastewater treatment facilities in Bönen, Kamen, Dortmund-Scharnhorst and Lünen. Those facilities are responsible of clearing the wastewater and to redirect it in the Seseke and its inflows. After the clearance of the waters the Seseke was freed from its forced straight riverbed in concrete plates to a more natural meandering, aiming at the river flow before the interventions during industrialization. The removing of the concrete plates and the flattening of the adjacent slopes improved the stabilization of the Seseke's riparian zone, which resulted in the development of aquatic ecosystems, the fauna of the area and soil conservation.

Nevertheless, the free-flowing nature of the Seseke was compromised during industrialization, which has contributed to a forever change in the ecosystem and natural potential of the river to respond to climatic changes. Aiming at restabilizing the conditions before the usage as a wastewater canal is the forest step towards the renaturation of the river, yet it will take many years.

4 A new ecological paradigm: “Ecological Logic”

The description in chapter 2.3.2 of the Joseph Beuys’ *7000 oaks* and Ursula Damm’s *Treibhauskonverter* showed the interest of artists towards environmental issues as well as scientific systems. Yet, their attention was more concentrated on addressing threats concerning climate change and the environment or on translating a scientific ecology into an artwork to make it understandable for the public. Moreover, artists mostly worked alone in the development of their works, not seeking active collaboration of a scientist. In the example of Damm though, the scientific insight of various theories and processes provided her the necessary information for the dynamics of the *Treibhauskoverter*. Yet, a scientist was not actively involved in the construction of the exhibition. Therefore, the following case studies have been chosen by observing two main criteria, which are the close collaboration between the domains of art and science where both play an important role and the solving of an environmental threat by creating action.

It was important to analyze a transdisciplinary approach where both art and science take action in addressing and solving the environmental threat they are dealing with. Otherwise the collaboration would tend towards either to be a scientific research or an artwork and loose its ambition of discovering the space in between, beyond and across the two disciplines. When both domains play their part in researching the phenomenon and in finding possible solutions, interesting and especially new solutions can be revealed. Additionally, the environmental threats are intertwined with other areas such as the social or economic one and interdepend with various elements. This also requires a transdisciplinary approach between art and science, since their collaboration provides the possibility of considering different areas and elements in the solution of the threat.

Furthermore, it was paramount to introduce case studies, which worked with the development of concrete solutions applicable in reality. Since most of the artworks in the environmental field do not deal with finding actual solutions to environmental threats and hence do not actively intervene in solving them, it is a fundamental criterion in the selection of the present case studies. Moreover, the current situation of the climate crisis demands immediate action in possibly mitigating and hopefully stopping the advancement of climate change and the impacts on the Earth System. Therefore, not only relevant production of knowledge concerning the addressed environmental threat is decisive but also the finding of an answer which can be applied in reality.

Ideally the presented solution to the environmental threat through the selected case studies should have the possibility of being applied globally since many of the environmental problems are existing on a wider scale. Yet, this criterion will be investigated in the description and analysis of the collaboration between Dunn and Crutchfield and the one between Lorenz and Pflugmacher.

4.1 A bio-acoustic sound experiment

4.1.1 Description

Dunn and Crutchfield recognized during an analysis of insect control strategies that there was a correlation between rapidly expanding insect populations, deforestation and global climate change (2008). California experienced in that time an infestation of bark beetles in its forests, which threatened to extend and to become a global issue. Imagining most forests of the world infested by beetles, which not only threatens the natural landscape but especially the home for millions of other species and the power of retaining CO_2 emissions to the atmosphere, is quite scaring. As already mentioned in chapter 3.2.1 Dunn and Crutchfield recognized that different elements (trees, insects, climate, soil) are in an interdependent relationship, which always thrives for an autonomous balance. Yet, the issue arises when one of the factors is overwhelming the other. In the case of the California bark beetle infestation the decisive element was the hotter climate, induced by mankind's action, which shifted the balance in favor of the propagation of the bark beetles. The resulting deforestation through the bark beetle infestation also induced higher risk of wildfires, which likewise increases emissions and deforestation (Leefeldt 2018). It is a very complex problem to solve and when approached from one side it can result into a raft of other problems.

The pinyon juniper woodlands are old forests which cover about 89 million acres of lands between California, Utah, Arizona, Colorado and New Mexico and are one of the slowest-growing pines on the planet. They expand during cold and rainy weather and shrink in hot one which makes them particularly sensible to climate change and longer periods of drought. Their role is fundamental as shade spender for various species inhabiting those areas such as coyotes and antelopes, yet also they protect crucial watersheds on mountain slopes (Nikiforuk 2011, 193). In 2002 various bark beetle species started to invade the forests of Arizona and Colorado as well as pinyons in New Mexico until reaching California. The bark beetles found "abused, fragmented, unappreciated, crowded and dried out" juniper forests by two hundred years of settlers mining, ranching and constructing of monster estates and gated communities (Nikiforuk 2011, 196). Several droughts started to hit the Southwest of the United States from the mid-1990s on until 2005 which affected the soil water content which got so low until the point that pinyon trees stopped transpiring and photosynthesizing altogether. "Drought-stressed pinyons gave the engraver beetle an opportunity to run riot in a landscape of undefended castles" (Nikiforuk 2011, 198). Their danger for the tree consists

in boring through the tree's vascular system, the phloem[7], which restricts their ability of drawing their necessary nutrients. Ultimately the needles of the tree fall of and it starts to grey. An area the size of Germany's Black Forest grayed from the dying trees and was visible for California's inhabitants. In order to stop the propagation of the bark beetles and to prevent wildfires trees have been cut down.

Figure 12 | Larvae of spruce bark beetles in Poland's Bialowieza Forest (Katz 2017; WOJTEK RADWANSKI/AFP/GETTY IMAGES)

Dunn started his research of the bark beetle infestation in New Mexico when he was asked to detect the affected trees through his to a microphone remodeled meat thermometer and a piezoelectric transducer from a greeting card used as a loudspeaker. He discovered a whole world of acoustics of clicks and pops in pinyons by the beetles and compared the encounter as listening to a skilled percussion group. Scientists discovered that insects do way more sounds then thought and developed sensitive digital technology which can actually hear their unique sounds coming from stridulation, an act were insects rub together a variety of body parts (Nikiforuk 2011, 200). Additionally, it is important to note that also trees produce sound, for example a dry pinyon tree "produces a variety of powerful pops that sound like distant drumbeats. Botanists call this collapse of cells "cavitation" and use it as a measure for drought stress" (Nikiforuk 2011, 203).

The stories of Pueblo elders such as the one of "beetles come when the trees cry" directed Dunn's research towards the acoustic domain between beetles and trees, which still

[7] Phloem is the vascular tissue in a tree, which transports carbohydrates produced during photosynthesis from source tissues such as leaf cells to sink tissues such as root cells. Hence this vascular tissue is vital for a tree's survival.

was an undiscovered area, yet of great importance for the bark beetle infestation. The chemical ecology model was the great discovery of the 20th century, used to explain the behavior of bark beetles. It is the "study of these compounds that attempts to unravel and map this extensive chemical language through analysis of both chemical compounds and observation of the behavior of living organisms correlated to them" (Dunn and Crutchfield 2008, 6)[8]. Yet Dunn through his investigation in the acoustic world of bark beetles, discovered that not only the pheromone system was used by bark beetles to detect their "prey" but also the sound system is a decisive factor for finding trees to be hosted. He discovered through his fieldwork a whole new ecology which puts the threat of the bark beetle under a different light, making it an important aspect to consider in climate change.

At this point Dunn and Crutchfield decided to join their forces being a sound artist and a physicist specialized in chaos theory, responding to an issue which seemingly has no outcome, which is to retain the infestation of bark beetles which are attracted by stressed trees and dry climates. They discovered, by researching and experimenting in 2008, that the bioacoustic interactions between insects and trees are the key drivers for the bark beetle infestation. Additionally, their investigation brought them to assume that the bark beetles will play an important role in global warming. "The chaos theorist and the musician calculate that the bark beetle has the potential to be not just a quick responder to higher temperatures but a generator of carbon, based on a number of feedback mechanisms" (Nikiforuk 2011, 211). Insects are poikilothermic that means that they are cold-blooded and therefore extremely sensitive to temperature, which makes them more active at higher temperatures (Dunn and Crutchfield 2008, 4). Dunn and Crutchfield call their theory concerning the contribution of bark beetles to the generation of carbon entomogenic climate change. They describe it as the following: "As more trees die, less carbon is sequestered and stored. The disappearance of forests, in turn, leads to the generation of less oxygen and the concentration of more carbon in the atmosphere. As the release of more forest carbon causes temperatures to rise further, the warming will put beetles on the landscape in ever-greater numbers and ever-expanding geographies" (Nikiforuk 2011, 211). In this feedback loop between bark

[8] The majority of the scientific research in the communication of the bark beetle world focused on communication through chemical signaling through compounds (pheromones) between members of the same species or through chemical hints diffused by a source of prey, in the case of the bark beetle a tree to be hosted.

beetles, forest and atmosphere the contribution of the bark beetles to climate change is decisive since they have the potential to drive the warming further and to affect greater areas.

Figure 13 | Various bark beetles (Rappaport 2017)

During their research Dunn and Crutchfield also discovered that the insect's social organizations are highly developed and sophisticated requiring "(…) ongoing communication through sound and substrate vibration" (Dunn and Crutchfield 2008, 10). The sound artist and physicist suppose that host selection, coordination of attack of the host, courtship, territorial competition and nuptial chamber excavation can be associated to the behavior of the bark beetle. Interestingly, Dunn and Crutchfield discovered that in "fully colonized trees the stridulations, chirps, and clicks can go on continuously for days and weeks, long after most of these other behaviors will have apparently run their course" (2008, 10). Hence, their multimodal communication system and the fact that pheromone and mechanical signaling are combined are important discoveries for further research and in the consideration of the bark beetle as an important element in climate change.

Through the help of a sound experiment they discovered the possibility of redirecting the behavior of the insects through their own stridulations. "We altered beetle behavior by playing back their own sound. We managed to turn them into cannibals. We created unprecedented behaviors" (Nikiforuk 2011, 193). Dunn called this experiment "acoustic warfare against beetles" and detracted the beetles sounds from a CD produced by himself,

called *The Sound of Light in Trees*[9]. This CD holds recordings of the interior sound of trees and hence as well the activity of different species of bark beetles.

About the same time another scientist Richard Hofstetter (entomologist from the University of Arizona) is interested in the sound ecology of bark beetles and encounters the project of Dunn and Crutchfield. Together with Reagan McGuire a scientist also from the University of Arizona they start an extraordinary experiment which observed the beetle's behavior. They fashioned in their lab a "phloem sandwich"[10] in order to film and record the reaction of the beetles to various sounds. During one experiment they changed the reproductive system of the beetle completely by putting inside the sandwich a female pine beetle and then introducing a male one, which immediately started to stridulate signaling the female his presence. Afterwards the scientists played the sound of another male chirp to which the female was immediately attracted to and abandoned the real male. Another experiment investigated the possibility of hybrid bark beetles, since during Dunn and Crutchfield's research they were never detected. Yet Hofstetter and Reagan McGuire thought there could be a possibility of hybrid species since they often attacked the same ponderosa tree in Arizona for example. Therefore, they introduced a female western bark beetle in the sandwich and lastly a southern pine beetle: "The female started signaling by making weak pulsing sounds. The male moved towards her and started to make a terrifying loud stridulation sound. The female froze in her tracks. Then the male came up to her and chewed her in half length-wise. It was sonic warfare" (Nikiforuk 2011, 207). They recorded the squirrel-like screech of the male beetle and played it in another experiment to a pair of western pine beetles. In this experiment the beetles mated two or three times and then in a sudden moment the male chewed the female into pieces.

In a different experiment the scientists Dunn, Hofstetter and McGuire played the mutated beetle sound on 14 bark beetle couples and on 14 not. Finally, this experiment showed that the couples without sound produced 200 eggs and tunnels of 15 to 30 centimeters, which are deadly for the tree. On the other hand, the 14 couples which were subject of their own sound only produced one egg all together and compared to the other couples their tunnels were short (NAU 2010). This shows the potential of influencing the

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[9] The sound of bark beetles in trees can be listened here http://earthear.com/solit.html

[10] It consists of two quarter-inch thick plates of Plexiglas with a piece of sugar-rich phloem inserted in between, Moreover, a single hole allows a beetle to enter in the desired interior of the "tree".

behavior of an insect which is devastating on a global level important forests and which is an important component in the entomogenic climate change. They recognized that by using specific sound the propagation of the bark beetles was being slowed down, diverted or even interrupted.

In 2016 Dunn received together with the Hofstetter and Mc Reagan a patent for a device which uses sound "as a targeted sonic weapon to disrupt the feeding, communication, reproduction, and various other essential behaviors of the insects" (Rappaport 2017). Currently they are working on the patented device in order to produce an effective system which can be applied to individual trees in order to retain the infestation.

Nevertheless, the drought in U.S. Southwest forests and the infestation of the bark beetles in the pinyon juniper woodlands changed not only the natural landscape but also the carbon budget of that entire region. According to a study of 2010 that region lost 5 million tons of carbon from the beetle's infestation and drought, which is more than it did from wildfire or logging in the researched period. "Spruce, lodgepole, and Douglas-fir forests generally hold two to three times as much carbon as the slow-growing pinyon. But beetles have dramatically whittled the capacity of those trees to hold carbon" argues Nikiforuk (2011, 211).

Yet, the possibility of researching a device which can defeat bark beetles and mitigate their forest-eating behavior could be a great alternative against deforestation, wildfires and poisoning methods. Acoustic ecology not only can be a new way of doing pest control as Hofstetter argues, but also a strategy in mitigating and defeating climate change.

4.1.2 Conceptual Analysis

Dunn being a sound artist was able to address and later partially solve a seemingly impossible to tackle issue in the scientific realm. He initiated research from a totally different angle for investigating on a very important insect, the bark beetle, and discovered with his first attempts of listening to trees the acoustic ecology of trees and bark beetles.

The interconnectivity and interdependence of different variables such as insects, tress, soil, climate and human activity asked for a transdisciplinary approach, where it was possible to consider all of these elements without leaving out any. The complex problem of bark beetles showed ramifications in different areas such as the ecology of the forest and the system of the climate. Hence a collaboration with the scientist Crutchfield was the solution to open up new paths and explore different spaces dimensions and relationships of the threat with those elements.

Moreover, the collaboration with Crutchfield is an example of how the transdisciplinary is induced by external conditions or issues in this case the bark beetle. In being a new decisive factor for accelerating global warming and the decay of forests the bark beetle infestation required a transdisciplinary research and experimentation. Creative thought solved a seemingly-impossible-to-overcome issue by working on a different angle with means outside of one's domain. The experimental collaboration between Dunn and Crutchfield with the further development and research by Dunn has discovered decisive information. Experimentation concerning the environmental threat of the bark beetle infestation between sound and physics revealed important information about the threat itself and the ecosystem they are intertwined with. This brings new knowledge to the surfaces such as the one concerning the acoustic world of trees and beetles and the interdependence between different factors such as trees, insects, climate and soil. Dunn and Crutchfield also managed to discover the impact the infestation of bark beetles can have on the acceleration of climate change, which is an extraordinary finding in terms of the future of the planet.

Moreover, the experiment shows that domains do not have proprietary rights over their discipline (Bennett 2012b,3). It shook the ground beneath the domains of science and art, bringing art and science beyond its institutional boundaries. Dunn started a scientific research while being an artist and Crutchfield as a scientist collaborated with an artist and his "artistic" material of sound recordings of bark beetles and the interior of trees. Additionally, in the experiments held with Hofstetter the material and knowledge gathered

by Dunn and Crutchfield was used in order to gain scientific evidence for the behavior of the bark beetles. This ultimately led them to the assumption that the own sound of bark beetles if used in a particular combination of sound and beetles was able to disrupt the behavior of the insect. Hence the recordings of Dunn of the CD *The Sound of Light in Trees* are of great importance to the development of the research. Additionally, Dunn developed together with Crutchfield the listening device, which is essential for the gathering of the different sounds that the bark beetles do. It is also necessary for the further development of a device which is not only able to listen but also to emit the recorded sounds. As already mentioned, it is patented and in development by the scientists and artist.

Figure 14 | Sound play back into a tree (Rappaport 2017)

This experiment goes beyond the conventional practices of their respective domains demanding to search for a different approach (Bennett 2012a, 12). In a context where at that time current insect-control strategies were not enough to cope, Dunn and Crutchfield established a connection between the micro-ecology of insect infestation, deforestation and global climate change: "Through transdisciplinary experimentation, then, they have opened up the unanticipated possibility of redirecting insect behavior" (Bennett 2012b, 2).

Definitely a positive outcome can be recognized with the finding of a concrete solution to the addressed problem. Art and science contributed both to the production of important knowledge concerning the environmental threat to the extent of being responsible for action. With the patenting of the devise to disrupt the bark beetle's behavior and to break the positive feedback loop on the advancement of climate change a concrete solution has been found.

This solution considers also the fact that the redirection of their behavior does not involve using pesticides or cutting down trees but influencing an ecological lifecycle in a positive and not invasive way. Hopefully in the future the patented device can be used actively in retaining the bark beetle infestation and in this way to allow the forests to persist, which is a fundamental aspect in fighting against climate change.

Nevertheless, questions still remain about the elaborated methodology, since insects are important in the ecology of the forest and in the grander system of the planet. If once the bark beetle's behavior has been redirected were shall they be placed if not in the affected forests? Does the redirection with their sound also impact other animals or ecosystem in a negative way? How can the device be applied on a global scale or let's say on a wider area then a singular tree? Points still in need to be investigated, which can be addressed if enough means are directed in transdisciplinary projects such as this one in order to mitigate climate change, if not completely stop it and contribute to a planet which does not experience negative disruption through human activity.

4.2 Line of Beauty

4.2.1 Description

The renaturation of the Seseke was further developed by the project ÜBER WASSER GEHEN (walking over waters) in occasion of Ruhr being nominated the cultural capital for 2010 (Emscher Genossenschaft n.d.; Regionalverband Ruhr 2017). Various art projects (11 permanent and several temporary one's), accompanied by a bike path, were installed in and along the Seseke, dealing with the mutation of nature and landscape. Interestingly, some of these projects are characterized by a direct intervention in the renaturation of the Seseke, aiming at supporting the further development of the river's ecosystem and its adjacent landscape. The swiss artist Thomas Striker for example intervened directly in the landscape of the river with his work *Landschaft im Fluss* (landscape in the river) by building an artificial island in the midst of the brighter riverbed. The landscape installation is populated by rare and very old swamp cypresses, which have not been seen in the area for decades, yet once were part of the natural landscape. The intent of the artist is to underline the process of redevelopment of the Seseke and that direct intervention through humans can restore previous vegetation.

Nevertheless, the most remarkable project of ÜBER WASSER GEHEN is the installation *Line of Beauty* by Lorenz and Pflugmacher which intervenes directly in the renaturation of the river Seseke in Kamen (Germany) in 2009. Today the once to a straight bed forced river flows "as a naturalised river in a new bed that is artificial but close to nature" (Lorenz 2009).

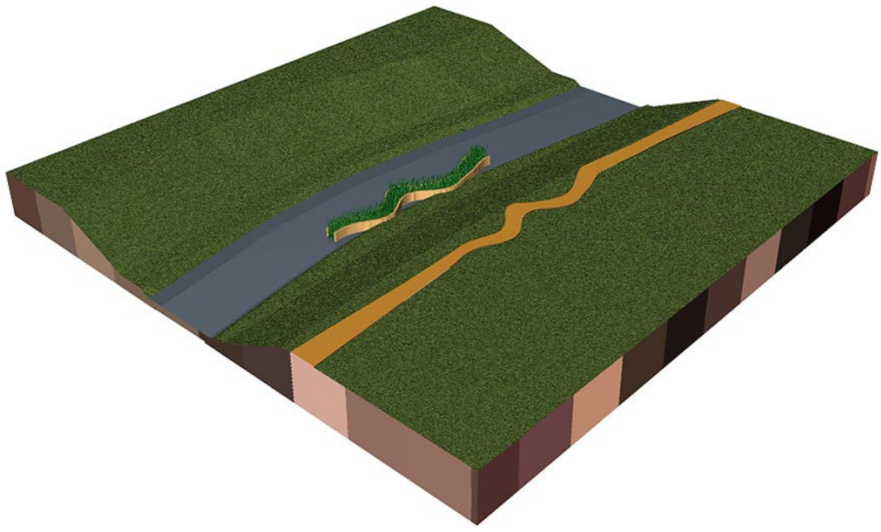

Figure 15 | The 5th wastewater treatment works (Lorenz 2009)

In the framework of the four existing wastewater treatment works Lorenz and Pflugmacher designed *das fünfte Klärwerk* (the 5th Wastewater Treatment works) which aimed at transforming the ecosystem of the water by exclusively plant induced processes. For that Lorenz and Pflugmacher projected an installation which is composed of wooden stems forming a small canal in the Seseke which follows the meandering line of a reduced-scale segment of the riverbed near Aden mill before 1920.

Figure 16 | The historical river Seseke before the straightening, at the site (Lorenz 2009)

In this wooden canal native water plants are planted which actually clean the water and function as a biofilter. The 5th wastewater treatment work aims at supplementing "the effect of the four existing water treatment works on the River Seseke, which are unable to ensure adequate water quality" (Lorenz 2009). With time the water plants should spread across the riverbed and contribute to a long-term river naturalization in order to contribute to the stabilization of existing ecosystems. The biking path accompanying the line of the installation, follows the same meandering form, which should integrate the viewer or passant directly in the experience of the intervention in the river (Borries et al. 2011, 86-87).

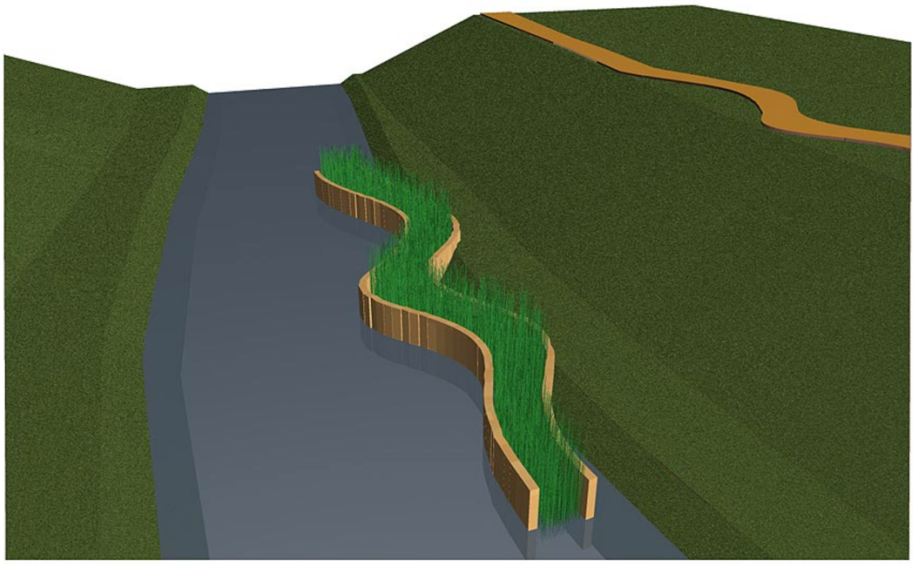

Figure 17 | The 5th wastewater treatment works from another perspective (Lorenz 2009)

Line of Beauty refers to the English painter and printer William Hogarth (1697-1764): the aesthetic form of nature of the 18th century was rather characterized by curves than by straight lines. During the 18th century a shift in lines from the straight ones to the curved or serpentine ones was experienced, especially in the conception of gardens. It was characterized by the change from baroque gardens to romantic ones.

Figure 18| high baroque garden (Turner 2005, 292)

Geometry was essential in the design of gardens during the baroque age and axes became a dominant feature. Axes played an important role because the work of the baroque style started by projecting them beyond the limits of closed Renaissance gardens. Hence "circles, squares, proportions and geometrical patters" of the Renaissance, which were used in design and perspective also play a role in the baroque garden (Turner 2005, 220). Moreover, axes "weld garden, architecture and landscape into unified geometrical compositions" and projected "beyond the boundaries of enclosed Renaissance gardens" by "bringing mountains, lakes and forests into composition with gardens" (Turner 2005, 268, 288). The avenue was a central element in the designing of the garden and is the most characteristic line of the baroque parks. Therefore, straight lines were a fundamental element in the designing of the gardens and in the perception of the beautiful, which later in the romantic age was contrasted by curving lines.

Figure 19 | Petworth Sussex, deer park landscaped by Brown with a serpentine hill (Turner 2005, 315)

In Romanticism the focus was on irregularity and where "(…) things grew wild and without trimming and in all the diversity of their natural shapes"[11] (Turner 2005, 309). Serpentine lines were an important feature of the work of an English garden designer Capability Brown whose style is described as "nature-like" or "nature-esque". Important elements were "circular clumps of trees, a grassy meadow in front of the house, a serpentine lake, an enclosing belt of trees and an encircling carriage drive" (Tuner 2005, 312). A close connection could be drawn between the serpentine line in the romanticism adopted by garden designers and the "line of beauty" of Hogarth.

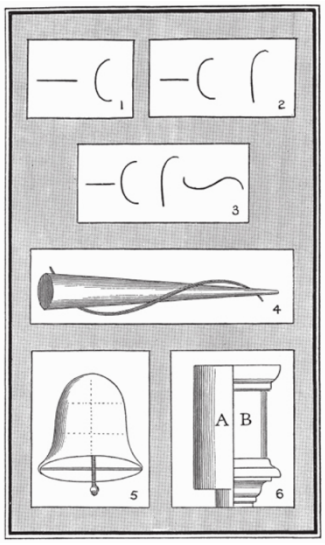

Figure 20 | Figure of straight and waving lines (Hogarth 2015, 73)

Hogarth exemplifies the serpentine-line as the one of beauty and of grace which "by its waving and winding at the same time in different ways, leads the eye in a pleasing manner along the continuity of its variety" (Hogarth 2015, 79). The single line presents a variety

[11] A remark by A.O.Lovejoy, read by Frank Clark to his class of 1969.

which may be expressed according to Hogarth to “enclose varied contents”. The line of most grace has the least of straight line in it and is represented by Hogarth by the help of a figure (image 4, figure 20). The serpentine line “(…) is represented by a fine wire properly twisted round the elegant and varied figure of a cone” (Hogarth 2015, 72). Lorenz applies the concept of line of beauty in her work as the “search for a visible formula for nature” which is embodied in the meandering form of the installation and in the goal of the installation to restabilize the ecosystem to increase the biodiversity again (Lorenz 2009). All of this is accomplished through one serpentine line as inspired by Hogarth which encloses varied contents as of beauty, nature, the river ecosystem and history.

But not only the aesthetic formula was being met in the art installation, also the scientific or practical one was of great importance. The system of the “green lever” acting as a biofilter had to be functional though integrated in an art installation, which was a great challenge for the scientific part developed by the biologist Pflugmacher.

Unfortunately, deeper insights concerning the building up of the art installation and the system concerning the “green lever” are not available. Compared to the first case study of the bioacoustic sound experiment, which has a great and relevant knowledge production and scientific documentation, the project line of beauty has not that much available information. This will be further discussed in the next chapter 4.2.2 dealing with the conceptual analysis of the project.

4.2.2 Conceptual Analysis

The title of the installation (*Line of Beauty)* between Lorenz and Pflugmacher "(…) refers to the search for a visible formula for nature" (Lorenz 2009). The greatest challenge in working on the installation was to actually make it function from a scientific point of view and not only an artistic project. Hence the artistic requirements resulted in a productive outcome which challenges the scientific praxis. On the other hand, the artistic work was challenged by the need to establish an installation which should depict processes through the technological help of science. The starting point for the project was a discussion about how to render the ecosystem of the river working again, which in the end resulted in an actual intervention in the ecosystem. As a result, new perspectives opened up in the discussion between nature, art, technology and the intervention of humankind to restore ecosystems (Borries et al. 2011, 92).

Figure 21 | *Line of Beauty* and the biking path (Lorenz 2009)

The work between Lorenz and Pflugmacher situates nature in form of the river Seseke in between the original free-flowing form, the one before 1920 and the anthropogenic one, which follows the original one but is a human made construction. In this context the "natural" form is given by human intervention, which was also the cause for the disappearance of the free-flowing and unpolluted river. (Borries et al. 2011, 87). Moreover, it adds an additional layer of historical meaning to the Seseke river now representing the state before 1920, the wastewater canal and the renaturized river. The reference to the

concept of line of beauty of Hogarth links the form of beauty to utility as in water purification and truly connects art with scientific purpose. Nevertheless, according to Lorenz questions regarding beauty still remain open: "Is beauty the visibly manmade: the straight alley of a Baroque garden, the canal as an expression of the engineer's ingenuity? Or is beauty the natural, a category itself requiring further definition: a naturally occurring form, a form constructed on the basis of natural parameters, or an artificial form becoming natural?" (Lorenz 2009). Today, were humanity is necessarily tied to the future of the planet the natura can rarely be thought separated from the artificial and constructed. The planet is the habitat we are depending on with its resources and only in remote regions of the arctic, the Amazon Basin and the Congo Basin FFR's can be found.

Similar to the bioacoustic sound experiment between Dunn and Crutchfield, the installation *Line of Beauty* tries to find through a creative angle a solution to an environmental problem. In this case the issue is not on a global level, but definitely significant on a regional one as the ecosystems of rivers are fundamental for the flora and fauna of their surrounding landscape and in the resilience against climatic change. The equilibrium between the scientific and artistic aspect is well distributed in this project, since both parts, by working together, created a functioning system for the renaturation of the river. Exact information about the positive outcome of the project is not available at the moment, yet several sources state that regional fish species such as the trout found their way back into the river Seseke. After the renaturation several species are again populating the river, which means that the projects introduced to make the Seseke livable again, were a success (Jannecke 2019). As well kingfisher, waterfowls, raptors and other species of birds have taken back the area around the Seseke and populate again this ecosystem (WA Werne 2017).

Nevertheless, the continuous assessment of the success of the installation is lacking, since the intervention in an ecology needs to be monitored in order to determine if the planted plants are functioning as a bio-filter or not and if therefore adjustments need to be made. Compared to the bioacoustic sound experiment between Dunn and Crutchfield, Lorenz and Pflugmacher did not continue with extensive research on their topic and did not consider the possibility of applying their "green-liver" system to other affected wastewater canals. If successful their project could be implemented in many other waters restoring lost ecosystems and fortifying the resilience of rivers against climatic changes, which are becoming more

severe. The peculiarity of their project lies in the fact that no machines and mechanical engineering are needed to "build" the naturalization system, which is only composed by the interaction between the water plants, the water and the surrounding flora and fauna. As in the other wastewater treatments big constructions are needed and complex systems required for the naturalization of the waters of the Seseke. Hence, they impact in a greater way their surroundings and do not integrate so well in the environment as the art installation *Line of Beauty*. Therefore, it would have been interesting to rely on a document with a description of the application of the project in the river Seseke and the development of the collaboration between the artist and the biologist. Dunn and Crutchfield on the other hand did an extensive research with various scientific findings which connected climate change to the threat of bark beetles and continued to develop their theories until even patenting successfully the device. Furthermore, they documented them through a publication which explains clearly their procedure and findings.

The parameter able to indicate the success of the wastewater treatments is the re-populations of aquatic and terrestrial animal species, which nevertheless cannot be directly tied to the project Line of Beauty between Lorenz and Pflugmacher, but to the whole of interventions made until today.

The lack of documentation and further development may be attributed to the supposition that the interest of the project was more directed towards the art installation, functioning also from a scientific point of view. The project happened under a wider series of other projects as already mentioned for ÜBER WASSER GEHEN for the nomination of Ruhr as cultural capital in 2010. Furthermore, the present information about the project is only explained through the website of the artist and not in collaboration with the biologist Pflugmacher, which may contribute to the fact that the artists interest is mainly the artistic element.

Another striking aspect of the project *Line of Beauty* is the claim of a naturalization project over beauty by not only following the serpentine line of an important age, the one of romanticism, but by referring "to the search for a visible formula for nature" (Lorenz 2009). Latter is an ambitious statement since the previous explanation in chapter 3.1 about the ESS showed how complex, interdependent and intertwined the planet, its system and subsystems are. Trying to limit nature to one formula as depicted in the project *Line of Beauty* through the serpentine line, may be a bit reductive. On the other hand, Hogarth argues that the

peculiarity of the single line of the serpentine line lies in the fact that it encloses varied contents through its twisting in many different ways. Nevertheless, it is difficult to attribute a specific formula to the river ecosystem, which is characterized by a variety of elements which cannot be all considered by the serpentine line.

To summarize the art installation contributed as far as can be assessed to an improvement of the ecosystem of the Seseke by a project in between art and science. Both parts have played an important role in the aesthetic, cultural heritage of the river and the technological aspect for the future of the ecosystem of the Seseke. More projects like this with the adequate monitoring and adjustment could create the needed resilience of rivers and waters which are affected by past and present human interventions which have contributed to the decline of their water quality and upholding of their ecosystem and the surrounding landscape.

5 Conclusion

Throughout the argumentation and discussion of the present thesis a correlation between climate shifts of deep history, current mutating processes of the Earth System and the capitalist-industrialization characterizing the history of life are revealed. Humankind is an impacting force, which has been shown in chapter 3.2.1 and in chapter 3.2.2 with the closer analysis of two ecosystems, the one of the forests and the one of the rivers. Yet an important aspect has to be highlighted, that the Earth System already existed before humankind populated the planet and will continue to do so when eventually the planet is not livable anymore. The coming actions in mitigating climate change are therefore fundamental in the preservation of everything concerning the Earth System.

Nature has been defined as varied in conception, biodiversity, processes and systems, impossible to reduce to one "right" definition. Human history is part of nature, since we have been living on the planet, by using its resources and by building a certain "way of life" we are holding today. Therefore, a deep understanding of the environment is fundamental to put into perspective the knowledge and perception humankind has of nature, the natural and wilderness. The theory of countervisuality proposed by Mirzoeff in chapter 2.2.1 offers a different mental space where art and science can collaborate to visualize environmental threats and furthermore make them heard on a global level. The revelation of nature for what it is with the countervisuality is paramount to create a sensibility and action in causes concerning climate change. As mentioned in chapter 2.3.1 culture studies as proposed by Santos revealed itself in both case studies as a facilitator of dialogue in the intersection between art and science. Both projects show an encounter between art and science which deals with the solution of an environmental threat which is important for the solving of climate change, the saving of the influenced ecosystem and for the affected territory. Therefore, also for the people, cultures, businesses and societies inhabiting the surrounding areas. Moreover, the complexity of the two environmental threats, one of the bark beetles and the other of the pollution of a river, demanded from culture studies to bring together art and science and start the dialogue between these disciplines.

The transdisciplinary approach in the two case studies across science and art addressing and answering to specific environmental threats resulted as beneficial. They are "(…) evidence of how creative thought can solve problems, first by providing a brand-new viewpoint, followed through with a new hybrid methodology, forged from an experimental

collaboration" (Bennett 2012a, 13). Both projects can be understood as transdisciplinary, working beyond, between and across their respective domains. As well art as science challenge the boundaries of their discipline by working on a problem through a transdisciplinary approach where they get unified with another discipline: "(…) unity in diversity and diversity through unity is inherent to transdisciplinary" (Nicolescu 2006, 7). Both domains find themselves in unknown territories trying to go across their own domain in order to find new perspectives.

As a result, in the bioacoustic sound experiment Dunn as a sound artist adventures himself in the realm of science and Crutchfield collaborates as an expert in the theory of chaos with an artist and the artist's sound tools at disposal. Dunn starts to record the interior of trees and the ways of communication of bark beetles with his artistic material. Art prospects itself here as "exciting and adventurous" experimenting with science, more precisely with an ecology (Bennett 2012a). The encounter with science develops the project by opening up and developing the research concerning the bark beetles and their interaction with the forest and the environment. Dunn and Crutchfield succeed by cooperating to produce important knowledge concerning the threat, especially by connecting global warming to the spreading of the bark beetles and the impact on the forests on a global level. Moreover, they also managed to induce action in the further progression of the research. The discovery of being able to redirect the behavior of the bark beetles by using the sound of the bark beetles on them is an important discovery which in the future can be applied to infested forests. Nevertheless, questions remain open, such as how to redirect on a wider range the behavior of bark beetles and where to lead them once they are redirected. Additionally, is it an ethical solution to let them eat each other when their sound is applied on them or is it necessary in order to save the forests from the infestation. Such conditions have to be further developed and the fact that Dunn has achieved the patenting of the device together with other two scientist shows that the research together with Crutchfield has been beneficial and has to a certain extent solved the threat. Some questions still remain open, which demand for a further research and implementation on a global level.

The art installation *Line of Beauty* on the other hand stands for a successful cooperation between art and science on how to integrate art in an ecology and how to make an art installation function from a scientific point of view. The challenge was to combine the art installation with the working of the water plants as biofilter for the water of the Seseke. Since

the aspiration of Lorenz and Pflugmacher was to support the ecosystem of the Seseke after its usage as a wastewater canal and to unify this in an art installation the requirements were different ones. The ecosystem of the river had to be known to the artist and the biologist to assert which water plants could live in the Seseke and work at best as biofilter to restore and reinforce the development of the ecosystem. The need to connect the system of the green lever with the artistic conceptualization represented a great challenge and shows how the encounter between art and science can bring to a merge between art and functioning science. Art challenged here the development and integration of a scientific process in an ecosystem productively. On the other hand, the potential of art embodied through the installation the understanding of the process of the green liver through the scientific contribution (Borries et al. 2011, 92). The encounter between Lorenz and Pflugmacher can be seen also as fruitful since it contributed to the renaturation of an ecosystem heavily impacted by human activity. Nevertheless, in comparison to the project between Dunn and Crutchfield it does not depict such a high and ongoing production of knowledge and no research in the applicability to other rivers or waters.

It is interesting to assert that both projects found applicable solutions to reality through experimentation and dialoguing with a completely different discipline in environmental matters. It can be argued that an approach across disciplines, in this case across science and art, can contribute decisively to the retaining and solving of human induced climate change. Mankind's agency and an active way of living in the Anthropocene, offers the possibility to produce knowledge and act, to make a difference by experimenting and researching more extensively in the becoming of the "transdomain" and "trans-cience". The point about both projects is that they approached the threat through ecological thought and hence by visualizing the ecology or lifecycle of the different intertwined elements. In this way Dunn and Crutchfield managed also to connect climate change to the deforestation of the bark beetles. Moreover, ecological thought permitted both collaborations to meet in between their domains and to develop a "trans-cience", which framed the complex environmental threat in question and defined a path of actions to solve it. This is a new paradigm, where science gets to be explained through art and art leads the development of systems and processes applicable into perishing ecosystems. It is, as Guattari describes it "ethico-aesthic in inspiration", being art, the discipline leading the research and meeting science in a fruitful encounter for the environment. As Nikiforuk believes: "the art world needs to ground

people's imaginations in a deeper understanding of the natural world. I think it is essential at this point that artists take a role in collaboration with the scientific world—that artists and scientists work together towards real-world problem solving" (2011, 192).

As we have seen in the chapter 2.1.1 climate change is induced to a great part anthropocentrically and will continue at a high speed if no countermeasures will be taken. The planet has always evolved as history of past epochs show and species have extinct always in the course of time. Nevertheless, the impact of human activity has started evidently during industrialization, when the involvement and exploitation of natural resources became greater and increased drastically. Furthermore, as Wilson (2000) argues after the four main changes of periods (Mesozoic spasms) species got extinct but also evolution readjusted in a very long frame of 10 million years by others. The issue of today is that we do not have that time anymore, because the loss in biodiversity inflected happened in a single lifetime. That is why action has to be taken now to be still able to indue a shift in mentality and in how the Earth System will function in the future.

The changes on the planet concerning global warming and environmental catastrophes are being witnessed in "real-time" since the development of the Anthropocene is happening in this very moment. The Earth System as explained in chapter 3.1, has become a concrete experience for many people. As a result, it is humankind's responsibility to use the technology at disposal for the environment and for the planet we are calling our habitat. The COVID-19 pandemic showed temporarily what impact industries and human emissions have on the ecosystems. The satellite images over northern Italy, the most affected part of the country, were clear from the smog clouds as they have not been since a long time. The waters of Venice's canals have been populated again by fish and other animals which have not been seen in these waters for a long time. This is all given by the stillstand of human activity related to the working of industries, constant travelling and the "way of life" we are used to. Furthermore, the COVID pandemic highlighted that humanity is strongly connected to the Earth System. Hence, humanity is also subject of climate change and of the threats deriving from environmental change. COVID-19 affected humanity severely in various ways, from the health to the economic system as humanity itself is affecting the Earth System. Yet changing policies for working against climate change have not been implemented on a global level. The governmental sphere has the capacity to induce such a change, which is needed in the climatic and environmental emergency.

It is true that solving environmental issues is complex since not only they depend on different elements such as in the case of the bark beetles on the forest, climate, soil and insects, but also are interconnected with societal, cultural, economic and political aspects. The freedom of the individual has been an argument of discussion during the COVID-19 pandemic, since people felt limited in their personal freedom of living their "way of life" before the pandemic. The same discourse is intrinsic in the discussion concerning policies for the environmental and climate emergency yet are not getting the attention they need. If the planet seizes to exist, we do to. This is already a very strong argument in favor of research such as the one undertaken by the bioacoustic sound experiment and the art installation *Line of Beauty*. Art and science have the potential to fill the knowledge gap concerning the interactions of humankind with the Earth System. Both case studies showed a clear correlation between the impact of humankind on the ecosystem and its resulting deterioration. Art and science can play an important role in this epoch of the Anthropocene to understand, research and act in solving seriously environmental threats.

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