Spring 6-11-2018

Restoration and Adaptation for Prospective Freshwater Shortages: An Integrative Evaluation and Actionable Approach

Krystal Hedrick
khedrick@uw.edu

Restoration and Adaptation for Prospective Freshwater Shortages: An Integrative Evaluation and Actionable Approach

Krystal C. Hedrick
Environmental Science
June 2018

Faculty Adviser: Dr. Elizabeth Bruch

Essay completed in partial fulfillment of the requirements for graduation with Global Honors, University of Washington, Tacoma

Restoration and Adaptation for Prospective Freshwater Shortages: An Integrative Evaluation and Actionable Approach

Krystal C. Hedrick
Environmental Science
June 2018

Faculty Adviser: Dr. Elizabeth Bruch

Essay completed in partial fulfillment of the requirements for graduation with Global Honors, University of Washington, Tacoma

Approved:

_______________________________ _______________
Faculty Adviser Date

_______________________________ _______________
Executive Director, Global Honors Date

Abstract

The availability of water resources is a growing concern throughout the world as more populations experience severe water shortages. Restoration ecology seeks to repair damage done to ecosystems through anthropogenic actions and climate change, making it a possible long-term solution and adaptive strategy to water shortages. This paper explores the practice of restoration ecology to assess its ability to help people adapt to a future with water challenges. Research revealed that restoration ecology can be used to better prepare people for a future with water shortages. By adopting the Society for Ecological Restoration Australasia's National Restoration Standards, the efficiency of all types of restoration, including vital aquatic resource restoration, can be improved. The Standards could also help to redefine international restoration legally and be a basis for global standards. Emphasizing climate change adaptation through restoration in Tacoma water management documents would result in bold, proactive, cohesive and adaptive water management locally. Finally, collaboration between the Society for Ecological Restoration and the University of Washington Tacoma would connect students and faculty to a global network, and resources necessary to research, design and implement the most effective restoration techniques possible for an uncertain future with water challenges.

Acknowledgements

A big thank you to my research team, Ryan Hanley and Dr. Elizabeth Bruch. The research process was complex, exciting, and would not have been the same without your contributions and advice.

Thank you to the Institute for Global Engagement and Global Honors Program. I would like to specifically recognize Alexis Wheeler, Paul Carrington, and Dr. Divya McMillin for their guidance and support throughout the research process.

To the Bamford Foundation, a very grateful thank you for your generosity. Without the Bamford Fellowship in Global Engagement, this research would not have been possible.

Table of Contents

Introduction

News of Cape Town, South Africa's severe water shortage has dominated media this year. A multi-year drought has finally reached a critical level with nearly four million people facing a dry water supply (Onishi and Sengupta 2018). Closer to home, frequent water shortages throughout the western United States are expected to increase, and water managers are struggling to find and maintain dependable water sources (Aguilar-Barajas et al. 2016). Increasing populations, habitat destruction, diminishing freshwater sources and fluctuations within the hydrologic cycle threaten human life by impacting health, food security, and increasing the potential for conflict.

Technological solutions to water shortages, like desalination, are on the rise. Technology-based solutions are important, and at times necessary, given the urgency of current water challenges. However, technological solutions can be used to justify continued ecologically harmful actions, like fossil fuel use, because of the belief that technology can fix any problem. To break away from the status quo, the objective of this research was to explore the practice of a non-technological strategy, restoration ecology, to assess its role in helping people adapt to a future with water shortages. To do this, restoration ecology, climate, and water management, on their own and in relation to each other, were thoroughly studied. A secondary objective was to specifically identify local and global actions that could strengthen preparedness on multiple levels. This paper seeks to argue that restoration ecology can be used to better prepare people for a future with water shortages, and that the practice can be utilized locally and globally most effectively:

- if the Society for Ecological Restoration Australasia's National Restoration Standards were adopted on various levels, including nationally, regionally, or locally.
- if climate change adaptation through restoration was emphasized in Tacoma's water management plans.
- if the University of Washington Tacoma collaborated with the Society for Ecological Restoration.

This paper provides an interdisciplinary evaluation of, and actionable approach to, water challenges by first discussing the background literature to provide a foundation for understanding ecological restoration, climate change, and adaptive water management. It focuses on the overall role of restoration in helping people adapt to a future with water shortages, while considering the interactions between restoration, climate, and water management throughout. The paper also briefly describes research methodology, then discusses analyses and concludes with a synthesis of all recommendations.

Background

Ecological restoration is a tool for adaptive change because of its interconnected, global nature. It is relevant because it considers not only varying environments, but also differences between people, economies and cultures. This is notwithstanding some challenges within the field. Climate change is global as well, and the connection between water and climate is vital to understanding the current state of the water shortage crisis. Water management is also important to consider because it dictates the use of available water resources, and how those resources are maintained for future generations.

Ecological Restoration

The practice of ecological restoration can be defined, at its simplest, as 'the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed' (Akhtar-Khavari, Cliquet and Telesetsky 2017; SER International Science and Policy Working Group 2004). The concept of restoring degraded environments in general is not new. However, peer-reviewed articles discussing restoration ecology have become more prominent only within the last couple of decades (Clary, Petersen and Young 2005). Ecological restoration stands out as a potentially powerful unifier for adaptive change because of its interconnected, global nature.

At its core, ecological restoration emphasizes the interconnectedness of all things. Aldo Leopold, an ecological scholar, has repeatedly described the significance of copious integrated parts within ecosystems (Leopold 1949). The complexity of relationships within ecosystems exposes the possibility of widespread system failure in the event of significant harm to a constituent part. Within the restoration ecology practice, the complexities of ecosystems are central to operations and varied elements such as composition, development, ecosystem context, security, resiliency, sustainability, and stewardship are all considered.

The Society for Ecological Restoration (SER) is a transnational organization made up of restoration professionals who work to gather knowledge and perspectives from around the world to connect and inform the global community while promoting the practice and science of ecological restoration (SER 2017). In *Ecological Restoration in International Environmental Law,* the authors note the truly global nature of restoration evident in the thousands of people they came across who were working to repair ecosystems in an attempt to gain disappearing ecological values that have been damaged through anthropogenic means (Akhtar-Khavari, Cliquet and Telesetsky 2017). As varied as the numerous restoration projects are, there seems to be a common ability of ecological restoration to reconnect all kinds of communities with each other, as well as with the environment itself. Restoration is not merely a scientific discipline, either. It is even referred to as an 'art and a science' (Apostol and Sinclair 2006). Each project is customized to its location, and each project requires utilization of knowledge from social sciences and input from communities. The practice of ecological restoration considers not only varying environments, but also social influences such as economy and culture. It provides a means of conquering todays greatest ecological issues, while taking into account the differences among people and nations.

Some researchers argue that there is an international responsibility for states to conduct restoration activities. They point to innovative restoration standards introduced in 2016 by the Society for Ecological Restoration Australia (SERA) and suggest that the standards could eventually redefine restoration in environmental law (Akhtar-Khavari, Cliquet and Telesetsky 2017). The SERA is a branch of the Society for Ecological Restoration's international organization. The SERA branch has been globally recognized for their new national standards for restoration, which were implemented by the Australian government. This brings us to the need to redefine restoration.

The changing climate is often a topic of hot debate within the restoration community because of the complications it creates in defining restoration ecology. Paddy Woodworth, a veteran journalist, spent years investigating ecological restoration efforts by conducting interviews and visiting restoration sites around the world. He has described various accounts where the relatively new formation of principles within the restoration movement were challenged due to the consequences of climate change (Woodworth 2015). Riley, an Executive Director at the Waterways Restoration Institute and Advisor of Watershed and Stream Protection/Restoration at the San Francisco Regional Water Quality Control Board, discusses the more traditional definitions of restoration ecology. When discussing the ability of the ecological restoration movement to repair not only ecosystems but also communities and relationships to the environment, she mentions the traditional view in the field that involves returning systems back to a 'historical reference point' (Riley 2016). The purpose of a historical reference point is to attempt to match the repair of a degraded ecosystem with that of the trajectory of the original ecosystem, before disturbance occurred (Clewell, Aronson and Winterhalder 2004). It is the 'historical' aspect of the traditional definition that is commonly challenged today as climate change alters the trajectories of ecosystems.

Additionally, regarding the use of restoration legally, mitigation and restoration are often considered synonymous. However, mitigation is frequently used to compensate for perceived environmental harm that is associated with development rather than assist in the recovery of an ecosystem (Apostol and Sinclair 2006). The most current definitions have been broadened in an attempt to quell disputes, but there have been other suggestions that approach the definition problem in a different way. Palmer and Ruhl suggest attaching clarifiers that identify the relationships and/or differences between specific practices and traditional ecological restoration. They provide examples such as 'mitigation', 'endangered species', 'ecosystem services,' and 'climate resilience restoration' as replacements for the all-encompassing term 'restoration' (Palmer and Ruhl 2015). The authors help to further explain the importance of solving the definition issues. Some projects that are labeled as restoration projects, because there is no clear legal definition for restoration in the United States, may not repair entire complex ecosystems (Palmer and Ruhl 2015). In other words, existing definitions decrease the effectiveness of ecological restoration because they often do not consider the important principles of restoration ecology, such as functionality and self-sustainability.

Climate Change

It is now widely understood that global climate change is caused by increasing amounts of carbon dioxide in the atmosphere, which is facilitated by human use of fossil fuels. The Intergovernmental Panel for Climate Change has reported that not only are there various changes in the climate that can be identified now, but that those and much worse are expected in the future unless big changes are made to curb anthropogenic atmospheric carbon dioxide contributions (IPCC 2007). Correspondingly, in the spring of 2016, the United Nations Environment Programme (UNEP) reported that over 60% of the categories under 'ecosystem services' are currently in decline, and the negative effects of the deteriorating environment on human health contribute to 23% of all deaths on the planet (UNEP 2016). Ecosystem services are essentially the goods and services that the environment provides, and includes things like food production, water production, and climate control.

Climate change influences water availability in a multitude of ways and most ecosystem services rely heavily on the availability of water, which is threatened even at its source. In 2016, an entire drainage basin was shifted (called river piracy) as the result of climate-driven glacier retreat (Shugar et al. 2017). The link between climate change and temperature increases has been well established. Warming temperatures can lead to an increase in precipitation. However, that precipitation falls as rain instead of snow, and high temperatures also result in increased drying of the land in some places, earlier snowmelt in others, changes in evaporation and transpiration, and profound changes in runoff and stream flow (see Appendix A, Fig. 1) (Graham, Parkinson and Chahine 2010). Consequently, food security is threatened by agricultural drought, access to drinking water is extremely unreliable and ecosystems are damaged or destroyed. Degraded environments then contribute to further increases in carbon dioxide build up in the atmosphere because those that might typically sequester carbon, like forests or wetlands, no longer function for their ecosystem services (Pearce and Moran 1994). There have been efforts to research the potential of river piracy, as well as quantify the value that freshwater (and other) systems have in terms of ecosystem services, generally for their protection. Still, the declining health of the earth is an indication that current operations are not working.

Water Management

Therefore, managing water resources is one of the most vital elements of water availability for people and ecosystems today. Water management can be thought of as management of water resource systems that are “combinations of constructed water control facilities and natural, or environmental elements” (Grigg 2005). Additionally, sustainable water management could be defined by including water structures that not only support ecosystem functions, but also meet the needs of society over generations (Poff et al. 2015).

Adaptation to climate change brings a breadth of concerns to mind. There are ecological, organismal and societal fears associated with the consequences of anthropogenic climate change, and a recognition that a failure to adapt on any of those levels could result in an equally wide range of costs (IPCC 2007). Adapting to climate change and water challenges may be accomplished through adaptive management, in addition to water management. Adaptive management, or the process where decision-makers act given some ambiguity regarding the future (Panel on Adaptive Management for Resource Stewardship 2004), intersects water management to form adaptive water management. Adaptive water management, then, can be described as a process where water institutions act given uncertainties, 'through governance systems that are flexible and dynamic' (Pahl-Wostl 2006; Wilder et al. 2010). This is important when considering the role of restoration in future water adaptation because, for people to best prepare for shortages, water must be managed in a sustainable and adaptable way, and that would logically include practices that move to protect or repair valuable water resources.

Methodology

A critical literature review was conducted, over the period of one year, to assess the role of restoration ecology for use as part of an adaptive water shortage strategy with local and global implications. Small-scale textual analyses were performed on specified documents, and conferences and symposiums were attended to augment research and help identify the most current research for water management and ecological restoration. Following exploration into the basics of restoration, climate, and water management, specific themes for more thorough analyses were identified. Those topics are organized below, and their individual methodology is described.

Research was largely focused on investigating ecological restoration overall because, to best answer the question of role of restoration in preparation for changes to water availability in the future, the complexities of ecological restoration on all levels must be considered now. Ecological restoration was further explored by looking into how it connects directly with water resources. The Water Management Conference hosted by the American Water Works Association and the Ecological Restoration Symposium, *Restoration in a Changing Climate: Adapting Practices to Meet Long-Term Goals*, were attended to identify current topics or ideas that could help answer the research questions. Next, the National Restoration Standards developed by the SERA were critically reviewed. The purpose of further study into the Standards is their potential to standardize restorative efforts not only nationally in Australia, but also here in the U.S. and ideally, on the global front eventually. It seemed imperative to assess how the Standards deal with the challenges of defining restoration, in addition to how or if they discuss adaptive management and climate. The Standards were not expected to address water resources specifically but were examined thoroughly for all related topics regardless. How the document addressed these topics helped to comprehend how effective they would be in the face of drastic water shortages.

Additionally, the presence of the Society for Ecological Restoration was further examined. Specifically, the regional and local distributions of the organization were considered. The purpose of further examination of the international group was to establish the type of involvement carried out by a leading restoration organization because, when thinking about actionable water shortage solutions and restoration, the leading organization is essentially responsible for the distribution of knowledge, practices and resources. While the presence of the organization globally is important, it is out of the scope of this project, and an evaluation of activities more locally would help create a foundation for later global comparisons. A more regional and local view of the SER would reveal where the Northwest and Tacoma fit into global restoration efforts. The relationship between the SER and the University of Washington was specifically explored, including an analysis of current restoration programs, for the same reasons. It is important to understand how academic institutions are involved in restoration efforts, and how or if they fit more broadly, into the global arena.

While general climate and water considerations were discussed in the background section and are undeniably important, there is a need to more closely examine climate variation and water sources in the Pacific Northwest as well as Tacoma, Washington for this study because the secondary objective of research was to connect global problems and local actions. To do this, electronic databases were used in conjunction with critical literature review methodology to locate materials related to the desired regional climate projections. Similar methods were used to identify water sources and availability for the city of Tacoma and neighboring areas.

While Tacoma, nestled in the Northwest, might not be considered a location of great concern when it comes to water availability, it could still be important to have adaptive water management strategies in place for future generations. Therefore, as part of the local action aspect of research, it seemed beneficial to study the city of Tacoma's water management plans. Studying the water management plans serves as a case study because it will also reveal the role of restoration in preparing for or dealing with water challenges. Tacoma Water has produced an array of documents for the City of Tacoma pertaining to water resource management. The Water System Plan, Green River Watershed Management Plan, and Green River Habitat Conservation Plan were reviewed for restorative and adaptive measures regarding water availability and use because they were identified as the most relevant documents.

Due to the extensive density of the water management documents, ranging in page length from 12 to over 700, a textual analysis was most effective in examining the material. Language in the documents was evaluated to determine their use of specified terms. The terms (restore/restoration, climate/climate change, adapt/adaptation), were chosen based on their relevance to the research themes (restoration, climate, water management). Thus, distinguishing the use and distribution of terms within the documents would ultimately reveal the role of restoration in water management in Tacoma now, as well as in the future.

Analysis

Ecological Restoration

On separate occasions, presenters at both the Water Management Conference and Ecological Restoration Symposium in Seattle, Washington discussed some of the current methods in ecological restoration that deal with repairing water resources. The Water Management Conference brought professionals from around the country to discuss sustainable water management strategies. At this conference, restoration was not a common topic but was discussed occasionally in terms of source water protection and watershed health. Overall, restoration was discussed sparingly. The Water Management Conference presenters were attentive to drought prediction and warning systems, integrated management, climate resiliency, and current successes or challenges to water management. Conversely, the Ecological Restoration Symposium was designed to introduce local restoration projects that specifically highlight issues in restoration and climate adaptation. In general, presenters at this event focused on discussing changes in restoration implementation in the face of a changing climate. The one element that was generally missing was freshwater. However, there were other resources that consider freshwater restorations more directly.

The literature on freshwater restorations is quite varied. For example, restoration is frequently used to improve the conditions of freshwater streams, rivers and lakes. Repair of riparian and aquatic habitats can improve water quality, enhance ecosystem function and in the setting of urban stream restoration, replace a resource that connects people to each other and the environment (Riley 2016). Additionally, ecological restoration plays a role in the hydrologic cycle in that it can encourage water catchment and soil fertility. For example, in locations where evaporation and transpiration are higher than that of precipitation (e.g. deserts), restoration can result in ecosystems that are more resilient, productive, and better able to supply dependable water resources (Abella et al. 2011). Similarly, in locations where water retention is a problem and excessive invasive species are present, ecological restoration would replace invasive plants with native plants that require less water because native species are often well adapted to the conditions.

Clearly, ecological restoration can improve water conditions. While the Water Management Conference only briefly mentioned ecological restoration, some speakers and practitioners did stress the importance of source water protection and watershed health. Both watershed health and protection of water sources can (and should) involve ecological restoration. Therefore, restoration can be used to protect the health of water sources and watersheds, while also improving elements like water quality, ecosystem function, water storage, soil health, etc. Interestingly, even though there is documented scientific proof that ecological restoration can help with water challenges, there are widespread inconsistencies in discussions, documentation and programs regarding the interconnectedness between the big three: restoration, climate change and water management (or the restoration-climate-water nexus). The Water Management Conference did not prioritize restoration but drought, water management and climate were prioritized. While those are important topics, ecological restoration is clearly deeply connected to each, and so should also be prioritized. Similarly, the Ecological Restoration Symposium ranked restoration and climate adaptation highly, but the link between them and water resources (or management) was not clearly established. Following research into the types of aquatic restoration, the National Restoration Standards were studied and analyzed.

The Society for Ecological Restoration Australasia released the National Restoration Standards with the goal to encourage all types of restoration projects throughout Australia (SERA 2017). In justifying the need for restoration Standards, the SERA pointed out the growing support and use of restoration in Australia and the difficulties that go along with a lack of standard definitions and principles (Standards Reference Group 2017). As part of an attempt to smooth out some of these issues, in addition to the upfront definitions presented in the opening of the Standards, the SERA also outlines the values of ecological restoration and the basics necessary to design, implement and monitor project development (Appendix B, Fig. 1-4 include examples of values, principles, and progress assessments). The SERA describes the design of the Standards as 'generic' and 'compatible' so that they can be used in conjunction with more specific or existing strategies (Standards Reference Group 2017). Even while remaining broad in some guidelines and definitions, the Standards tackle issues related to climate change, adaptive processes, and push the use of adaptive management specifically when designing restoration projects.

The Standards classify ecological restoration using the definition provided by the SER: 'the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed' (SER International Science and Policy Working Group 2004; Standards Reference Group 2017). It distinguishes between full ecosystem recovery, partial recovery, and rehabilitation. Classifications for type of restoration depends on whether the ecosystem is repaired entirely (full), repaired partially but without all function (partial), or minimally recovered native plant life, animal life, or ecosystem function (rehabilitation) (Standards Reference Group 2017). While the goal for restoration is the highest level of ecosystem recovery possible, the document includes best practices for cases where there is irreversible environmental degradation. In the face of increasing rates of climate change, there will be whole ecosystems destroyed when there is no way for migration to occur due to fragmentation of ecosystems, such as the case with many aquatic and temperate ecosystems. Some species may survive or adapt if they are not restricted by fragmentation and are able to migrate or adapt genetically (Standards Reference Group 2017). The Standards suggest restoration modifications that could help species adapt as well. The document discusses adaptation further under adaptive management considerations.

Adaptive management in the National Restoration Standards is clearly valued and includes an emphasis on ecosystem monitoring. The SERA claims that “adaptive management can and should be a standard approach for any ecological restoration project irrespective of how well-funded that project may be”, and monitoring is a way to learn from restorative actions so that future actions can be adapted or improved (Standards Reference Group 2017). In conjunction with adaptive management strategies, the national document addresses ways in which practitioners can incorporate climate considerations early in the restoration planning stage. The SERA encourages the use of climate predictions to identify how climate change may affect ecosystems, using web-based tools for example, and suggest coordination with researchers for the best possible predictions of species responses to climate change and fragmentation (Standards Reference Group 2017). The National Restoration Standards provide numerous examples of the adaptive strategies possible during ecological restoration. Some believe there are global implications for these adaptive strategies if restoration efforts are organized through a governance structure, such as the law (Akhtar-Khavari, Cliquet and Telesetsky 2017). The Standards have specifically been identified as potentially significant on a larger scale, or outside of Australia, because of their ability to standardize best practices for restoration. Therefore, it is possible that defining standards could lead to redefining restoration for legal purposes, and subsequently help to “negotiate and implement rules to create a positive legal trajectory for progress towards long-term ecological restoration outcomes” (Akhtar-Khavari, Cliquet and Telesetsky 2017). However, the document did not specifically address aquatic restoration or water resources.

The role of water resources within the National Restoration Standards was not prominent, but the value in the Standards comes more from their ability to circulate a practice that improves the condition of aquatic environments. Clearly, the SERA took care to define ecological restoration through significant guidelines, definitions, and management strategies. The organizational branch chose to separate ecological restoration into 'restoration' and sub-restoration categories. Some legitimacy may be lost when the term 'restoration' is dropped because it carries so much meaning (interconnectedness, stewardship, community engagement). Additionally, partial recovery and rehabilitation are broad distinctions (as they were meant to be), that do not provide as much clarity in terms of identifying the relationships between specific practices as using terms like 'mitigation restoration' or 'climate resilience restoration' might. Still, the National Restoration Standards can regulate restoration on various levels by providing standardized definitions to nations, cities and townships. Circulating the document on a grand scale would improve the water situation further by distributing an official document that fully considers climate and adaptive management. After exploring the Standards and discovering how they address issues with definitions, climate, and adaptive management the presence of the SER in the Northwest was studied.

The Society for Ecological Restoration has an active Northwest chapter that, among many things, works to further develop ecological restoration through 'technical education, training, and knowledge' (Akhtar-Khavari, Cliquet and Telesetsky 2017). The SER-NW chapter sponsors conferences and other means of information sharing throughout the region. The SER offers a Student Association Program that currently includes student groups in the U.S. and Canada and aims to gather those interested in ecological restoration and provide them resources, as well as involve them in conferences, events, and 'in SER's global network' (SER 2018). The UW's Seattle campus is a part of the program with 25 registered members, but the University's Tacoma campus is not. There are about 22 registered student organizations at different universities and colleges. The registration process involves filling out an information packet online and paying an annual fee, and in return the student association is officially recognized by the SER in addition to benefits like free Society memberships, subscriptions, and networking benefits (SER 2018). Associated with ecological restoration but not the SER, the University of Washington (UW) has an ecological restoration program, the University of Washington Restoration Ecology Network (UW-REN), that is a tri-campus program in which students work through all the phases of a restoration to earn a Restoration Ecology certificate (Akhtar-Khavari, Cliquet and Telesetsky 2017; University of Washington Tacoma 2018).

The Northwest Chapter of the SER was examined because it would help to establish the type of involvement carried out locally by an organization that has clear international involvement. There is clearly a need to more fully engage organizations like the SER in academic and legal settings since ecological restoration has quickly exceeded existing instructive and policy development (Apostol and Sinclair 2006). The results show that the Northwest branch provides a variety of resources, opportunities, and certifications to members and students in the region that could potentially be used to further the study of aquatic or climate resilient restoration. After thoroughly studying ecological restoration through conferences, the Standards, and the SER, focus was turned to climate considerations.

Climate Change

The Pacific Northwest is not always in excess of fresh water, contrary to popular belief. In 2015 a drought that began in California a few years earlier spread throughout the West Coast to include Washington and Oregon, resulting in emergency conservation efforts (Wise 2016). Around the same time this severe drought was coming to a pinnacle, Tacoma Power requested a report from the Climate Impacts Group. The report was meant to show the impacts of climate change on hydropower sources for the area and included temperature, distribution, and energy projections for the future (Lee, Mauger and Whitely 2015). The projections were prepared for climatic and hydrologic conditions expected for the 2030s. Study findings revealed average annual temperatures for Tacoma are expected to rise between 2.8 – 3.3°F, and increasing temperatures are expected to result in more rain during the winter, decreased snow accumulation, and ultimately less available water in the summer because of less snowmelt to contribute to flows (Lee, Mauger and Whitely 2015). Additionally, the Columbia River, which produces between 70 and 80% of the Pacific Northwest's (USBR 2011a), and more than 50% of Tacoma's energy supply annually, is also expected to experience impacts on hydropower energy production given changes in temperatures, snowfall and streamflow (Lee, Mauger and Whitely 2015).

Much of the drinking water for Puget Sound originates from rivers coming down from the Cascades. Reservoirs are found along the rivers that store water from snowmelt in the spring that is used throughout the summer and fall for 'municipal and environmental' purposes (Palmer, Polebitski and Traynham 2010). Water for the City of Tacoma comes primarily from the Green River gravity supply system that runs from the Cascade Mountains to Tacoma where it is distributed to more than 300,000 people in both Pierce and King counties or stored in reservoirs (Fig. 2; Tacoma Public Utilities [TPU] 2018). However, some projections estimate that, under current operations, Tacoma's reservoirs will refill in the spring 50% less than historically by 2075 (Palmer, Polebitski and Traynham 2010). While Tacoma Water can supply residents with well water or groundwater if necessary, there have also been joint efforts to store more water. The Green River, for a cooperative effort between Tacoma Water, the Regional Water Supply System and the U.S. Army Corps of Engineers, is used as the source for the Howard Hanson Additional Water Storage Project aimed at increasing the supply of water behind the dam for municipal use in the area (TPU 2018).

The investigation of climate change in the Pacific Northwest and the Tacoma area suggest that role of restoration in helping to adapt to water challenges is more relevant and important than expected. Even Tacoma cannot escape the negative effects of climate change like drought, energy discrepancies, and glacial melt. More concerning is the potential effects of temperature increases in this region. It is encouraging to see that there have been efforts made to store water in the region, and impressive documents complied in an effort to manage and conserve water resources.

Water Management

Tacoma Water has an array of complex and detailed documents regarding the management of water resources. Out for public review currently (until 22 June 2018), a Water System Plan has been updated for the year 2018 with the overall purpose to help manage and maintain water resources (Tacoma Water 2018). In addition, the Green River Watershed

Management Plan and Green River Habitat Conservation Plan were useful to examine for their use of the restoration, climate and water management strategies.

Within the substantial Water System Plan, the draft of which was reviewed for this study, are sections dedicated to adaptive and restorative strategies. Some of those sections include topics in water conservation, water quality, and system resiliency. Under Water Conservation, Tacoma Water describes water conservation goals, such as reducing certain watering practices during summer months, and the programs involved in reaching those goals (Tacoma Water 2018). Each of the plans overlap to some extent, and the Water System Plan includes a brief description of both the Watershed Management and Habitat Conservation Plan, which are also lengthy individual documents.

In assessing the use of adaptive and restorative strategies, it was discovered that the Water System Plan focused more on overall adaptive strategies, while the Habitat Conservation Plan (the separate document) contained most of the information on restorative practices. The Water System Plan addressed adaptation in its discussions of conservation and resiliency. For resiliency, potential climate change influences on water availability were briefly described (Tacoma Water 2018). However, an ongoing resiliency study has not developed mitigation strategies for climate change because ‘a number of strategies employed for other risks can apply to climate change as well due to the similar nature of impacts’ (Tacoma Water 2018). Within the 192-page Water System Plan document, ‘climate change’ was mentioned ten times, all in association with resiliency. Meanwhile, ‘restore/restoration ’and ‘adapt/adaption’ were each used less than five times.

Under the Habitat Conservation Plan and other environmental agreements, Tacoma Water maintains and monitors restoration projects. The extensive Habitat Conservation Plan describes the purpose of habitat conservation, legal requirements, animal species information, monitoring, and research all while it prioritizes the repair of fisheries along the Green River and discusses the restoration activities of parties other than Tacoma (Tacoma Water 2001). This 733-page document (including appendices) uses the word 'restoration' 190 times, 'restore' 36 times, 'adapt' 72 times, 'adaptation' 14 times, and 'climate change' zero times. Out of the 72 times 'adapt' was used, 55 of those refer to 'adaptive management'. Adaptive management is used frequently in this document when discussing frameworks for the protection of fish and wildlife, as well as in discussions of monitoring and research (Tacoma Water 2001). Restoration is not defined directly, and there is no mention of the University of Washington outside of citations. The 298-page Watershed Management Plan mentions 'climate' twice, but there are no references to 'climate change'. There are also no references to 'adapt/adaptation' or 'restore', but 14 references to 'restoration'.

While the Water System Plan had sections dedicated to adaptive and restorative strategies and the Habitat Conservation Plan discussed restorative practices in detail, the documents overall shared a similar issue with that of other documentation and conferences. Tacoma Water has prepared some excellently detailed documents that provide a framework for water management in the city. They could, however, use more cohesion and deliberate acknowledgement of the restoration - climate - water management nexus. The Habitat Conservation Plan is so organized and detailed, but curiously did not mention climate change at all, or describe the practice of restoration. Similarly, a document meant to be an overarching plan for water management, the Water System Plan, scant mentions climate change or restoration. There is consensus regarding the looming devastation of climate change, and its impact on water resources. Therefore, the documentation and plans that dictate water management should reflect that fact to best prepare people for water challenges in the future.

Conclusion

South Africa and the southwestern United States have something significant in common. Both regions are struggling to keep water available to their citizens, and desalination is a quickly growing option that provides more water (Slaughter 2018; Wilder et al. 2010). Harmful ecological effects from desalination have been difficult to monitor (Roberts, Johnston and Knott 2010), and it is interesting that desalination use has been growing so quickly given that the technological fix for one ecological problem (water shortage) could cause another ecological problem that we are not yet fully aware of. The objective of this research was to explore the practice of restoration ecology to assess its role in helping people adapt to a future with water shortages. To do this, restoration ecology, climate, and water management, on their own and in relation to each other, were thoroughly studied. Based on research, the critical interventions identified for improving the water shortage challenge include adopting the SERA's National Restoration Standards, emphasizing climate change adaptation through restoration, and establishing collaboration between the SER and the University of Washington.

This is because the Society for Ecological Restoration Australasia's National Restoration Standards are significant on a larger scale, outside of Australia alone. The pliable nature of ecological restoration allows it to be applied to any project of any size in any nation, and if the Standards were circulated locally, regionally and globally, then the projects taking place worldwide would be using restoration's best practices. Innovative standards could not only improve the efficiency of ecological restoration on a national scale, but they could be a basis for global standards (Akhtar-Khavari, Cliquet and Telesetsky 2017). The standards help to effectively manage ecological communities, ensure science is used to support actions, encourage partnerships, and guide recovery of ecological systems (Standards Reference Group 2017). This is an amazing feat for a single document and should be shared with the world. Ideally, the National Restoration Standards would be implemented nationally in the U.S. However, ecological concerns are not incredibly salient among political leaders in the United States currently. Though, the Standards could be implemented at any level, including regionally and locally.

In addition, emphasis on climate change adaptation through restoration will help people prepare for the future because the water management plans for the city of Tacoma, if bold, proactive and cohesive, would better prepare people for uncertainties in the future than the existing plans. Research shows that there has been drought in the past (Wise 2016), and that Tacoma will be directly influenced by climate change in the future (Lee, Mauger and Whitely 2015). Yet, while Tacoma has many substantial documents guiding water management for the city, none of them fully addresses the intersection of ecological restoration, climate change and water management. To emphasize climate change adaptation through restoration and acknowledge the restoration-climate-water nexus, the SERA's National Restoration Standards should be adopted on a local level. The combination of water management documents for the city of Tacoma and restoration Standards would adequately address the nexus and work to not only better prepare the city for changes to water availability, but also help to implement the first intervention. There is evidence that local actions can influence global change (Wilbanks and Kates 1999), and when influential states like Washington start a trend there is a higher chance that the trend will propagate throughout the United States and even the rest of the world. It is not hard to imagine then, that local adoption of restoration Standards would help to form the foundation for global Standards later, in addition to contributing to more effective aquatic ecological restoration in Tacoma.

Finally, ecological restoration could help with water challenges even more if the University of Washington Tacoma collaborated with the SER because the SER's Northwest Chapter and Student Association Program gather those interested in ecological restoration and provides them with resources, involves them in conferences and events, and provides them access to a global network (SER 2018). Water availability is a growing global problem, but students and faculty on the University of Washington Tacoma campus would have more opportunities to test theories, share information, and work to improve global problems starting with local actions if this collaboration existed. Implementation would involve the establishment of a SER student association at UWT. The University and faculty in the Restoration Ecology program should strongly encourage students in coming years to organize a student association and seek out collaboration with the Northwest SER.

All the recommendations support, improve or share the benefits of ecological restoration while improving the outlook of water shortages for people both locally and globally. However, there were limitations to this study, and there are always possible complications in implementing recommendations. The field of restoration ecology is vast, and even one year dedicated to studying the intricacies was not enough. Each section of this paper could have been made into a separate study, and much more time and effort should be put into exploring and prioritizing the restoration-climate-water nexus. For the first and second recommendations, there may not be enough time before the newest water management documents are closed for public review to include the changes. Therefore, it could be a longer process than is ideal to include the restoration Standards locally and emphasize climate change adaptation through restoration in water management documents for Tacoma. Additionally, if students and faculty at the University of Washington Tacoma do not make an effort collaborate with the SER, they could be missing an opportunity to collaborate with an international organization and influence global change with local actions. However, this paper provides an opportunity.

It is an opportunity to act. Ecological restoration provides a means of improving the water shortage issue on a large scale through Standards that are applicable everywhere, adaptable practices that repair damage, and organizations that support students and research. Water managers should be pressured to address the ecological restoration - climate change - water management nexus, and to standardize restoration practices through adoption of the SERA's National Restoration Standards. Students should be inspired to connect to international organizations that have the power to connect people, ideas, and resources. My hope is that this paper is a starting point from which to move forward and build so that future generations have access to fresh water, and a practice that moves to repair environments and connect people.

References

Abella SR, Craig DJ, Smith SD, Newton AC. 2011. Identifying native vegetation for reducing exotic species during the restoration of desert ecosystems. Restoration Ecology [Internet]. [cited 28 May 2018]; 20(6): 781-787. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/j.1526-100X.2011.00848.x

Aguilar-Barajas I, Sisto NP, Magana-Rueda V, Ramirez AI, Mahlknecht J. 2016. Drought policy in Mexico: a long, slow march toward an integrated and preventive management model. Water Policy [Internet]. [cited 20 May 2018]; 18(S2): 107-121. Available from: http://wp.iwaponline.com/content/18/S2/107

Akhtar-Khavari A, Cliquet A, Telesetsky A. 2017. Ecological restoration in international environmental law. New York (NY): Routledge. 328 p.

Apostol D, Sinclair M. 2006. Restoring the Pacific Northwest: the art and science of ecological restoration in Cascadia. Washington (DC): Island Press. 508 p.

Clary JJ, Petersen DA, Young TP. 2005. The ecology of restoration: historical links, emerging issues and unexplored realms. Ecology Letters [Internet]. [cited 20 May 2018]; 8(6): 662-673. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/j.1461-0248.2005.00764.x

Clewell A, Aronson J, Winterhalder K. 2004. The ser international primer on ecological restoration [Internet]. Society for Ecological Restoration International Primer on Ecological Restoration; [cited 20 May 2018]. Available from: http://www.ser.org/content/ecological_restoration_primer.asp#3

Graham S, Parkinson C, Chahine M. 2010. Water cycle [Internet]. Greenbelt (MD): The Earth

Observatory; [cited 28 May 2018]. Available from: https://earthobservatory.nasa.gov/Features/Water/

Grigg NS. 2005. Water resources management. Water Encyclopedia [Internet]. [cited 20 May 2018]. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/047147844X.wr241

IPCC [Intergovernmental Panel on Climate Change]. 2007. Fourth assessment report [Internet]. Geneva (Switz): Intergovernmental Panel on Climate Change; [cited 24 May 2018]. Available from: http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

Lee S-Y, Mauger G, Whitely Binder L. 2015. Climate change impacts on Tacoma power watersheds [Internet]. Seattle (WA): University of Washington Climate Impacts Group; [cited 24 May 2018]. Available from: https://cig.uw.edu/news-and-events/publications/climate-change-impacts-on-tacoma-power-watersheds/

Leopold A. 1949. The land ethic. In: A sand county almanac. Oxford (UK): Oxford University Press, Inc. p. 237-261.

Onishi N, Sengupta S. 2018. Dangerously low on water, Cape Town now faces ‘day zero’ [Internet]. New York (NY): New York Times Company; [cited 24 May 2018]. Available from: https://www.nytimes.com/2018/01/30/world/africa/cape-town-day-zero.html

Pahl-Wostl C. 2006. Transitions towards adaptive management of water facing climate and global change. Water Resources Management [Internet]. [cited 28 May 2018]; 21(1): 49-62. Available from: https://link.springer.com/article/10.1007/s11269-006-9040-4

Palmer MA, Ruhl JB. 2015. Aligning restoration science and the law to sustain ecological infrastructure for the future. Frontiers in Ecology and the Environment [Internet]. [cited 28 May 2018]; 13(9): 512-519. Available from: https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/150053

Palmer R, Polebitski A, Traynham L. 2010. Impacts of future climate conditions and forecasted population growth on water supply systems in the Puget Sound region. Water Resources Planning and Management [Internet]. [cited 28 May 2018]; 137(4). Available from: https://ascelibrary.org/doi/10.1061/(ASCE)WR.1943-5452.0000114

Panel on Adaptive Management for Resource Stewardship. 2004. Adaptive management for water resources project planning. Washington (DC): The National Academies Press.

Pearce D, Moran D. 1994. The economic value of biodiversity. London (UK): Earthscan from Routledge.

Poff NL, Brown CM, Grantham TE, Matthews JH, Palmer MA, Spence CM, Wilby RL, Haasnoot M, Mendoza GF, Dominique KC, Baeza A. 2015. Sustainable water management under future uncertainty with eco-engineering decision scaling. Nature Climate Change [Internet]. [cited 28 May 2018]; 6:25-34. Available from: https://www.nature.com/articles/nclimate2765

Riley A. 2016. Restoring neighborhood streams: Planning, design, and construction. Washington (DC): Island Press.

Roberts DA, Johnston EL, Knott NA. 2010. Impacts of desalination plant discharges on the marine environment: a critical review of published studies. Water Research [Internet]. [cited 28 May 2018]; 44(18): 5117-5128. Available from: https://www.sciencedirect.com/science/article/pii/S0043135410002903

SER International Science and Policy Working Group. 2004. The ser international primer on ecological restoration. Restoration Ecology [Internet]. [cited 28 May 2018]; 2(2): 132-133. Available from: https://www.ctahr.hawaii.edu/littonc/PDFs/682_SERPrimer.pdf

Shugar DH, Clague JJ, Best JL, Schoof C, Willis MJ, Copland L, Roe GH. 2017. River piracy and drainage basin reorganization led by climate-driven glacier retreat. Nature Geoscience [Internet]. [cited 20 May 2018]; 10(1): 370-375. Available from: https://www.nature.com/articles/ngeo2932

Slaughter A. 2018. Desalination? Africa should rather manage its water resources better. SABI Magazine [Internet]. [cited 28 May 2018]; 10(3): 28. Available from: https://journals.co.za/content/journal/10520/EJC-ca90a51a7

Society for Ecological Restoration. 2017. Society for ecological restoration [Internet]. Washington (DC); [cited 20 May]. Available from: http://www.ser.org/

Society for Ecological Restoration. 2018. Ser [Internet]. Washington (DC): Society for Ecological Restoration; [cited 28 May 2018]. Available from: https://www.ser.org/default.aspx

Standards Reference Group SERA. 2017. National standards for the practice of ecological restoration in Australia [Internet]. Washington (DC): Society for Ecological Restoration Australasia; [cited 2018 May 20]. Available from: www.seraustralasia.com

Tacoma Power. 2017. Integrated resource plan [Internet]. Tacoma (WA): Tacoma Power –

Tacoma Public Utilities; [cited 28 May 2018]. Available from: https://www.mytpu.org/file_viewer.aspx?id=64787

Tacoma Public Utilities [TPU]. 2018. Tacoma public utilities [Internet]. Tacoma (WA): Tacoma Public Utilities. [cited 28 May 2018]. Available from: https://www.mytpu.org/

Tacoma Water. 2001. Tacoma water habitat conservation plan: green river water supply operations and watershed protection [Internet]. Tacoma (WA): Tacoma Water - Tacoma Public Utilities. [cited 28 May 2018]. Available from: https://www.mytpu.org/files/library/habitat-conservation-plan_002.pdf

Tacoma Water. 2018. Water home [Internet]. Tacoma (WA): Tacoma Water – Tacoma Public Utilities. [cited 28 May 2018]. Available from: https://www.mytpu.org/tacomawater/

United Nations Environment Programme [UNEP]. 2016. UN environment annual report 2016 [Internet]. Nairobi (Kenya): UNEP. [cited 28 May 2018]. Available from: http://web.unep.org/annualreport/2016/

University of Washington Tacoma [UWT]. 2018. University of Washington Tacoma [Internet]. Tacoma (WA): University of Washington Tacoma. [cited 28 May 2018]. Available from: http://www.tacoma.uw.edu/

USBR. 2011a. Secure water act section 9503(c) – reclamation, climate change and water, report to congress. Washington (DC): US Bureau of Reclamation.

Wilbanks TJ, Kates RW. 1999. Global change in local places: how scale matters. Climatic Change [Internet]. [cited May 28 2018]; 43(3): 601-628. Available from: https://link.springer.com/article/10.1023/A:1005418924748

Wilder M, Scott CA, Pablos NP, Varady RG, Garfin GM, McEvoy J. 2010. Adapting across boundaries: climate change, social learning, and resilience in the U.S.-Mexico Border Region. Annals of the Association of American Geographers [Internet]. [cited 28 May 2018]; 100(4). Available from: https://www.tandfonline.com/doi/abs/10.1080/00045608.2010.500235

Wise EK. 2016. Five centuries of U.S. west coast drought: occurrence, spatial distribution, and associated atmospheric circulation patterns. Geophysical Research Letters [Internet]. [cited 28 May 2018]; 43(9). Available from: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL068487

Woodworth P. 2015. Our once and future planet: Restoring the world in the climate change century. Chicago (IL): The University of Chicago Press.

Appendix A

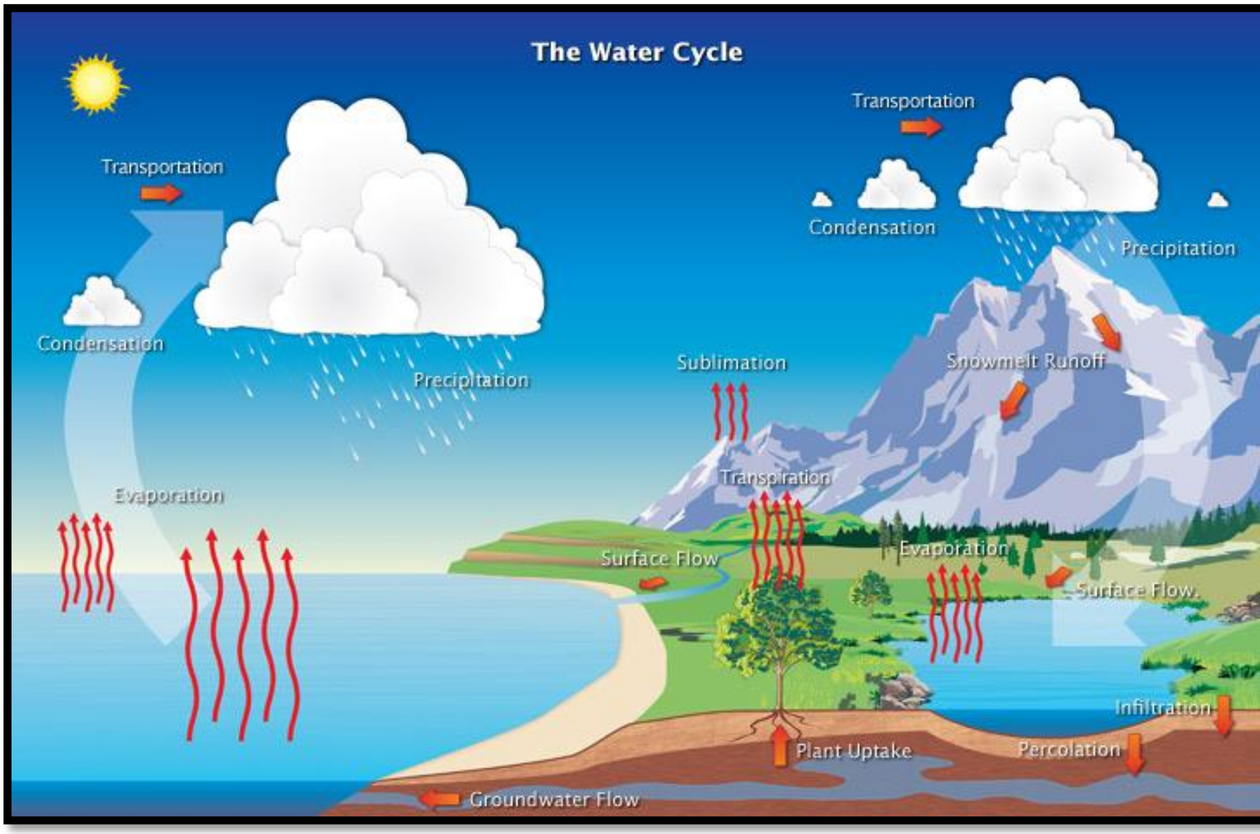

Figure 1. Warming temperatures lead to an increase in precipitation as rain, rather than snow (Graham, Parkinson and Chahine 2010).

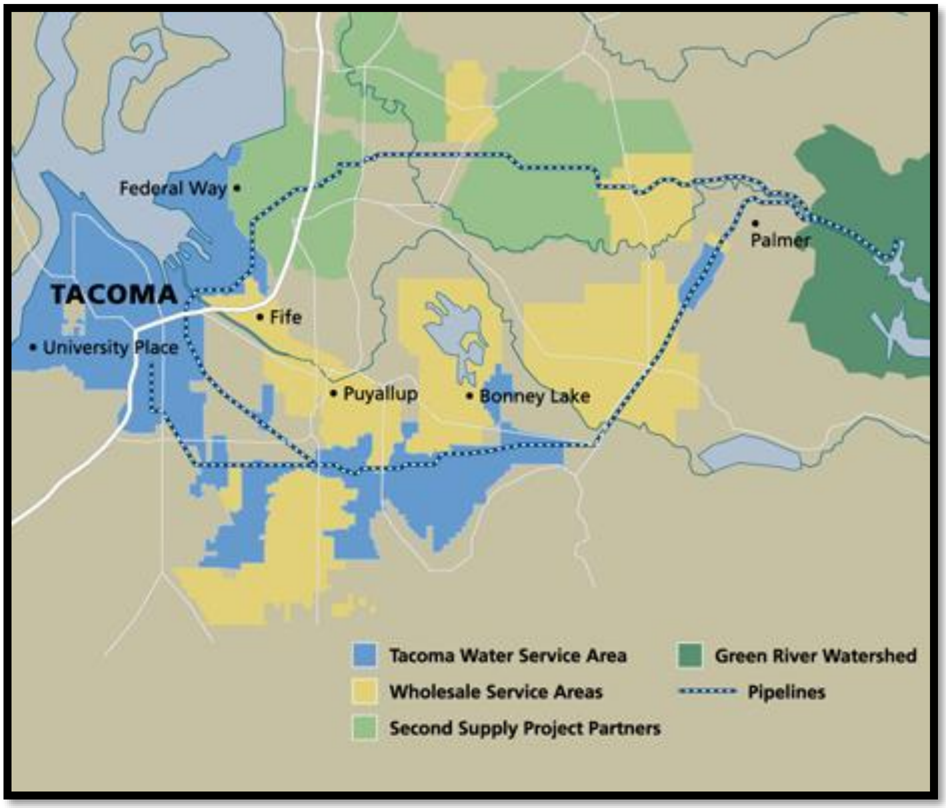

Figure 2. Map depicting the Green River watershed, pipelines, and service area for Tacoma Water (Tacoma Water 2018).

Appendix B

First order

Ecological restoration:

- **Supports and is modelled on indigenous ecosystems and does not cause further harm.** Australia contains large tracts of relatively intact land and water ecosystems, which represent an invaluable natural heritage. Appreciation of the long history of evolution of organisms interacting with their natural environments underlies the ethic of ecological restoration within the Australian context.
- **Is aspirational.** The ethic of ecological restoration is to seek the highest and best conservation outcomes for all ecosystems. Even if it takes long timeframes, full ecological restoration should be the goal wherever it may be ultimately attainable and desirable. Where full ecological restoration is clearly not attainable or desirable, continuous improvement in the condition of ecosystems and substantial expansion of the area available to nature conservation is encouraged.
- **Is universally applicable and practiced locally with positive regional and global implications.** It is inclusive of aquatic and terrestrial ecosystems, with local actions having regional and global benefits for nature and people.
- **Reflects human values but also recognises nature's intrinsic values.** Ecological restoration is undertaken for many reasons including our economic, ecological, cultural and spiritual values. Our values also drive us to seek to repair and manage ecosystems for their intrinsic value, rather than for the benefit of humans alone. In practising ecological restoration, we seek a more ethical and satisfying relationship between humans and the rest of nature.
- **Is improved by rigorous, relevant and applicable knowledge drawn from a dynamic interaction between science and practice.** All forms of knowledge, including knowledge gained from science, nature-based cultures and restoration practice are important for designing, implementing and monitoring restoration projects and programs. Results of practice can be used to refine science; and science used to refine practice. Primary investment in practice-applicable research and development increases the chance of restoration success and underpins regulatory confidence that a desired restoration outcome can be achieved.
- **Is not a substitute for sustainably managing and protecting ecosystems in the first instance.** The promise of restoration cannot be invoked as a justification for destroying or damaging existing ecosystems because functional natural ecosystems are not transportable or easily rebuilt once damaged and the success of ecological restoration cannot be assured.

Figure 1. First order values and principles underpinning ecological restoration, from the Society for Ecological Restoration Australasia's National Restoration Standards (Standards Reference Group SERA 2017).

Second order

Successful ecological restoration depends upon:

Ecological

- **Addressing causes at multiple scales to the extent possible**. Degradation will continue to undermine restoration inputs unless the causes of degradation are addressed or mitigated. The range of anthropogenic threats include over-utilisation, clearing, erosion and sedimentation, pollution, altered disturbance regimes, reduction and fragmentation of habitats and invasive species. All these threats are capable of causing ecosystem decline in their own right, and can be exacerbated when combined, particularly over long time frames. Habitat loss and fragmentation, in particular, exacerbates the threats to biodiversity from climate change.
- **Recognising that restoration initiates a process of natural recovery.** Re-assembling species and habitat features on a site invariably provides just the starting point for ecological recovery; the longer term process is performed by the organisms themselves. The speed of this process can sometimes be increased with greater levels of resourcing.
- **Recognising that undesirable species can also be highly resilient to the disturbances that accompany restoration,** with sometimes unpredictable results as competition and predator-prey relationships change. Invasive species, for example, can intensify or be replaced with other invasives without comprehensive, consistent and repeated treatment.
- **Taking account of the landscape/aquatic context and prioritising resilient areas.** Sites must be assessed in their broader context to adequately assess complex threats and opportunities. Greatest ecological and economic efficiency arises from improving and coalescing larger and better condition patches and progressively doing this at increasingly larger scales. Position in the landscape/aquatic environment and degree of degradation will influence the scale of investment required.
- **Applying approaches best suited to the degree of impairment.** Many areas may still have some capacity to naturally regenerate, at least given appropriate interventions; while highly damaged areas might need rebuilding 'from scratch'. It is critical to consider the inherent resilience of a site (and trial interventions that trigger and harness this resilience) prior to assuming full reconstruction is needed (Box 2).
- **Addressing all biotic components.** Terrestrial restoration commonly starts with re-establishing plant communities but must integrate all important groups of biota including plants and animals (particularly those that are habitat-forming) and other biota at all levels from micro—to macro-organisms. This is particularly important considering the role of plant-animal interactions and trophic complexity required to achieve the reinstatement of functions such as nutrient cycling, soil disturbance, pollination and dispersal. Collaboration between fauna and plant specialists is required to identify appropriate scales for on-ground works and to ensure the appropriate level of assistance is applied to achieve recovery.
- **Addressing genetic issues.** Where habitats and populations have been fragmented and reduced below a threshold/minimum size, the genetic diversity of plant and animal species may be compromised and inbreeding depression may occur unless more diverse genetic material is reintroduced from larger populations, gene flow reinstated and /or habitats expanded or connected.

Figure 2. Second order values and principles underpinning ecological restoration, from the Society for Ecological Restoration Australasia's National Restoration Standards (Standards Reference Group SERA 2017).

Logistical

- **Knowing your ecosystems and avoiding past mistakes.** Success can increase with increased working knowledge of (i) the target ecosystem's biota and abiotic conditions and how they establish, function, interact and reproduce under various conditions including anticipated climate change; and (ii) responses of these species to specific restoration interventions tried elsewhere.
- **Gaining the support of stakeholders**. Successful restoration projects have strong engagement with stakeholders including local communities, particularly if they are involved from the planning stage. Prior to expending limited restoration resources, potential benefits of the restored ecosystem to the whole of society must be explicitly examined and recognised and it must be previously agreed that the restored ecosystem will be the preferred long-term use. This outcome is more secure when there are appreciable benefits or incentives available to the stakeholders; and where stakeholders are themselves engaged in the restoration effort.
- **Taking an adaptive (management) approach.** Ecosystems are often highly dynamic, particularly at the early stages of recovery and each site is different. This not only means that specific solutions will be necessary for specific ecosystems and sites; but also that solutions may need to be arrived at after trial and error. It is therefore useful to plan and undertake restoration in a series of focused and monitored steps, guided by initial prescriptions that are capable of adaptation as the project develops.
- **Identifying clear and measurable targets, goals and objectives.** In order to measure progress, it is necessary to identify at the outset how you will assess whether you have achieved your restoration outcomes. This will not only ensure a project collects the right information but it can also better attune the planning process to devise strategies and actions more likely to end in success (Box 3 and Appendix 4).
- **Adequate resourcing.** Budgeting strategies need to be identified at the outset of a project and budgets secured. When larger budgets exist (e.g. as part of mitigation associated with a development) restoration activities can be carried out over shorter time frames. Smaller budgets applied over long time-frames can be highly effective if works are limited to areas that can be adequately followed-up within available budgets before expanding into new areas. Well-supported community volunteers can play a valuable role in improving outcomes when budgets are limited.
- **Adequate long-term management arrangements.** Secured tenure, property owner commitment and long-term management will be required for most restored ecosystems, particularly where the causes of degradation cannot be fully addressed. Continued restoration interventions aid and support this process as interactions between species and their environment change over time. It can be helpful to identify likely changes in species, structure and function over the short, medium and longer term duration of the recovery process.

Figure 3. Second order logistical values and principles of ecological restoration, from the Society for Ecological Restoration Australasia's National Restoration Standards (Standards Reference Group SERA 2017).

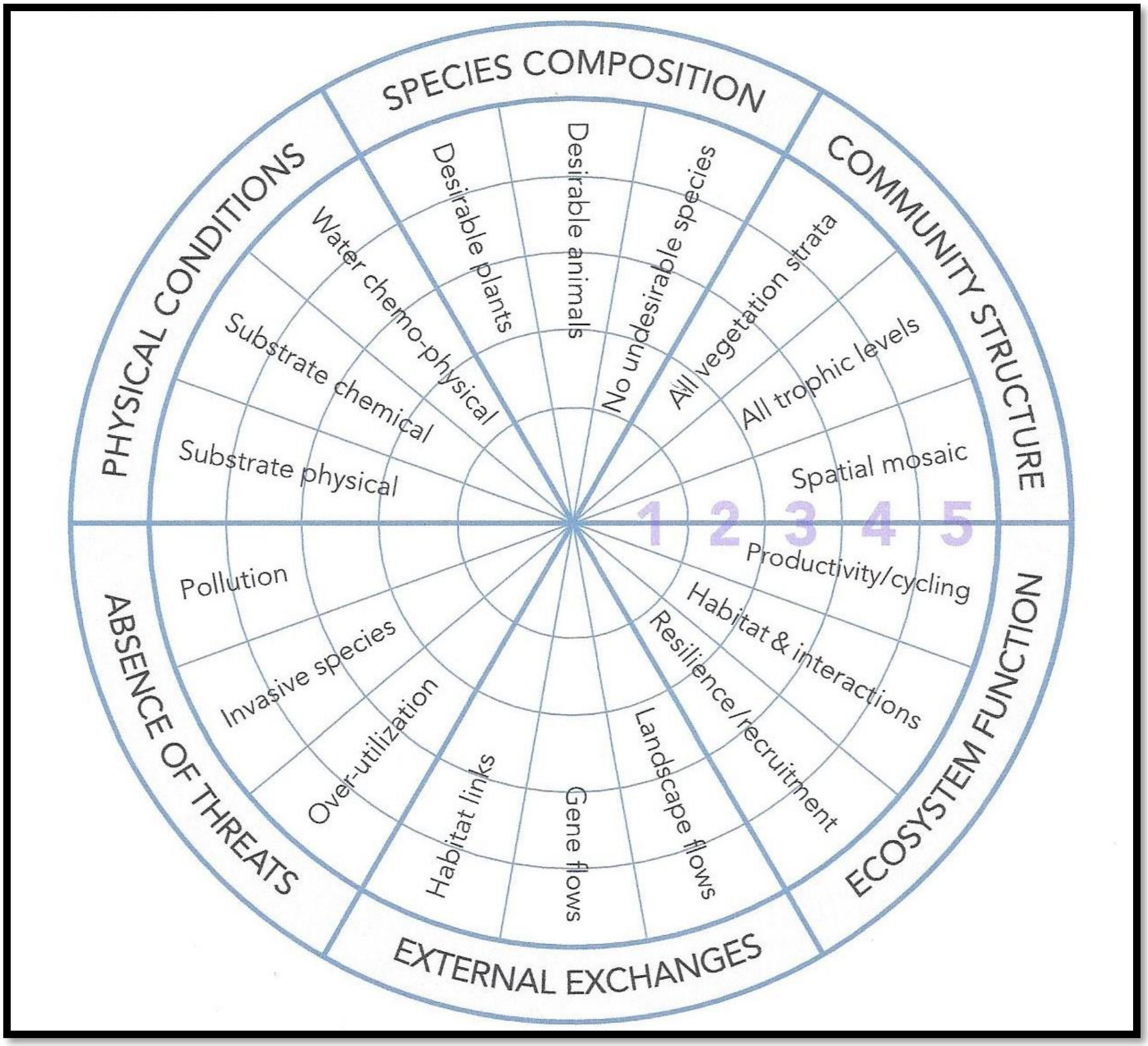

Figure 4. Examples of blank progress assessment template for practitioner use from the Society for Ecological Restoration Australasia's National Restoration Standards (Standards Reference Group SERA 2017).