Chapter 6
Ecological Restoration in Support of Sustainability Transitions: Repairing the Planet in the Anthropocene

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Abstract In the Anthropocene it is widely recognized that we need to embrace the concept of sustainable transitions. Strangely, ecological restoration is entirely decoupled from the concept of sustainability transitions. We argue that alongside radical changes in socio-technical systems that define sustainability transitions there will also be a need to conduct extensive ecological restoration. Indeed, that would in and of itself represent a major transition – normalizing ecological restoration where ecosystems that are degraded are restored. We are considering actions needed to have ecological restoration become a part of the radical change that defines sustainability transitions including: Learn and refine as we do restoration; Embrace bold and creative ideas; Adopt a design and systems-thinking approach; View restoration as a complement than a safety net; Work with nature; Create

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opportunities for massive engagement; Bridge science and practice; Ensure that restoration is equitable and just; Insert restoration into social-technical systems; Invest in restoration and sustainability transitions. Sustainability transitions alone have the potential to limit further ecosystem degradation but will not repair the planet. Similarly, focusing solely on restoration is a losing battle without changing societal relationships with the environment. We conclude that restoration of ecosystems can be done in tandem with sustainability transitions to attain greater and prolonged benefit to achieve a good Anthropocene for the planet and its peoples.

Keywords Anthropocene · Practice · Restoration · Sustainability · Transitions

6.1 Introduction

People have dramatic effects on the planet (Vitousek et al. 1997; Dirzo et al. 2014). Forests have been cleared to make way for agriculture and urban centers. Wetlands have been filled to make way for parking lots and shopping malls. Water courses have been dammed to generate electricity. Air, land, and water have been polluted. Biodiversity has been lost. By all accounts the planet today is much different than it was even just a half century ago (Steffen et al. 2015). Indeed, the level of human impact on planet Earth is now to the extent that many scholars agree that we have entered a new Epoch distinct from the Holocene known as the Anthropocene (Crutzen 2006). Although there is debate as to when the Anthropocene began, the date of the Trinity nuclear detonation (i.e., July 16, 1945) is often acknowledged as the beginning (Lewis and Maslin 2015). We are at a point where not only is the planet in jeopardy but also humanity given our reliance on the environment for well-being, health, prosperity, and survival (Sandifer et al. 2015; Raworth 2017).

The term “Anthropocene” has an inherently negative connotation, yet some have also suggested that it is possible to achieve a “good Anthropocene” (Dalby 2016). Others have suggested that the term “Symbiocene” would better reflect an aspirational goal of thinking beyond the Anthropocene and achieving transformative change (Prescott and Logan 2017; see https://symbioscene.com/). The recognition that we currently are in the Anthropocene could (or should) be a rallying call for humanity to engage in activities that could yield meaningful change. Although there are efforts to identify and share opportunities for such change on a local scale (e.g., see Bennett et al. 2016) it is also clear that there is a need for major transitions in our quest for sustainability that are truly global (Truffer and Coenen 2012). Sustainability transitions are defined as “radical transformation towards a sustainable society, as a response to a number of persistent problems confronting contemporary modern societies” (Grin et al. 2010). Much effort has focused on thinking about what those transitions could or should involve – transitioning to green energy sources, renewing our relationship with nature, building a green economy, and rethinking food systems, to name a few. There are growing calls for fundamental transformation towards more sustainable modes of production and consumption

(Markard et al. 2012). Yet, the reality is that even if such transitions are entirely achieved, the planet has already been damaged. Great efforts will be needed to assist recovery of damaged and degraded ecosystems, restore biodiversity, and foster sustainable engagement with ecosystems (Suding et al. 2015).

To date, discussions of sustainability transitions have focused almost entirely on socio-technical systems e.g., transportation, water supply (Markard et al. 2012) and governance systems (Loorbach et al. 2017). A recent comprehensive research agenda for sustainability transitions failed to include any mention of ecological restoration (Köhler et al. 2019) while a systematic review of the literature related to sustainability transitions entirely ignores the restoration of ecosystems or landscapes (Sengers et al. 2019). Ecological and ecosystem restoration are largely decoupled from the concept of sustainability transitions - which is concerning. The fact that the United Nations has just launched the Decade on Ecosystem Restoration is a signal that ecological restoration is sorely needed (Cooke et al. 2019; Young and Schwartz 2019). We argue that alongside radical changes in socio-technical systems that define sustainability transitions there will also be a need to conduct extensive ecological and ecosystem restoration. As an example, a policy brief from Ramsar convention on wetlands calls for the restoration of 25 million ha of peatlands by 2030 and 50 million ha by 2050 towards the objective of constraining warming to 1.5 C to 2 °C (COV 2021). Indeed, that in and of itself would represent a major transition – normalizing ecological restoration where ecosystems that are degraded are restored. Restoration of ecosystems can be done in tandem with sustainability transitions to achieve greater and prolonged long-term benefit that is so much needed in the Anthropocene. Here we first provide a brief overview of the foundations of ecological restoration. Next, we consider actions needed to have ecological restoration become part of the radical change that defines sustainability transitions. We conclude with a candid discussion how ecological restoration can be done in tandem with sustainability transitions to enable humanity to achieve a good Anthropocene for the planet and its peoples.

6.2 A Primer on Ecological Restoration

The official (Society for Ecological Restoration) definition of ecological restoration (Society for Ecological Restoration 2004; Gann et al. 2019) is "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It is distinct from restoration ecology, the science that supports the practice of ecological restoration." Ideally, restoration practice should reflect ecological successes, but several guidelines have advocated an expanded view, including social dimensions, of what counts as restoration success (Parks Canada and the Canadian Parks Council 2008; Keenelyside et al. 2012; Suding et al. 2015). To explore the complementarity of ecological restoration - theory and practice - we often substitute 'ecosystem' for 'ecological', but that entails a narrower scope. While there have been debates about the specifics and nuances (Higgs 2003), especially in earlier iterations, the definition has not changed much over the years. What has changed is the context and the challenges. Climate change was recognized early as a significant challenge to conventional models of restoration (Harris et al. 2006). Authors as varied as Hobbs et al. (2009), Higgs et al. (2014) and Balaguer et al. (2014) recognize that historical reference conditions and ranges of variation are valuable guideposts; many acknowledge that emerging novelty is becoming a significant factor shaping restoration (Hobbs et al. 2013; Heger et al. 2019). Increasing attention is given to the critical role people play in restoration, from recognizing and respecting Indigenous land stewardship to the benefits of social, cultural, and political support for long term success. People also benefit from the restoration of ecosystem services, including less tangible outcomes from the direct engagement that restoration practice provides.

There is still disagreement on the appropriate conceptual model for ecological restoration given the pace of global changes: one promising path is to consider the predictive paths and trajectories of restoration – essentially, looking forward rather than backward (see Brudvig and Catano 2017). To that end, Brudvig et al. (2017) had proposed looking at the role of origins of variability of system (from individuals to ecosystems) structure and function (Gellie et al. 2018), more specificity in goal setting, an emphasis on distributed experimentation (replication of experiments using common attributes across wide geographical and edaphic ranges), and better use of statistical models to better partition the origins and impacts of system variation. If one adds in the potential for using metrics like species pools and functional traits (e.g., Keddy and Laughlin 2021), and improved understanding of threshold and alternative stable states (Suding and Hobbs 2009) there are clear paths for innovation to address the challenges to ecological and ecosystem restoration.

There have been calls for more consistency and cooperation amongst restoration ecologists, so the impact of each local experiment is amplified, and knowledge is shared openly (Ladouceur et al. 2022). Fortunately, there also are efforts underway to do just this. However, these efforts have been slowed by the COVID-19 pandemic; and in addition, the institutional barriers should not be underestimated. For example, biases in granting agencies and metrics inherent to academia reward novelty over cooperative replication. Ironically, the eternal focus on innovation threatens to thwart exactly that.

Bolstered further with a commitment to ensuring that translation from science into practice is equitable and just (and funding mechanisms are available to support it), this is the proper approach – ecological restoration requires networks of restoration ecologists alongside practitioners and other knowledge holders focused on building approaches, datasets and analyses that collectively allow us to better understand and model ecological trajectories, set goals based on choosing which trajectories are desirable based on positive ecological effect size, work backwards to ensure proper steps are taken and tie into sovereignty, legal, governance, and policy frameworks. The last step may seem unpromising given the hostility of countries, political parties, and large numbers of lobby groups and citizens to the principles of good governance. Ecological restoration, however, given a heavy reliance of local actions by myriad practitioners, seems to be rather resilient as a domain to even the worst political madness – at least, the development here has been ‘less bad’ than what has happened to pollution regulations, water governance, endangered species laws, and a general despair created by regulatory capture in too many nations. Still, the increased emphasis on the policy, laws, and governance and ecological restoration is not restricted to academics but is finding its way into actual practice (e.g., the ongoing efforts of coastal restoration in Louisiana, the 2021 Florida Wildlife Corridor Act, the efforts of the European Union to create a Nature Restoration Law). True transformative change (Díaz et al. 2019) via restoration will come from multi-actor, multi-scale collaborative actions, drawing on key leverage points specific to each context.

Overall, accelerating ecological restoration as a joint socio-ecological science and practice rooted in social justice is long overdue. With the recent dawn of the UN Decade on Ecosystem Restoration, it is clear there is momentum and evidence-based action on the trends identified above. The next phases of linking ecological restoration to intersectional issues of social and environmental justice is going to be even more difficult but ecological restoration never has been easy, or fast (Jones et al. 2018; Moreno-Mateos et al. 2017). As part of a wider sustainability transition, ecological and ecosystem restoration's current research and action paths have much to offer.

6.3 Actions Needed for Ecological Restoration in the Anthropocene

Here we consider actions that are needed for ecological restoration to become part of the radical change that defines sustainability transitions. As outlined above, ecological restoration as a discipline and practice has evolved and matured over the last several decades. Yet, more advancements are needed to ensure that ecological restoration contributes to the radical change needed.

6.3.1 Learn and Refine as We Do Restoration

Ecological restoration is an evolving science and practice (Young et al. 2005). As such, there is need for continued learning about which restoration strategies are most effective. This will undoubtedly require refinements, particularly when it comes to applying restoration strategies in different contexts, e.g., ecosystems, regions, threat landscapes. Every restoration project represents a learning opportunity which is best realized through a rigorous monitoring program (Lindenmayer 2020) with relevant comparators such as reference sites and before-after data (i.e., BACI designs; Conner et al. 2016; Palmer et al. 2005). However, rigorous monitoring is unrealistic for every project (Bernhardt et al. 2005) so there is need for monitoring strategies that can be easily operationalized by restoration practitioners

(Cooke et al. 2019). There are a growing number of academic journals that recognize the importance of practitioner monitoring observations and other reflections on successes and failures. With restoration there is likely a file drawer effect where we celebrate and share (e.g., publish) the successes (Zedler 2007) when there is much to learn from the failures (Suding 2011). It is important to build a rich evidence base that will enable formal evidence synthesis including systematic review and meta-analysis (Cooke et al. 2018). Such efforts will ensure that the limited resources available for restoration are focused on restoration activities that are effective. Success is rarely cut and dry (Zedler 2007) which is opportune for using an adaptive (management) approach to restoration (Murray and Marmorek 2003; LoSchiavo et al. 2013). Structured decision-making approaches including quantitative expert judgment (e.g., Koch et al. 2015) can interface with adaptive management approaches to include values of different actors in the process (Failing et al. 2013).

6.3.2 Embrace Bold and Creative Ideas

Given the state of the planet there is need to be bold and creative when it comes to ecological restoration (Lodwick 2013). Being bold and creative comes in different forms and spans efforts to generate awareness and political will through to actual restoration activities (e.g., use of novel materials or approaches). One of the more creative initiatives over the last few decades has been the development and deployment of artificial floating wetlands to address water quality issues and enhance biodiversity (Shahid et al. 2018). Obtaining sufficient native seed supply is often a challenge in restoration yet there have been creative efforts to engage Indigenous and local communities in boosting seed supply (Urzedo et al. 2022). 3-D printing has recently been used for coral restoration projects although uncertainties remain regarding long term benefits (Albalawi et al. 2021). When attempting new approaches, appropriate monitoring needs to be conducted to assess effectiveness but in some cases risk assessment may be needed a priori e.g., genetic technologies, (Sandler 2020) and assisted migration (Mueller and Hellmann 2008). Being bold and creative should not be equated with being reckless or engaging at a large intractable scale with uncertain impacts.

6.3.3 Adopt a Design and Systems-Thinking Approach

Ecological systems are inherently complex, inextricably linked by species and functional attributes that re-enforce healthy, sustaining mechanisms. Despite many large-scale restoration strategies underway globally, they are likely insufficient (Moreno-Mateos et al. 2017, 2020) and degraded ecosystems have acquired properties that make them resilient to restoration (Barrett et al. 2021. Emerging novelty across scales (Heger et al. 2019) can disrupt conventional restoration practice and compel alternative approaches to restoration of biodiversity and ecosystem services. There are new opportunities emerging at the intersection of restoration, ecological novelty, and design (Higgs 2017). What if we took a systems-thinking and design approach to restoration? What might happen if we approached restoration as a strategic enterprise, integrating behavioral and ecological science, policy and practice into a solution that accelerated testing, optimizing and implementation? Would the restoration plan and resultant outcomes be the same? There is no one way that ecological restoration will achieve success but the strategic engagement of key leverage points to accelerate and ensure transformation (Díaz et al. 2019). Elsewhere on the planet, great strides have been made in the past decade to develop, optimize, and launch business products such as software applications (apps) however such innovation can be applied to many other efforts including restoration. The Google Venture Sprint framework (Knapp et al. 2016) has quickly become a popular framework for business enterprises, and likewise offered a pathway for watershed-scale restoration in Aotearoa New Zealand. Living Water, a ten-year, multi-million-dollar industry-government partnership in Aotearoa New Zealand, the first and one of the largest of its kind, made it its mission to undertake freshwater restoration in agricultural landscapes across five focal catchments in the country. Fonterra, New Zealand's largest company and the federal Department of Conservation embarked on a shared journey to address freshwater restoration. In one focal watershed - the Ararira L2 river catchment in lowland Canterbury - the many complex challenges typical of agricultural landscapes (channelized drains, intensified agricultural practices, diminished water quality) were also met with legal and cultural obligations and constraints. Notably, contemporary stream and river networks are man-made or channelized, and offer critical infrastructure and flood mitigation roles while also supporting biodiversity and key recreational, cultural and water purification ecosystem services. In 2017, Living Water adapted the Google Sprint framework into a five-day workshop where experts and knowledge holders came together to systematically address the challenges for the watershed, design a 'prototype' solution which was then 'tested' by key decision-makers who would be essential to seeing the program through (Fig. 6.1). The resultant outcome was a series of undertakings that included partnering with freshwater restoration ecologists undertaking research in the region (Febria et al. 2020), supporting the creation of new roles in local government focused on biodiversity, highly-visible roadside demonstrations, and the formation of Te Mana Ararira, a Māori-centered advisory group for the catchment (https://www.livingwater.net.nz/catchment/ararira-lii-river/) (Fig. 6.1).

6.3.4 View Restoration as a Complement Rather Than a Safety Net

Restoration is about repairing damage that has been done (Hobbs and Harris 2001). Yet, restoration is imperfect (Cooke et al. 2019), often implemented ineffectively as mitigation (Palmer and Hondula 2014). It has mixed success (Jones et al. 2018;

Fig. 6.1 A design approach to freshwater restoration with Living Water in Aotearoa, New Zealand. Living Water is a funded partnership between the Federal Department of Conservation and Fonterra, the nation's largest corporation and agricultural enterprise. In one catchment Ararira/L2, a strategic solutions design process was undertaken to determine a multi-prong catchment-wide restoration approach (top) that included societal, cultural, and governmental aspects alongside empirical research efforts (bottom). (Photo: Living Water)

Moreno-Mateos et al. 2017, 2020) and should never be used as an excuse for intentionally degrading ecosystems. Protecting ecosystems and working to ensure that threats are mitigated to the extent possible should be prioritized over accepting that environmental harms will occur and that through restoration the damage can be repaired. Moreover, preservation is almost always much less expensive than restoration (Cairns Jr 1993). When doing restoration work the first step is often to preserve the current ecosystem structure and function assuming that some elements will be desirable with restoration building upon that (Broadbent et al. 2015). That assumes that the current system is not a highly resilient degraded ecosystem for which preserving those elements can be problematic. Preservation of degraded systems so that no further degradation occurs without engaging in restoration is wholly insufficient (Colston 2003). Similarly, engaging in restoration without addressing the underlying threats is unlikely to achieve desirable outcomes (Allan et al. 2013). Restoration needs to be used as a complement to other activities such as preservation rather than viewed as a safety net to fix problems that could have been prevented.

6.3.5 Work with Nature

The concept of nature-based solutions is sometimes considered when thinking about sustainability transitions (Cohen-Shacham et al. 2016; Davies and Lafortezza 2019), particularly when rethinking urban design and infrastructure (e.g., stormwater; Wendling and Holt 2020). Nature-based solutions are also being embraced as approaches to inform and enhance ecological restoration. For example, nature-based solutions are being used in lake (Dondajewska et al. 2018) and peatland (Bonn et al. 2016) restoration. There is opportunity to learn from and emulate natural structure and functions rather than trying to engineer systems and constraining them using artificial materials (e.g., concrete) or approaches that do not lead to long term success (Chapman 2006). As we embrace nature-based solutions as part of sustainability transitions there are parallel opportunities to make meaningful advances in restoration.

6.3.6 Create Opportunities for Massive Engagement

Ecological restoration is an important form of environmental stewardship that can be conducted by anyone – including federal governments, corporations, community groups, and private individual – and anywhere – from national parks to empty lots or backyards. Thus, it is one of the most accessible, actionable methods of creating environmental change. Not everyone can reform energy policy, or build green transportation infrastructure, but nearly anyone can pull invasive species in their local park and seed native flowers in their garden. Sustainability transitions require altered individual behaviors (Schäpke and Rauschmayer 2014), often driven by feelings of altruism or environmental responsibility that are created through acts of stewardship (Krasny and Delia 2015). Emphasizing and leveraging the accessibility of restoration, and the resulting feelings of reconnection and embeddedness in the landscape (Bramston et al. 2011), will be pivotal to achieving a successful sustainability transition. In addition, including the community can be essential to successful restoration. It is increasingly clear that restoration is not a "one and done" activity, and that continued interventions are needed, sometimes in perpetuity (Hobbs and Harris 2001). Engaged communities are often the determining support for continuous management practices. Oak-meadows are some of the most threatened and degraded ecosystems in Canada (Fuchs 2001), and their restoration often takes the form of weekly or even daily volunteer efforts from local community members (Shackelford et al. 2019). These sites are an example of ecological communities that evolved with, and depend on, Indigenous management practices (Pellatt and Gedalof 2014). They are proof that continuous human stewardship is the historical and ecological norm for many threatened landscapes. In parallel with rising global recognition of Indigenous sovereignty (United Nations General Assembly 2007), community-engagement and leadership are becoming an increasing priority in many restoration contexts. Inclusive opportunities for community-driven restoration also support innovation and shared learning in a diverse field. Volunteer and user observations in restoration sites can lead to shifts in project decisions under an adaptive, experimental management framework (Bliss et al. 2001). Citizen science tools like iNaturalist can act as long-term monitoring methods (Callaghan et al. 2020) and educational outreach strategies. In addition, emerging tools such as Google's Restor (https://restor.eco/) are increasing the public availability of restoration-focused information such as appropriate native trees and local ecosystem types. Continued innovations in how restoration science collects and disseminates knowledge within communities will enhance the global pace of advancement and overall reach of restoration practice.

6.3.7 Bridge Science and Practice

Our current age is not only one of crises, it is at the same time also one of remarkable progress. Technological advances include artificial intelligence, machine learning and the development of smart infrastructure. It is high time that these advancements are being leveraged to counter the biodiversity and climate crises. Restoration ecology could (and should) become a 'sand box' for developing tools that allow quick discovery of existing knowledge. Novel tools developed in computer and library sciences could be adapted to provide links between ecological theory, restoration ecology and the practice of ecological restoration (Heger, unpublished manuscript). The benefits of developing tools for efficient knowledge discovery would be manifold. Most importantly, the knowledge created by practitioners and scientists alike could be leveraged efficiently to assure constant improvement of restoration techniques. Currently, information on the outcome of restoration projects and scientific research is very likely to get lost - even if it is published in some scientific journal, it will probably drown in the ocean of information, becoming harder to find over time amongst the ever-increasing number of published papers (Jeschke et al. 2019). Novel knowledge discovery tools are being developed that help finding relevant information more efficiently (e.g., Open Knowledge Maps, Connected Papers), and semantic web applications allow summarizing available information on demand (e.g., Scholia). If such tools were adapted and implemented for restoration ecology, practitioners could use them to quickly find information on best practices and underlying theoretical findings, and scientists could easily link their research to practical challenges. What is needed to achieve these aims is a teaming up of the restoration ecology community with computer and library scientists, experts in semantic web techniques and data management.

6.3.8 Ensure that Restoration is Equitable and Just

Sustainability transitions are not just about biodiversity - they are also about people, societies and cultures and enhancing human wellbeing (Rauschmayer and Omann 2014), and this is the central theme of the Sustainable Development Goals (UNEP). In the context of restoration, and a long history of environmental degradation in impoverished communities, it is therefore essential that restoration is equitable and just. The concept of equity in restoration is reasonably new yet has inherent relevance given that restoration is value laden (Kimmerer 2011) and because the degradative processes that necessitate restoration are often driven by societal inequities (Schell et al. 2020). Often individuals who (could) engage in restoration may not have access to sites where restoration is needed (see Wells et al. 2021). Women, youth, individuals with disabilities, racialized minorities, and rights holders (i.e., Indigenous peoples) are often excluded from engaging in restoration as well as reaping the benefits of restoration (Wells et al. 2021), despite growing evidence that restoration that centers, amplifies and maximizes local and Indigenous communities and knowledge systems are essential to achieving restoration (Suding et al. 2015; Ban et al. 2018; Rayne et al. 2020). Recently Osborne et al. (2021) presented several principles for achieving long-lasting, resilient, and equitable ecological restoration. For example, by privileging local knowledge and practices through actions such as strengthening community organizations and empowering such groups to engage in decision making (Armitage 2002). By ensuring the participation of most impacted groups there is opportunity to consider the complex trade-offs and synergies that can arise during restoration planning and implementation (Ferwerda and Gutierrez 2021). Equity can also be addressed by explicitly considering who benefits from restoration or bears the cost of restoration interventions (Chaudhary et al. 2018) while ensuring that restoration initiatives do not violate human rights (including Indigenous rights) or contribute to social or environmental injustice (Adams and Hutton 2007). Using relevant social indicators when assessing restoration can ensure that well-being is considered (Alba-Patino et al. 2021). For example, prioritizing Indigenous treaty rights and cultural practices may be essential to legitimizing and accelerating ecological restoration (Wehi and Lord 2017) and through reparation of social and ecological connections, restoration can be one form of reconciliation with Indigenous communities and lands (Kimmerer 2011). Collectively these actions will ensure that restoration benefits all people and encourages stewardship.

6.3.9 Insert Restoration into Social-Technical Systems

Social-technical systems such as transportation, energy, and urban design are essential for humans yet many of these systems have been implicated in environmental degradation. Moving forward there are opportunities to consider how restoration can interface with these systems. Better designs for future developments are certainly important (e.g., rethinking road networks; Dolan et al. 2006; redesigning airports to include more native vegetation; Yue and Shi 2017) but much of this infrastructure already exists. During infrastructure renewal there may be opportunities to incorporate restoration principles and achieve environmental gains (i.e., renewal ecology; Bowman et al. 2017). For example, as dam infrastructure associated with hydropower is being renewed there are opportunities to incorporate technologies such as fish passage structures that restore connectivity (Neeson et al. 2018). In some cases, such as hydropower dams, operational changes can be made without directly modifying infrastructure, thus restoring environmental flows (Richter and Thomas 2007). In urban centers much effort has been focused on restoring water infiltration so water recharges groundwater rather than running off and creating stormwater management challenges (Li et al. 2017). Regulatory levers or incentives could be useful for ensuring that restoration principles are incorporated into infrastructure renewal projects although changes in governance or economic systems (e.g., a circular economy) that enable restoration also exhibits considerable potential (Priyadarshini and Abhilash 2020).

6.3.10 Invest in Restoration and Sustainability Transitions

Restoration and sustainability transitions both require significant financial investments for them to deliver on their promise. Restoration is chronically underfunded but also has itself been identified as the potential to be a major economic driver through conservation, restoration, and mitigation action conducted under the auspices of the "Restoration Economy" (BenDor et al. 2015). There are efforts underway to explore models such as taxation (Hochard 2022) and incentives (Canning et al. 2021) to fund or enable the massive level of restoration activity that is needed (De Groot et al. 2013). Similarly, sustainability transitions will be economically costly in the short term but will yield long term payoffs (Naidoo 2020). It is for that reason that corporations are willing to invest in sustainability transitions (Hernández-Chea et al. 2021). What is clear is that there is mutual benefit with investing in both restoration and sustainability transitions given inherent overlap in goals and rewards. Failure to adequately support such activities will constrain the ecosystem services that can be derived from intact, functional ecosystems that generate manifold benefits for humans (Palmer and Filoso 2009; Fischer et al. 2021).

6.4 Conclusion: Thinking about Ecological Restoration and Sustainability Transitions

Above we considered actions needed to have ecological restoration become part of the radical change that defines sustainability transitions. Ecological restoration is imperfect and there are challenges that exist for ensuring that restoration is effective and equitable (Suding et al. 2015). As we enter the UN Decade on Ecosystem Restoration it is an opportune time to further the science and practice of restoration (Cooke et al. 2019). Ecological and ecosystem restoration is itself not a sustainability transformation - or at least, it has not been viewed that way by scholars focused on socio-technical based transitions. Yet, imagine what would be possible if ecological restoration was normalized and was itself considered a radical transition focused on repairing our planet. Imagine if governments, institutions, and individuals committed to funding and doing restoration. Many of the transitions being proposed have the potential to improve the ways in which we impact the environment, but it is unlikely that those transitions, no matter how radical, will magically restore the damage that has already occurred to ecosystems across the planet. Similarly, restoration alone will be insufficient if we do not engage in the transitions needed for a sustainable future. We may see short term or localized successes but if we continue to build infrastructure, extract resources, and commoditize nature as we have for the last few centuries, restoration is nothing but a band aid on a hemorrhaging wound. In that sense ecological restoration and sustainability transitions are inherently linked. One without the other is not as great as when they are considered together (Fig. 6.2).

To achieve a good Anthropocene will require the collective efforts of many. Existing frameworks for restoration (e.g., Hobbs and Norton 1996; Copeland et al. 2021) could easily intersect with frameworks for sustainability transitions (e.g., Rogge and Reichardt 2016; Kanger et al. 2020). There are opportunities for the UN Decade on Ecosystem Restoration to help enable the practical bridging of ecological restoration and sustainability transitions. In many ways, ecological restoration could be viewed as a foundation upon which transitions can further amplify and sustain conservation gains. If we do not transform how we move goods and people, grow food, generate electricity, harvest raw materials, and so on, restoration efforts will be ineffective in the long term. The level of investment that would be needed to continually try to mitigate ongoing damage would be astronomical and that does not

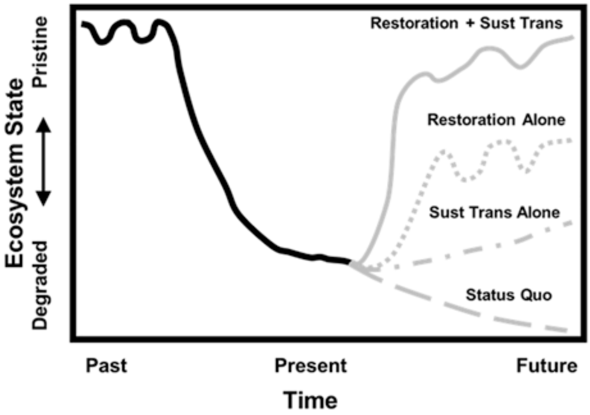

Fig. 6.2 Ecosystem state over time relative to different interventions. Historically the ecosystem state was more "natural/pristine" but due to human activities there has been extensive ecosystem degradation. Failure to intervene (i.e., the status quo as indicated by grey long-dashed line) would likely result in continued degradation. If we can enact sustainability transitions there would be rapid changes in human activities and impacts which would presumably halt further degradation and perhaps enable slow recovery (i.e., the sust trans alone as indicated by grey dot-dash-dot line). If sustainability transitions were not to occur but much effort was devoted to restoration (i.e., the restoration alone as indicated by grey dotted line) then there would be some level of recovery towards a more pristine state, but conditions would be such that pressures would continue so it would be unlikely to be fully successful, particularly in the long run. If restoration and sustainability transitions were both to occur one might anticipate the most improvement in ecosystem state given that the transition would reduce pressures such that the restoration would be more effective and more likely to lead to long-term benefit (i.e., restoration + sustainability transition as indicated by solid grey line)

account for the fact that the starting point today is one in which we have already degraded ecosystems and lost biodiversity. If there were to be a future with only a sustainability transition, then there is a strong likelihood that we would halt further degradation but would not be able to repair ecosystem damage to the extent that would be possible if done in tandem with ecological restoration.

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