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Research

Indigenous and local knowledge in sustainability transformations research: a literature review

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ABSTRACT. Scholars, politicians, practitioners, and civil society increasingly call for sustainability transformations to cope with urgent social and environmental challenges. In sustainability transformations research, understandings of transformations are often dominated by Western scientific knowledge. Through a systematic literature review, we investigated how indigenous and local knowledge (ILK) is represented in peer-reviewed empirical scientific papers that apply ILK in contexts of transformation, transition, and change. Our results show, first, that all papers applied ILK to confirm and complement scientific knowledge in contexts of environmental, climate, social-ecological, and species change. Only four papers (5%) applied ILK to conduct research on transformations. Second, we identified four research clusters that apply ILK in contexts of transformation, transition, or change in (1) Arctic, (2) terrestrial, (3) coastal, and (4) grass and rangelands environments. These clusters are located along two axes: tropic to Arctic and marine to terrestrial. Finally, our results indicate that indigenous and local understandings of transformations are currently neglected in the scholarly transformations discourse. The reviewed papers do not focus on how indigenous peoples and local communities understand transformations, instead they focus on what changes indigenous peoples and local communities observe and describe, resulting from their daily experiences and activities. We argue that because of its in-depth local, place-based character, ILK can substantially contribute to a more plural understanding of transformations and the assessment of transformative change. We conclude that future research needs to investigate how to gain a more plural understanding of transformations that leads potentially to more inclusive actions toward more just, equitable, and sustainable futures on a local and global level.

Key Words: *indigenous and local knowledge; knowledge system; multiple evidence base approach; traditional ecological knowledge; transformation; transition*

INTRODUCTION

For more than two decades, sustainability transformation research has sought to better understand how large system changes toward just, equitable, and sustainable futures can be fostered (Loorbach et al. 2017). Diverse definitions of and approaches to transformation exist in the literature (Patterson et al. 2017, Blythe et al. 2018). They are decisively influenced by Western scientific knowledge because it is currently the dominant knowledge system that sets prevailing standards for research (Davis and Ruddle 2010). Knowledge systems exist through "agents, practices and institutions that organize the production, transfer and use of knowledge" (Cornell et al. 2013:61). Knowledge from other knowledge systems, such as indigenous and local knowledge (ILK) systems are rarely involved in research, especially in transformation research (Blythe et al. 2018).

The contributions of ILK for sustainability and research are increasingly considered in sustainability science (Mistry and Berardi 2016, Tengö et al. 2017). Indigenous and local knowledge is defined as a "cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes 2018:8). Its contributions are especially highlighted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). For example, Brondizio and Le Tourneau (2016) argued that involving indigenous peoples and local communities is essential to develop and implement more effective environmental governance systems for ecosystems and biodiversity. Another example is the exchange of ILK and scientific knowledge in the case of pollinator conservation (Hill et al. 2019). Indigenous peoples and local communities practice biocultural approaches to pollinator conservation in all continents, except Antarctica, which maintain biodiversity and Nature's contributions to people (Díaz et al. 2018, Hill et al. 2019). The contribution of ILK is also exemplified by the combination of observations from Tibetan pastoralists and scientific knowledge on climate change to support the hypothesis of delayed summers on the Tibetan Plateau (Klein et al. 2014, Mistry and Berardi 2016). Reasons for this growing interest are the long-standing relationships of indigenous peoples and local communities with their surrounding environments, the holistic knowledge accumulated in centuries to govern social-ecological systems, and the ability of these communities to overcome crisis and changes of all different types (e.g., livelihood change, climate and ecosystem change, availability of resources; Pearce et al. 2015, Berkes 2018).

Despite these positive examples of how ILK can contribute to sustainability and research, studies that investigate how indigenous and local understandings of transformation can support working toward just, equitable, and sustainable futures are less abundant. In fact, the transformation discourse seems to pay insufficient attention to social differentiation, issues of power and plurality which threatens the legitimacy of the discourse (Blythe et al. 2018). To overcome some of these challenges, we argue that a more inclusive and plural understanding of transformations is needed, which views transformations from the perspective of diverse knowledge systems.

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The aim of this study is to review to what extent indigenous and local understandings of transformation are represented in the scientific sustainability transformation literature. To reach this goal, we conducted a systematic literature review of ILK in contexts of transformation, transition, and change. The findings intend to stimulate the debate on transformations to enable a more plural and comprehensive understanding of transformations, which includes insights from diverse knowledge systems.

SUSTAINABILITY TRANSFORMATION RESEARCH

The interest in sustainability transformations is increasing among scholars with different theoretical backgrounds and has led to the emergence of different conceptual approaches to transformations (Olsson et al. 2014). Reviews from Feola (2015), Loorbach et al. (2017), and Patterson et al. (2017) provide detailed overviews and discussions of these conceptual approaches to transformations that show the diversity of how transformations can be understood within the Western scientific knowledge system. Following Patterson et al. (2017), we briefly introduce how four prominent conceptual approaches to transformations from the global sustainability literature understand transformations: (1) social-ecological transformations, (2) sustainability transitions, (3) transformative adaptation, and (4) sustainability pathways (Table 1).

Table 1. Overview of four prominent conceptual approaches to transformation based on Patterson et al. (2017). These conceptual approaches to transformation have different perspectives, foci, and aims, which show the plurality of how sustainability transformations are understood within research.

Approach to transformation	Perspective	Focus	Aim
Social-ecological transformations	Place based	Social-ecological systems	Resilient natural resource use and management
Sustainability transitions	Sectoral	Social-technical systems	Sustainable production and consumption
Transformative adaptation	Systemic and structural	Power issues in transformative processes	Opportunities and possibilities for vulnerable groups
Sustainability pathways	Contextually grounded sustainable development	Human development	Sustainable and just pathways of change

First, the social-ecological transformations approach focuses on social-ecological systems (e.g., forest, fishery, agriculture systems) while often taking a place-based research perspective (Berkes et al. 2002, Gunderson and Holling 2002; Table 1). Its disciplinary roots are in ecology but are strongly widened by social sciences (Patterson et al. 2017). Social-ecological transformations literature is based on complex adaptive systems theory that discusses resilience, adaptability, and transformability as key properties of social-ecological systems (Berkes et al. 2002, Gunderson and Holling 2002, Walker et al. 2004). This approach understands transformations as "shifts that fundamentally alter human and environmental interactions and feedbacks" (Walker et al. 2004, Olsson et al. 2014:1).

Second, the sustainability transitions approach generally focuses on social-technical systems while often taking a sectoral perspective (e.g., energy, water, waste, food systems; Grin et al. 2010, Köhler et al. 2019; Table 1). This approach investigates long-term societal change toward sustainability. Its disciplinary roots are in innovation studies, complex systems theory, technology studies, institutional analysis, and evolutionary as well as institutional economics (Patterson et al. 2017). This approach understands transformations as transitions (see Hölscher et al. 2018 for a comparison of the terms transformation versus transition) and thus as "co-evolution processes that require multiple changes in socio-technical systems or configurations," "multi-actor processes," "radical shifts from one system or configuration to another," "long-term processes," and "macroscopic" (Grin et al. 2010:11-12).

Third, the transformative adaptation approach focuses on power issues within transformative processes as an adaptive response to climate change (Pelling et al. 2015; Table 1). It takes a systemic and structural perspective on human vulnerability and equity concerns linked to climate change (Pelling 2010, O'Brien 2012). Transformative adaptation aims to change fundamental systemic structures and paradigms that produce vulnerability for people. Its disciplinary origins are in development studies, human geography, and political ecology (Patterson et al. 2017). This approach understands transformations, for instance, as "physical and/or qualitative changes in form, structure or meaning-making (…). It can also be understood as a psycho-social process involving the unleashing of human potential to commit, care and effect change for a better life" (O'Brien 2012:670).

Fourth, the sustainability pathways approach focuses on human development while often taking a contextually grounded sustainable development perspective (Leach et al. 2007, Scoones et al. 2015; Table 1). This approach investigates the governance aspects of transformations and highlights the role of citizens at the same time (Scoones et al. 2015). Its disciplinary roots are in development studies, political science, complex systems theory, anthropology, and economics (Patterson et al. 2017). This approach does not relate to one specific definition of transformation due to the differences of context and perspectives (Scoones et al. 2015). However, this approach highlights the role of pathways to sustainability in which a pathway is "the way in which a given system changes over time, depending on the issue in question, several different scales may be important, sometimes simultaneously and in overlapping ways" (Leach et al. 2007:12).

This brief overview does not claim to be exhaustive, but shows how transformation is understood differently within the Western scientific knowledge system. Scholars with different theoretical backgrounds have different foci in transformations (e.g., social-ecological, social-technical systems), apply different perspectives (e.g., place-based, sectoral), and pursue different aims (e.g., resilience and sustainable production and consumption; Table 1). Despite these differences, they jointly contribute to a more comprehensive understanding of what a transformation in the sense of a large system change means. They all call for large-scale societal change toward sustainability while understanding transformations as nonlinear, complex, long-term, multilevel, multiphase, and cross-scale processes (Olsson et al. 2014, Loorbach et al. 2017). Indigenous and local knowledge systems

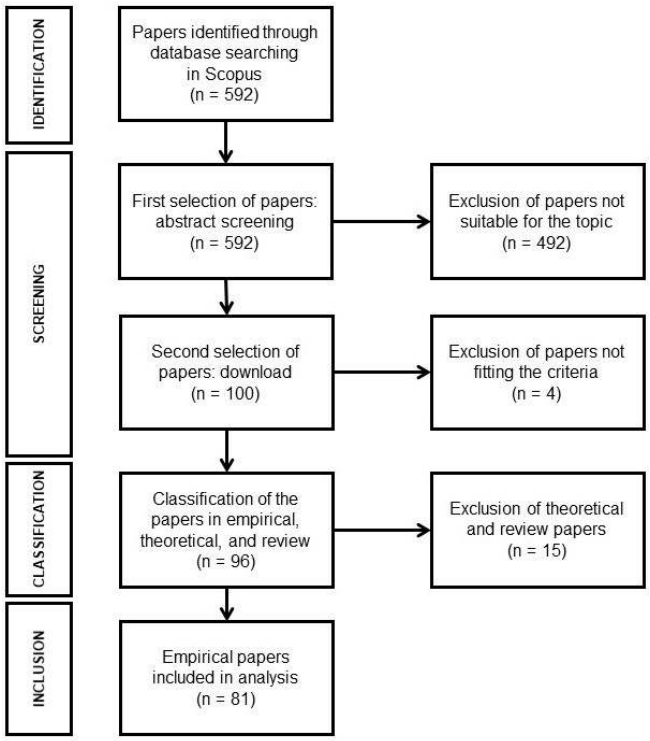
may contribute different insights to the scientific understandings of transformations because of their (1) accumulation of knowledge, practices, and beliefs; (2) strong connection to the environment of indigenous peoples and local communities; and (3) emphasis on relationships of living beings with another and with their environment (Berkes 2018).

METHODS

Systematic literature review

To identify the existing body of research on ILK in sustainability transformation research, we conducted a systematic literature review (Pullin and Stewart 2006, Luederitz et al. 2016; Fig. 1). First, we searched for primary research articles on ILK and sustainability transformations in the Scopus database. The search string used for the review comprised two main elements: (1) transformation (e.g., transformation, transition, or change) and (2) ILK (e.g., indigenous ecological knowledge, local ecological knowledge, or traditional ecological knowledge). The terms "transition" and "change" were selected because of their possible interpretation in the sense of transformation (i.e., large system change; Appendix 1). The search was applied to abstracts, titles, and keywords of published papers written in English between 2000 and 2016. The year 2000 was set as the starting date because at this time research in combination with ILK was becoming ubiquitous in different scientific fields, such as resource management (Cruikshank 2001).

Fig. 1. Flow diagram of the selection process used in the systematic literature review.



The search returned 592 papers (Fig. 1), of which 492 were disregarded after the screening of titles and abstracts because they did not meet the following criteria: (1) they did not apply or observe indigenous, traditional, or local knowledge; and (2) they were not connected to transformation, transition, or change. We also excluded papers that were not published in English (n = 4).

Then, we classified the remaining papers (n = 96) into the groups of review, theoretical, and empirical papers to filter only empirical papers for our literature review (n = 81; Appendix 2 for complete list of reviewed empirical papers). We excluded review and theoretical papers because we were only interested in empirically supported evidence for indigenous and local understandings of transformations.

Data analysis

We conducted qualitative content analysis and coded the content of the final set of 81 papers using the software MAXQDA 12 (Mayring 2014). We developed the coding scheme (Appendix 3) according to the research aims and the variables that help to answer the research questions. Main categories of the coding scheme were general paper characteristics, methodological approach, location of case study, the occurrence and use of the terms transformations and ILK and their synonyms, and the connection of ILK and transformations in the reviewed literature. We continuously adapted and refined the coding variables during the iterative process of coding the papers until we reached a consistent information level.

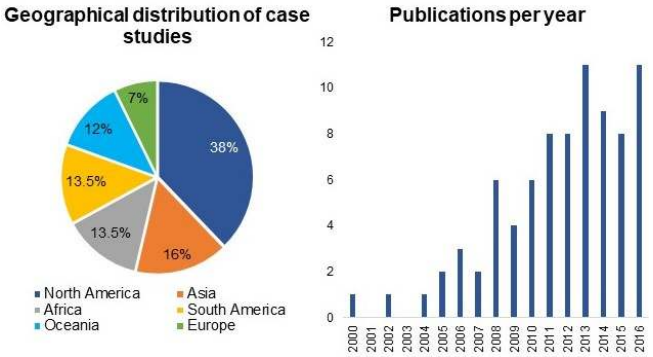
In addition, we quantitatively analyzed the full text of the final set of 81 papers. All words that appeared in at least one of the papers were extracted to examine the abundance of the individual terminologies across all papers (Abson et al. 2014, Partelow et al. 2018). The extracted list contained n = 5570 unique words, which was further reduced by excluding adjectives, pronouns, articles, numbers, and abbreviations that were content-wise not relevant to the topic. In addition, words with ambiguous meaning that had no connection to the topic were excluded (e.g., background or cycle). Our final list contained n = 842 words. With the final multivariate word by paper matrix, we conducted a detrended correspondence analysis with R software to derive a visualization of the principal gradients found within the abundance of words in the papers (Hill and Gauch 1980). Using the detrended correspondence analysis to visualize the first two axes of the multivariate space, we in addition clustered papers into groups that shared the same wording, using Wards clustering (Abson et al. 2014). Different groups were visualized within the ordination by different colours. Detrended correspondence analysis is a standard ordination analysis predominantly used in ecology with sparse datasets, extracting main gradients out of multivariate datasets based on reciprocal averaging (Hill and Gauch 1980). Statistical significance of cluster groups was supported by an indicator species analysis, which allowed the identification of words that were significantly occurring and hence indicating a specific cluster group.

RESULTS

Geographical and temporal distribution

The 81 papers investigated 82 case studies (1 paper with 2 case studies). The biggest part of the research was conducted in North America with 31 papers (38%), followed by Asia with 13 papers (16%), Africa with 11 papers (13.5%), South America with 11 papers (13.5%), Oceania with 10 papers (12%), and Europe with only 6 papers (7%; Fig. 2). We also identified a general increase in publications per year, especially since 2008 (Fig. 2).

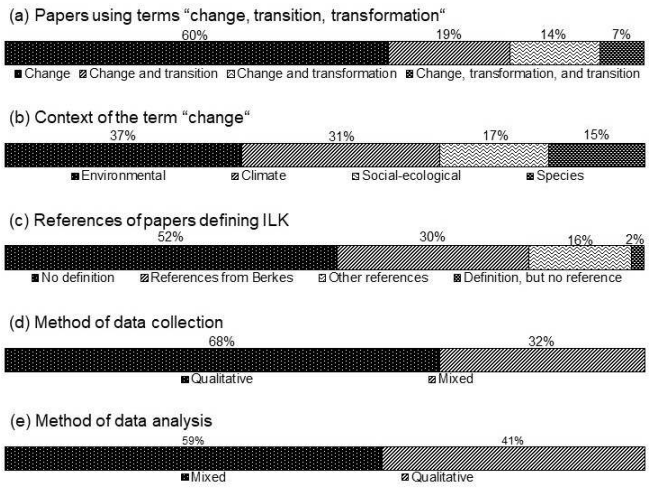
Fig. 2. Geographical distribution of case studies (n = 82, because one paper investigated two case studies) and temporal distribution of publications (n = 81).



Understandings of transformations

We found few empirical papers that included ILK to understand transformations among the reviewed scientific papers. The application of the words "transformation," "transition," and "change" in the reviewed papers showed a clear focus on the use of the word "change" in combination with ILK. In all 81 papers (100%) the word "change" was mentioned, "transition" in 21 papers (26%), and "transformation" in 17 papers (21%; Appendix 4). In 49 papers (60%), only "change" was used (Fig. 3a). The combination of "change" and "transition" was used in 15 papers (19%). The words "change" and "transformation" were used together in 11 papers (14%). Six papers (7%) used all three words.

Fig. 3. Overview of results (n = 81). Note ILK = indigenous and local knowledge.



Only four papers (5%) used the term "transformation" in the sense of a social-ecological system change (i.e., Kassam 2009, Andrachuk and Armitage 2015, Apgar et al. 2015, Jandreau and Berkes 2016). Eleven papers (14%) used "transformation" or "transition" in the sense of a system change, but did not define it, such as a transition of a pastoral system (Homann et al. 2008). Furthermore, 11 papers (14%) used these terms in ecological contexts, such as "transition of temperature and landscape" or "environmental transformations" (e.g., Chalmers and Fabricius 2007, Fernández-Llamazares et al. 2015, de Almeida et al. 2016). Additionally, the "transformation of living conditions" was researched in four papers (5%; e.g., Klein et al. 2014, Herman-Mercer et al. 2016).

Regarding the term "change" the predominant focus of the analyzed literature body lies in observations and perceptions of environmental (n = 30, 37%) or climatic (n = 25, 31%) changes by ILK holders (Fig. 3b). The papers dealing with environmental changes focus, for instance, on marine (e.g., Taylor et al. 2011, Moshy and Bryceson 2016) or terrestrial environments (e.g., Paré et al. 2010, Kgosikoma et al. 2012). Papers focusing on climatic change often investigated indigenous and local perceptions of climate change and interpretations of climate variables, such as temperature or precipitation (e.g., Boillat and Berkes 2013, Boissière et al. 2013). Fourteen papers (17%) dealt with social-ecological changes, for example, changing livelihood circumstances due to environmental alterations (e.g., Ford et al. 2006, Kassam 2009). The remaining 12 papers (15%) dealt with change in terms of changes in species abundance and behavior (e.g., Kendrick et al. 2005, Carter and Nielsen 2011).

Conceptualization of indigenous and local knowledge

The term of ILK summarizes all the different descriptions of indigenous, traditional, or local knowledge systems occurring in the reviewed literature body. Some authors constrain to one description, for instance, traditional ecological knowledge (Gill and Lantz 2014) or indigenous knowledge (Wilson et al. 2015), but most of the papers (n = 60, 74%) used the different terms synonymously.

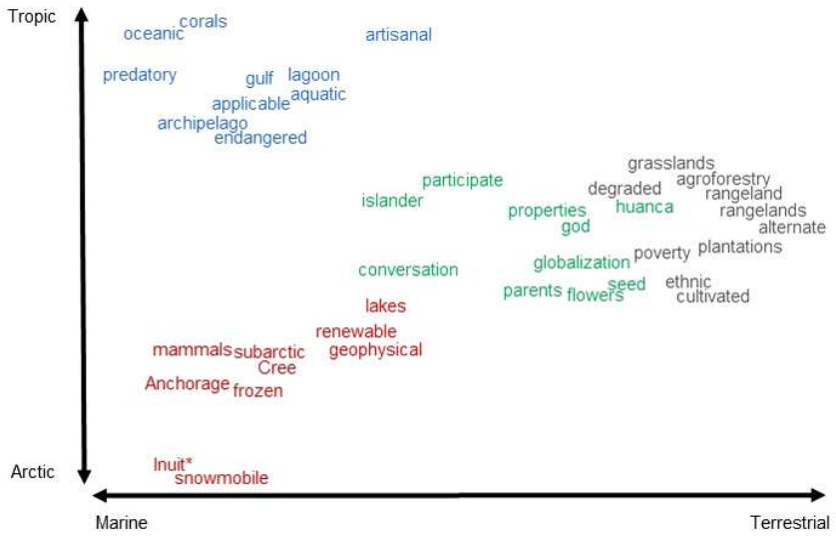
Only 39 papers (48%) explicitly defined ILK (Fig. 3c), of which 24 papers (30%) referenced literature from Fikret Berkes who defined ILK (or traditional ecological knowledge) as "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes 2018:8). Thirteen papers (16%) used other definitions and references to define ILK, for instance, ILK defined as "place-based knowledge that is rooted in local cultures and generally associated with long-settled communities which have strong ties to their natural environments" (Orlove et al. 2010:244). Two papers (2%) did not link their definition of ILK to other literature.

Methodological approach in indigenous and local knowledge research

The methodological approach of the data collection in the reviewed literature showed a strong tendency to qualitative methods (Fig. 3d). Fifty-five papers (68%) used qualitative methods exclusively, particularly semistructured interviews and focus-group discussions, and 26 papers (32%) conducted a mix of qualitative and quantitative methods.

In 48 papers (59%), data analysis included both qualitative and quantitative methods, indicating that data collected through qualitative methods often were analyzed through statistical methods (Fig. 3e). In 33 papers (41%), solely qualitative methods were used, such as content analysis of the interviews (e.g., McCarthy et al. 2012, Altschuler and Brownlee 2016).

Fig. 4. Research clusters resulting from detrended correspondence analysis: research in Arctic environments (red), research in terrestrial environments (green), research in coastal environments (blue), and research in grass and rangeland environments (gray). *wording adjusted.



Clusters of scientific literature on transformations and indigenous and local knowledge

The cluster analysis, which is visualized in the detrended correspondence analysis of the words used in the reviewed papers, yielded four distinct research clusters: (1) research in Arctic environments (red), (2) research in terrestrial environments (green), (3) research in coastal environments (blue), and (4) research in grass and rangeland environments (gray). These clusters were distributed along two axes: (1) marine vs. terrestrial environments (X-axis) and (2) Arctic vs. tropic climatic conditions (Y-axis; Fig. 4). Appendices 5 and 6 present more information for each research cluster (e.g., geographical distribution of case studies, key research aspects) and a complete list of significant indicator words, respectively.

The cluster of research in Arctic environments comprised 26 papers (32%; red). This cluster focused solely on case studies in Arctic environments, including Alaska, the Canadian Arctic, and Siberia. Actors involved in the research were members of different indigenous communities in Arctic regions, such as the Inuit, the Cree, or the Chipewyan Dene. The key research aspects of this cluster were observations and understandings of changing climatic and environmental conditions. Because of the widespread subsistence activity of hunting mammals on land and ice, especially changes in sea ice and the distribution and abundance of different animal populations in the Arctic regions were objects of research in this cluster.

The cluster of research in terrestrial environments included 22 papers (27%; green). The spatial focus of this cluster lay mostly in case studies in Oceania and South America. Actors involved in this research cluster were either from indigenous communities or local communities. The research focused on the perception of climatic changes and the adaptive capacity of the local communities to these changes. Unlike the other clusters, this cluster paid high attention to societal aspects and culturally important issues in the communities, such as education, globalization, government, beliefs, spirituality, and traditions.

The cluster of research in coastal environments comprised 14 papers (17%; blue). This cluster focused strongly on coastal and island regions of all continents. Actors involved in the research of this cluster included local fishers or divers with local ecological knowledge of the marine environments in these regions. Key research objects in this cluster were changes in marine ecosystems, such as coral reefs and lagoons, which served as habitats for endangered fish and plant species, and appropriate management strategies for a positive development of these ecosystems.

The cluster of research in grass and rangeland environments included 19 papers (24%; gray). The spatial focus of this cluster lay in Africa and Asia. Participants were predominantly actors with an agricultural background, for instance, local herders, smallholder farmers, and households owning small land areas or livestock. Hence, the research focus lay in environmental changes of grass- and rangelands and the consequences for livestock management and farming. Problematic issues mentioned in this cluster were desertification and vegetation changes as well as mitigation processes against these changes.

DISCUSSION

Three major insights gained through our literature review: (1) a lack of research to understand transformations from the perspective of ILK systems, (2) challenges of researching ILK in contexts of change, and (3) a pledge for a more plural understanding of transformation. Based on these insights we formulated relevant starting points for future research.

Lack of research to understand transformations from the perspective of indigenous and local knowledge systems

This study demonstrates a gap in understanding transformations from the perspective of ILK systems in the sustainability transformation literature. Despite our comprehensive search

string (Appendix 1), we identified only four papers (5%) in our review that applied indigenous and local observations of change to investigate transformations from social-ecological literature (i.e., Kassam 2009, Andrachuk and Armitage 2015, Apgar et al. 2015, Jandreau and Berkes 2016). This result might be explained by two main reasons: (1) potential caveats of this study, and (2) an actual lack of consideration of ILK in sustainability transformation research.

The first explanation relates to an important caveat of this research, which is that we only sampled peer-reviewed papers published in English referenced on Scopus. This sampling method can lead to a systematic sampling bias because the consideration of ILK to foster sustainability transformations could mostly appear outside of this body of academic literature and in languages other than English (Vinyeta and Lynn 2013). Research on ILK with a focus on understanding transformations, for instance, from cultural anthropology or ethnobiology may exist in other sources, such as books or papers that are not accessible through Scopus and are written in other languages. A similar sampling bias has previously been reported in systematic reviews of ILK with regard to conservation initiatives (Benyei et al. 2020). Furthermore, most of the case studies of the reviewed papers conduct research in North America, which might also be a bias. This would be true if the reason for this is the fact that North America is generally the continent with the highest amount of academic literature worldwide (King 2004), which therefore may also lead to more research in this area. However, another possible reason for this focus could be that the regions of Alaska and the Canadian Arctic are some of the most affected regions by global climate change worldwide (Hinzman et al. 2005). The loss of sea ice due to climate change has an especially strong impact on the livelihood of indigenous peoples and local communities in Arctic regions. Because indigenous and local observations of climate change and its consequences are treated a lot in the reviewed literature body, it could be a logical outcome that case studies in these affected regions dominate the reviewed literature.

The second explanation could be that sustainability transformation research has indeed not engaged thoroughly with ILK yet despite the recognition that more plural perspectives and worldviews need to be considered to advance sustainability transformation research (Loorbach et al. 2017). We only found four papers from social-ecological transformations literature that investigated transformations with ILK. Indigenous and local understandings of transformation have the potential to relate the values, contexts, worldviews, and cultures of indigenous peoples and local communities to the transformations discourse (Apgar et al. 2015), such as in environmental governance (Brondizio and Le Tourneau 2016), climate change (Savo et al. 2016), conservation (Benyei et al. 2020), and resource management research (Ban et al. 2018). The engagement of ILK in sustainability transformation research is still emerging and in its infancy. Including more than simply Western scientific knowledge systems to change perspectives and find solutions for sustainability challenges still gets relatively little attention (Golden et al. 2015). However, the number of recent papers that showcase the value of bridging ILK and scientific knowledge for climate change mitigation and biodiversity conservation is increasing (Gavin et al. 2015, Brondizio and Le Tourneau 2016, Garnett et al. 2018, Hill et al. 2019). A challenge is that in contrast to scientific knowledge, ILK is often regarded as "subjective, arbitrary, and based on qualitative observations of phenomena and change" (Mistry and Berardi 2016:1275). Also, current research approaches that try to apply ILK are often driven by Western research methods and political agendas, such as predominant conservation and development approaches, which is questionable because all knowledge is value driven and linked to socially situated actors (Weiss et al. 2013, Mistry and Berardi 2016). For example, the perception and interpretation of climate change is very different whether the observation approach is local or global, or from an ILK or scientific knowledge perspective (Byg and Salick 2009). Another example is from Golden et al. (2014), who presented the challenge of mutual understanding and negative connotations to Western terms and concepts. In their study, they described the absence of the word or concept "adaptation" in the culture of First Nations in Canada and argued that it makes a common approach to research on adaptation almost impossible.

Challenges of researching indigenous and local knowledge in contexts of change

Our results support the trend of increasing research that engages with ILK in contexts of environmental, climate, social-ecological, and species change in different environments (Figs. 2, 3, 4). However, our results indicate three challenges that accompany research with ILK in contexts of change: (1) the added value of ILK, (2) the use of qualitative methods, and (3) the focus on change and adaptation.

First, understanding the added value of ILK for sustainability research is difficult because ILK is very different from scientific knowledge (Berkes 2018) and in our review, 42 papers (52%) did not even provide a definition for ILK. Indigenous and local knowledge is "local and context-specific, transmitted orally or through imitation and demonstration, adaptive to changing environments, collectivized through a shared social memory, and situated within numerous interlinked facets of people's lives" (Mistry and Berardi 2016:1274). However, the trend is still to assimilate ILK within scientific knowledge instead of acknowledging ILK as an equally relevant knowledge system (Tengö et al. 2014, Mistry and Berardi 2016). Hence, engaging with ILK means encountering different worldviews, practices, ethics, identities, power relations, and rights (Tengö et al. 2017). The results from the detrended correspondence analysis also show that the green cluster (i.e., terrestrial environments) was the only one that presented social aspects of ILK, such as belief, culture, and language (Fig. 4; Appendix 5).

Second, the different methodological approaches used in the reviewed papers show the predominant use of qualitative methods both in data collection and data analysis, which indicates the complexity involved in investigating and understanding ILK. Csonka (2005) mentioned the mostly oral character of these knowledge systems, which requires the use of qualitative methods and the contribution of "qualitative, historical field data" (Vinyeta and Lynn 2013:14). However, Davis and Ruddle (2010) criticized that the standards of accountability and transparency for research on ILK need to be improved, starting with "the requirement that researchers provide descriptions of research designs and methodologies sufficient to enable assessment of the reliability and representativeness of findings, and to facilitate comparison, generalization, and evidence-based conclusions"

(Davis and Ruddle 2010:892). Others see great potential in the open and qualitative character of research on ILK because of the "readiness, reliability and low cost" of associated methods (Hallwass et al. 2013:402) and the possibility to support and complement the usually more quantitative data of Western scientific research (Moshy and Bryceson 2016). Furthermore, qualitative approaches may also be more likely to capture and articulate aspects of ILK systems that are holistic and not directly commensurable with reductionist science (Whyte et al. 2016).

Third, the detrended correspondence analysis revealed four research clusters that generally focus on observing changes with indigenous peoples and local communities in Arctic, terrestrial, coastal, and grass and rangeland environments (Fig. 4; Appendices 5, 6). Research on change that includes ILK can be better differentiated by the environments in which the research is conducted than by the theoretical or methodological approaches used. This indicates greater diversity of the biophysical conditions studied compared to the theoretical and methodological approaches used. The focus of observing change lays with natural phenomena, such as melting of ice, change of flora and fauna, and climate variations. This research on change in different environments tends to be driven more by natural science research, such as ecology or biology, with less focus on social aspects. Additionally, the research clusters generally focus on the practices of indigenous peoples and local communities in their respective environments and how these practices have adapted to changes. One example is the change in hunting practices of the Inuvialuit people in Canada's Western Arctic due to climate change (Berkes and Jolly 2002). However, none of the research clusters indicates a focus on understanding which practices or strategies indigenous peoples and local communities apply to navigate and manage their environments toward desired states, i.e., often breaking out of and transforming negative situations.

Summing up, future sustainability transformation research that engages with ILK should be transparent about how ILK is understood and which research designs and methodologies are applied. Research, which engages with ILK, needs to also apply different innovative methods to deal with the complexity of ILK and to make insights from local and place-specific ILK useful for other regions of the world that also undergo processes of change. Possible methods could include the analysis of stories and songs that are a repository of ILK (Fernández-Llamazares and Cabeza 2018, Fernández-Llamazares and Lepofsky 2019). Additionally, insights from more contextualized and place-based research modes such as transdisciplinary research might provide helpful approaches (Lang et al. 2012, Balvanera et al. 2017*a*). With the societal problems or phenomena as a point of departure and not a specific theory or methodology, transdisciplinarity can serve as a research practice that allows for collaboration between ILK systems and scientific knowledge systems on equal footing. Transdisciplinary research highlights close collaboration between scientific as well as societal actors and is therefore promoted by global sustainability research initiatives (e.g., IPBES, Future Earth) to cocreate knowledge for sustainability transformations (Mauser et al. 2013, Pascual et al. 2017).

Need for plural understanding of transformations

Sustainability transformation research and practice aims at changing how people interact within the systems they live in, such as food or energy systems. For transformative change to improve the living conditions for people from different knowledge systems, it becomes critical to connect with their view on how the world works and changes, how to act for transformations (i.e., what to do to foster change), and what just, equitable, and sustainable futures could be (Braun 2015, Blythe et al. 2018). Thus, we argue for a plural understanding of transformations because this (1) could substantially improve understandings of transformations, (2) is ethically required, (3) could increase agency for contributing to sustainability transformations, and (4) could support research on transformative change.

First, we believe that including people with different knowledge systems can improve the sustainability transformation discourse and practices because it potentially widens the conceptual understanding and provides more variety for actions to foster just, equitable, and sustainable futures. The scientific sustainability transformation discourse has its own understandings or approaches to transformations (Feola 2015), such as social-ecological transformations, sustainability transitions, transformative adaptation, and sustainability pathways (Table 1). Due to different disciplinary roots, they apply different perspectives on transformations (e.g., place-based, sectoral), foci (e.g., social-ecological systems, human development), and pursue different aims (e.g., resilience, sustainable pathways; Table 1; Patterson et al. 2017). What unites them is their call for large-scale societal change toward the normative goal of sustainability and a scientific approach to transformations by viewing transformations as nonlinear, complex, long-term, multilevel, multiphase, and cross-scale processes (Olsson et al. 2014, Loorbach et al. 2017). Indigenous and local understandings of transformation could bring additional perspectives, foci, and aims concerning transformations due to alternative normative goals and emotional as well as spiritual connections to nature (Reid et al. 2006, Gray 2016).

The dominant sustainability transformation discourse aims for the normative goal of sustainability (Loorbach et al. 2017), which is primarily influenced by Western worldviews, values, and knowledge systems (Kothari et al. 2014). A plural understanding of transformation could carefully consider and reflect on alternative normative goals, such as "Buen Vivir," which is a concept that captures a culture of life for collective well-being of people and nature together with different interpretations across South America (Gudynas 2011, Monni and Pallottino 2015), or "Ubuntu," which is a moral concept of caring that connects humanity and has origins in South Africa (Metz 2011). Normative goals of transformations vary between people in different places and from diverse knowledge systems and worldviews. They may also vary among different actors within a place. Perceptions of the normative goal shape possible and preferred actions that may foster change toward a desired direction. Engaging with indigenous peoples and local communities for transformation can therefore be a promising endeavor to collaboratively explore alternative actions for and desired directions of transformations. A reflexive view on the normative aspect of transformations is critical to consider for scholars conducting social-ecological transformations, sustainability transitions, transformative adaptation, or sustainability pathways research in places where indigenous peoples and local communities live, to avoid repeating or reinforcing previous or existing patterns of injustice and marginalization.

Indigenous and local knowledge systems can also provide guidance for how to include emotional and spiritual aspects into the often very positivistic sustainability transformation discourse because ILK systems are knowledge-action-belief complexes and entail different conceptualizations of human-nature connectedness (Gadgil et al. 1993, Reid et al. 2006, Gray 2016, Berkes 2018). Recent literature highlights that successful transformations will not only rely on changing structures and practices, but also on the change of human-nature connectedness as well as values and mindsets (Abson et al. 2017, Horcea-Milcu et al. 2019, Ives et al. 2020). The sustainability transformation literature discusses the need to change people's connection to nature as well as values and mindsets instead of only developing and scaling out new social-technical innovations, such as new technologies (O'Brien 2016, Olsson et al. 2017). However, discussions on how to achieve these changes for transformations at the societal level are still in its infancy. Indigenous peoples and local communities have very different connections to nature and worldviews than do Western societies. Some of them regard themselves as one unit with nature with deep relations to their place and all living beings, which includes mountains, rivers, lakes, and animals (Berkes 2018). These different human-nature connections and worldviews might provide critical reflections for the current Western scientific approaches to transformations (Table 1). A possible reflection could be on how to understand relations between people and nature (e.g., one unit versus divided, or as biocultural relations; Sterling et al. 2017), or the systems of interest (e.g., social-technical systems), which in science often separate people from nature and thus insufficiently recognize the relations and patterns between living beings. Finally, such reflections could lead to new actions to foster transformations that go beyond scaling out of new technologies (e.g., renewable energies) and changing dominant practices by including, for instance, spiritual and emotional values of nature (i.e., scaling deep) or by emphasizing local identity, place, and kinship relations (i.e., scaling down).

Second, there is a strong ethical imperative for engaging with different people and actors concerned with transformations and their aspirations, knowledge, and conditions (Castree et al. 2014, Daedlow et al. 2016). A more collaborative approach to working with indigenous peoples and local communities as partners, might dismantle the power imbalance between ILK and scientific knowledge concerning the notion of transformations (Tengö et al. 2017). This is particularly important in engagement with indigenous peoples and local communities, who have often been marginalized and deprived of livelihoods and self-governance in the name of development and change (Smith 2012). Working toward a plural understanding of transformations might acknowledge cognitive justice, which legitimizes the existence of different knowledge systems, suggests going beyond epistemic supremacy, and is part of processes of decolonizing knowledge (de Sousa Santos 2008, Rodriguez 2017). Cognitive justice "demands recognition of knowledges, not only as methods but as ways of life. This presupposes that knowledge is embedded in an ecology of knowledges, where each knowledge has its place, its claim to a cosmology, its sense as a form of life. In this sense knowledge is not something to be abstracted from a culture as a life form; it is connected to a livelihood, a life cycle, a lifestyle; it determines life chances" (Shiv Visvanathan in Rodriguez 2017:2). A rewarding yet challenging endeavor for sustainability transformation researchers is to reach out to indigenous peoples and local communities and learn from their worldviews and knowledge systems what transformations possibly mean for them, and from there to explore a common ground for transformations to sustainability or any other normative goal. Working with indigenous peoples and local communities as partners can be key to better understand and act for transformations. For instance, the collaboratively developed fire management system in the Canaima National Park in Venezuela shows how ILK and practices of fire management from the Pemon indigenous peoples informed a counter narrative of landscape change that led to a shift in the environmental discourse and policy making regarding fire management in the park (Rodriguez 2017). Another example is related to effective environmental governance (Brondizio and Le Tourneau 2016, Garnett et al. 2018). Indigenous peoples and local communities manage vast areas of land, ecosystems, and biodiversity, and in many cases, their governance systems are sources of sustainable practices, developed and implemented by communities with limited external involvement and embedded in their worldviews (Berkes 2018, Mistry and Berardi 2016, Timoti et al. 2017).

Third, by involving people with diverse knowledge systems, we hope to also draw attention to the challenges related to agency in transformations (Westley et al. 2013, Olsson 2017). Understanding the creation and distribution of agency between different people across scales is key to work collectively and inclusively toward just, equitable, and sustainable futures (Moore 2017). The notion of transformation in sustainability science is currently promoted dominantly by Western scientific knowledge systems, which limits the distribution of agency. A plural understanding of transformations, should involve a more diverse and inclusive set of actors representing diverse knowledge systems, and it should lead to more diverse actions to solve current sustainability problems, other than the often applied approach of solving problems with technological innovations.

Fourth, plural understandings of transformations could contribute to research on transformative change that specifically collaborates with indigenous peoples and local communities. The number of studies investigating transformations is increasing and predicted to grow in the future (Köhler et al. 2019). Most recently, the IPBES outlined, in its next work program until 2030, to assess "factors in human society, at both the individual and collective levels, that can be leveraged to bring about (...) transformative change in favour of biodiversity while taking into account broader social and economic imperatives in the context of sustainable development" (IPBES 2019:18). One explicit ambition from IPBES is to include knowledge from natural sciences, social sciences, humanities, and ILK systems in its assessments through participation and inclusiveness (Díaz et al. 2015, Díaz-Reviriego et al. 2019). Assessing factors that lead to transformative change in favor of biodiversity with ILK systems will entail understanding transformation and transformative change from the perspective of indigenous peoples and local communities as a prerequisite. However, our results show that this is currently neglected in research. We therefore see epistemological, ontological, and methodological challenges that an assessment of transformative change, which includes ILK, could face if it considers cognitive justice and wants to avoid the supremacy of Western scientific knowledge systems.

In summary, we need a plural understanding of transformations because the sustainability challenges we face are as diverse as people are. It is important to be inclusive to different kinds of engagement with sustainability transformations to avoid a supremacy of Western scientific knowledge systems in identifying and prioritizing ways forward. Bridging diverse knowledge systems concerning transformations, could lead to involvement of more people, increased mutual understanding, cocreation of actions across knowledge systems with stronger impact and effectiveness, and support collaborative research on transformative change. As the urgency to solve sustainability problems increases, collaborations between diverse knowledge systems may provide helpful ways of thinking about how to foster transformations.

Future research

Our literature review reveals that the discourse on sustainability transformations lacks understandings of transformations from ILK systems. To address this gap, we suggest two concrete research activities to move forward toward a more plural understanding of transformations: (1) exploring other sources to understand sustainability transformations from an ILK perspective through consultations and collaborations with experts on ILK (i.e., researchers who have studied ILK systems) and ILK holders (i.e., knowledge holders representing their knowledge system, its integrity, and rights), and (2) active engagement of ILK holders and ILK experts in research processes (Tengö et al. 2017). These two research endeavors could also reveal more local understandings of transformations, which in return can potentially contribute to a better understanding of global transformations (Balvanera et al. 2017*b*).

First, consultations and collaborations with experts on ILK and ILK holders who are familiar with the concept of sustainability transformation and who have worked with indigenous peoples and local communities for a long time in their research and other activities can reveal other sources and existing work on different understandings of transformations. The experts on ILK and ILK holders should be used to seeing ILK and scientific knowledge as both legitimate and complementary. Particularly important persons to consult are indigenous scholars and ILK holders with experience in interacting with science and policy, for example in the Convention on Biological Diversity and IPBES. The consultations and collaborations could provide entry points to potential alternative understandings, concepts, and ways to describe and talk about transformation among indigenous peoples and local communities. This could provide insights about diverse views on human-nature connections and alternative perspectives on time, future, change, scale, and amplification (i.e., a different scaling understanding to foster transformations), which are fundamental elements of the Western scientific understanding of transformations.

Second, active engagement with ILK holders and experts on ILK could deepen and broaden the understanding of practices and strategies for transformation as well as contribute to shifting the power dynamics between knowledge systems and addressing the ethical requirements in sustainability transformations research. Tengö et al. (2017) emphasized the need to engage with the actors and institutions that represent ILK systems, rather than scientist interpreting ILK and the main interfaces with scientific and other knowledge systems (Tengö et al. 2017). One possible approach to bridge different understandings of transformations is the multievidence base approach, which recommends five tasks for successful collaborations across knowledge systems: to mobilize, translate, negotiate, synthesize, and apply (Tengö et al. 2017). This set of tasks can guide a knowledge collaboration to facilitate mutual respect and understanding, usefulness for all actors involved and thus both expand the joint knowledge base for transformation as well as strengthen the ethical practices in sustainability transformation research. Joint and deepened understanding can also create a foundation for agency for transformation. Such an encounter of knowledge holders would contribute to going beyond the dichotomy and power asymmetry of ILK versus scientific knowledge (Agrawal 1995). It would help to see the different knowledge systems as equally relevant and complementary, to bridge them (rather than integrate), and hopefully at the end enable them to work together. Furthermore, it would also increase cognitive justice concerning transformations to avoid suppressing nonscientific knowledge systems and amplifying epistemic supremacy of Western knowledge systems (de Sousa Santos et al. 2008, Rodriguez 2017). As discussed, fostering sustainability is only one possible goal besides others that could arise from traditionally marginalized groups, such as Buen Vivir or Ubuntu. By going beyond acknowledging ILK systems within their own frames and worldviews and treating them as an equally relevant and parallel type of knowledge with differing fundamentals (Berkes et al. 2002, Leonard et al. 2013, Tengö et al. 2014), a basis for true collaboration could be built for an enhanced understanding and fostering toward just, equitable, and sustainable futures.

CONCLUSION

This systematic literature review investigated the current role of ILK in sustainability transformation literature. Our study reveals a research gap in understanding transformations from the perspective of ILK systems. We gained an understanding of how ILK is studied in different contexts of change, which is currently applying ILK to confirm and complement scientific knowledge on environmental, climate, social-ecological, or species change. We propose future research endeavors that could yield a plural understanding of transformations and hence, provide an enriched picture of how we could foster inclusive transformations in times of pressing sustainability challenges. Collaborating with indigenous peoples and local communities for transformations has the potential to substantially enrich and question scientific approaches to transformations by providing, for instance, alternative and complementary goals to sustainability, such as Buen Vivir or Ubuntu. Sustainability transformation research needs to avoid the risk of neglecting nonscientific knowledge systems and the risk of perpetuating the supremacy of Western scientific knowledge systems as we endeavor to foster transformations toward just, equitable, and sustainable futures.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/11305

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LITERATURE CITED

Abson, D. J., J. Fischer, J. Leventon, J. Newig, T. Schomerus, U. Vilsmaier, H. von Wehrden, P. Abernethy, C. D. Ives, N. W. Jager, and D. J. Lang. 2017. Leverage points for sustainability transformation. *Ambio* 46(1):30-39. https://doi.org/10.1007/s13280-016-0800-y

Abson, D. J., H. Wehrden, S. Baumgärtner, J. Fischer, J. Hanspach, W. Härdtle, H. Heinrichs, A. M. Klein, D. J. Lang, P. Martens, and D. Walmsley. 2014. Ecosystem services as a boundary object for sustainability. *Ecological Economics* 103:29-37. https://doi.org/10.1016/j.ecolecon.2014.04.012

Agrawal, A. 1995. Dismantling the divide between indigenous and scientific knowledge. *Development and Change* 26(3):413-439. https://doi.org/10.1111/j.1467-7660.1995.tb00560.x

Altschuler, B., and M. Brownlee. 2016. Perceptions of climate change on the island of Providencia. *Local Environment* 21 (5):615-635. https://doi.org/10.1080/13549839.2015.1004165

Andrachuk, M., and D. Armitage. 2015. Understanding social-ecological change and transformation through community perceptions of system identity. *Ecology and Society* 20(4):26. http://dx.doi.org/10.5751/ES-07759-200426

Apgar, M. J., W. Allen, K. Moore, and J. Ataria. 2015. Understanding adaptation and transformation through indigenous practice. *Ecology and Society* 20(1):45. http://dx.doi.org/10.5751/ES-07314-200145

Balvanera, P., R. Calderón-Contreras, A. J. Castro, M. R. Felipe-Lucia, I. R. Geijzendorffer, S. Jacobs, B. Martín-López, U. Arbieu, C. I. Speranza, B. Locatelli, N. P. Harguindeguy, I. R. Mercado, M. J. Spierenburg, A. Vallet, L. Lynes, and L. Gillson. 2017*a*. Interconnected place-based social-ecological research can inform global sustainability. *Current Opinion in Environmental Sustainability* 29:1-7. https://doi.org/10.1016/j.cosust.2017.09.005

Balvanera, P., T. M. Daw, T. A. Gardner, B. Martín-López, A. V Norström, C. Ifejika Speranza, M. Spierenburg, E. M. Bennett, M. Farfan, M. Hamann, J. N. Kittinger, T. Luthe, M. Maass, G. D. Peterson, and G. Perez-Verdin. 2017*b*. Key features for more successful place-based sustainability research on social-ecological systems: a Programme on Ecosystem Change and Society (PECS) perspective. *Ecology and Society* 22(1):14. https://doi.org/10.5751/ES-08826-220114

Ban, N. C., A. Frid, M. Reid, B. Edgar, D. Shaw, and P. Siwallace. 2018. Incorporate indigenous perspectives for impactful research and effective management. *Nature Ecology and Evolution* 2 (11):1680-1683. https://doi.org/10.1038/s41559-018-0706-0

Benyei, P., G. Arreola, and V. Reyes-García. 2020. Storing and sharing: a review of indigenous and local knowledge conservation initiatives. *Ambio* 49:218- 230. https://doi.org/10.1007/s13280-019-01153-6

Berkes, F. 2018. *Sacred ecology*. Fourth edition. Routledge, New York, New York, USA.

Berkes, F., J. Colding, and C. Folke, editors. 2002. *Navigating social-ecological systems: building resilience for complexity and change*. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9780511541957

Berkes, F., and D. Jolly. 2002. Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. *Ecology and Society* 5(2):18. https://doi.org/10.5751/ES-00342-050218

Blythe, J., J. Silver, L. Evans, D. Armitage, N. J. Bennett, M.-L. Moore, T. H. Morrison, and K. Brown. 2018. The dark side of transformation: latent risks in contemporary sustainability discourse. *Antipode* 50(5):1206-1223. https://doi.org/10.1111/anti.12405

Boillat, S., and F. Berkes. 2013. Perception and interpretation of climate change among Quechua farmers of Bolivia: indigenous knowledge as a resource for adaptive capacity. *Ecology and Society* 18(4):21. https://doi.org/10.5751/ES-05894-180421

Boissière, M., B. Locatelli, D. Sheil, M. Padmanaba, and E. Sadjudin. 2013. Local perceptions of climate variability and change in tropical forests of Papua, Indonesia. *Ecology and Society* 18(4):13. https://doi.org/10.5751/ES-05822-180413

Braun, B. 2015. Futures: imagining socioecological transformation: an introduction. *Annals of the Association of American Geographers* 105(2):239-243. http://dx.doi.org/10.1080/00045608.2014.1000893

Brondizio, E. S., and F.-M. Le Tourneau. 2016. Environmental governance for all. *Science* 352(6291):1272-1273. http://dx.doi.org/10.1126/science.aaf5122

Byg, A., and J. Salick. 2009. Local perspectives on a global phenomenon - climate change in eastern Tibetan villages. *Global Environmental Change* 19(2):156-166. http://dx.doi.org/10.1016/j.gloenvcha.2009.01.010

Carter, B. T. G., and E. A. Nielsen. 2011. Exploring ecological changes in Cook Inlet beluga whale habitat though traditional and local ecological knowledge of contributing factors for population decline. *Marine Policy* 35(3):299-308. http://dx.doi.org/10.1016/j.marpol.2010.10.009

Castree, N., W. M. Adams, J. Barry, D. Brockington, B. Büscher, E. Corbera, D. Demeritt, R. Duffy, U. Felt, K. Neves, P. Newell, L. Pellizzoni, K. Rigby, P. Robbins, L. Robin, D. B. Rose, A. Ross, D. Schlosberg, S. Sörlin, P. West, M. Whitehead, and B. Wynne. 2014. Changing the intellectual climate. *Nature Climate Change* 4:763-768. https://doi.org/10.1038/nclimate2339

Chalmers, N., and C. Fabricius. 2007. Expert and generalist local knowledge about land-cover change on South Africa's wild coast: can local ecological knowledge add value to science? *Ecology and Society* 12(1):10. https://doi.org/https://doi.org/10.5751/es-01977-120110

Cornell, S., F. Berkhout, W. Tuinstra, J. D. Tàbara, J. Jäger, I. Chabay, B. de Wit, R. Langlais, D. Mills, P. Moll, I. M. Otto, A. Petersen, C. Pohl, and L. van Kerkhoff. 2013. Opening up knowledge systems for better responses to global environmental change. *Environmental Science and Policy* 28:60-70. http://dx.doi.org/10.1016/j.envsci.2012.11.008

Cruikshank, J. 2001. Glaciers and climate change: perspectives from oral tradition. *Arctic* 54(4):377-393. https://doi.org/10.14430/arctic795

Csonka, Y. 2005. Changing Inuit historicities in West Greenland and Nunavut. *History and Anthropology* 16(3):321-334. http://dx.doi.org/10.1080/02757200500207458

Daedlow, K., A. Podhora, M. Winkelmann, J. Kopfmüller, R. Walz, and K. Helming. 2016. Socially responsible research processes for sustainability transformation: an integrated assessment framework. *Current Opinion in Environmental Sustainability* 23:1-11. http://dx.doi.org/10.1016/j.cosust.2016.09.004

Davis, A., and K. Ruddle. 2010. Constructing confidence: rational skepticism and systematic enquiry in local ecological knowledge research. *Ecological Applications* 20(3):880-894. http://dx.doi.org/10.1890/09-0422.1

de Almeida, G. M. A., M. A. Ramos, E. L. Araújo, C. Baldauf, and U. P. Albuquerque. 2016. Human perceptions of landscape change: the case of a monodominant forest of *Attalea speciosa* Mart ex. Spreng (Northeast Brazil). *Ambio* 45(4):458-467. https://doi.org/10.1007/s13280-015-0761-6

de Sousa Santos, B., editor. 2008. *Another knowledge is possible: beyond northern epistemologies*. Verso, London, UK.

de Sousa Santos, B., J. A. Nunes, and M. P. Meneses. 2008. Opening up the canon of knowledge and recognition of difference. Pages xvix-1 *in* B. de Sousa Santos, editor. *Another knowledge is possible: beyond northern epistemologies*. Verso, London, UK.

Díaz, S., S. Demissew, J. Carabias, C. Joly, M. Lonsdale, N. Ash, A. Larigauderie, J. R. Adhikari, S. Arico, A. Báldi, A. Bartuska, I. A. Baste, A. Bilgin, E. Brondizio, K. M. A. Chan, V. E. Figueroa, A. Duraiappah, M. Fischer, R. Hill, T. Koetz, P. Leadley, P. Lyver, G. M. Mace, B. Martin-Lopez, M. Okumura, D. Pacheco, U. Pascual, E. S. Pérez, B. Reyers, E. Roth, O. Saito, R. J. Scholes, N. Sharma, H. Tallis, R. Thaman, R. Watson, T. Yahara, Z. A. Hamid, C. Akosim, Y. Al-Hafedh, R. Allahverdiyev, E. Amankwah, S. T. Asah, Z. Asfaw, G. Bartus, L. A. Brooks, J. Caillaux, G. Dalle, D. Darnaedi, A. Driver, G. Erpul, P. Escobar-Eyzaguirre, P. Failler, A. M. M. Fouda, B. Fu, H. Gundimeda, S. Hashimoto, F. Homer, S. Lavorel, G. Lichtenstein, W. A. Mala, W. Mandivenyi, P. Matczak, C. Mbizvo, M. Mehrdadi, J. P. Metzger, J. B. Mikissa, H. Moller, H. A. Mooney, P. Mumby, H. Nagendra, C. Nesshover, A. A. Oteng-Yeboah, G. Pataki, M. Roué, J. Rubis, M. Schultz, P. Smith, R. Sumaila, K. Takeuchi, S. Thomas, M. Verma, Y. Yeo-Chang, and D. Zlatanova. 2015. The IPBES conceptual framework - connecting nature and people. *Current Opinion in Environmental Sustainability* 14:1-16. http://dx.doi.org/10.1016/j.cosust.2014.11.002

Díaz, S., U. Pascual, M. Stenseke, B. Martín-López, R. T. Watson, Z. Molnár, R. Hill, K. M. A. Chan, I. A. Baste, K. A. Brauman, S. Polasky, A. Church, M. Lonsdale, A. Larigauderie, P. W. Leadley, A. P. E. van Oudenhoven, F. van der Plaat, M. Schröter, S. Lavorel, Y. Aumeeruddy-Thomas, E. Bukvareva, K. Davies, S. Demissew, G. Erpul, P. Failler, C. A. Guerra, C. L. Hewitt, H. Keune, S. Lindley, and Y. Shirayama. 2018. Assessing Nature's contributions to people. *Science* 359(6373):270-272. https://doi.org/10.1126/science.aap8826

Díaz-Reviriego, I., E. Turnhout, and S. Beck. 2019. Participation and inclusiveness in the intergovernmental science-policy platform on biodiversity and ecosystem services. *Nature Sustainability* 2(6):457-464. http://dx.doi.org/10.1038/s41893-019-0290-6

Feola, G. 2015. Societal transformation in response to global environmental change: a review of emerging concepts. *Ambio* 44 (5):376-390. http://dx.doi.org/10.1007/s13280-014-0582-z

Fernández-Llamazares, Á., and M. Cabeza. 2018. Rediscovering the potential of indigenous storytelling for conservation practice. *Conservation Letters* 11(3):e12398. https://doi.org/10.1111/conl.12398

Fernández-Llamazares, Á., I. Díaz-Reviriego, A. C. Luz, M. Cabeza, A. Pyhälä, and V. Reyes-García. 2015. Rapid ecosystem change challenges the adaptive capacity of local environmental knowledge. *Global Environmental Change* 31:272-284. https://doi.org/10.1016/j.gloenvcha.2015.02.001

Fernández-Llamazares, Á., and D. Lepofsky. 2019. Ethnobiology through song. *Journal of Ethnobiology* 39(3):337-353. https://doi.org/10.2993/0278-0771-39.3.337

Ford, J. D., B. Smit, and J. Wandel. 2006. Vulnerability to climate change in the Arctic: a case study from Arctic Bay, Canada. *Global Environmental Change* 16(2):145-160. https://doi.org/10.1016/j.gloenvcha.2005.11.007

Gadgil, M., F. Berkes, and C. Folke. 1993. Indigenous knowledge for biodiversity conservation. *Ambio* 22(2-3):151-156. https://www.jstor.org/stable/4314060

Garnett, S. T., N. D. Burgess, J. E. Fa, Á. Fernández-Llamazares, Z. Molnár, C. J. Robinson, J. E. M. Watson, K. K. Zander, B. Austin, E. S. Brondizio, N. F. Collier, T. Duncan, E. Ellis, H. Geyle, M. V. Jackson, H. Jonas, P. Malmer, B. McGowan, A. Sivongxay, and I. Leiper. 2018. A spatial overview of the global importance of indigenous lands for conservation. *Nature Sustainability* 1(7):369-374. https://doi.org/10.1038/s41893-018-0100-6

Gavin, M. C., J. McCarter, A. Mead, F. Berkes, J. R. Stepp, D. Peterson, and R. Tang. 2015. Defining biocultural approaches to conservation. *Trends in Ecology and Evolution* 30(3):140-145. https://doi.org/10.1016/j.tree.2014.12.005

Gill, H., and T. Lantz. 2014. A community-based approach to mapping Gwich'in observations of environmental changes in the Lower Peel River Watershed, NT. *Journal of Ethnobiology* 34 (3):294-314. https://doi.org/10.2993/0278-0771-34.3.294

Golden, D. M., C. Audet, and M. A. (Peggy) Smith. 2015. "Blue-ice": framing climate change and reframing climate change adaptation from the indigenous peoples' perspective in the northern boreal forest of Ontario, Canada. *Climate and Development* 7(5):401-413. http://dx.doi.org/10.1080/17565529.-2014.966048

Gray, M. 2016. More than science: reflections on science, spirit, tradition, and environment. *Journal for the Study of Spirituality* 6(2):155-167. http://dx.doi.org/10.1080/20440243.2016.1235176

Grin, J., J. Rotmans, and J. Schot, editors. 2010. *Transitions to sustainable development: new directions in the study of long term transformative change*. Routledge, New York, New York, USA. https://doi.org/10.4324/9780203856598

Gudynas, E. 2011. Buen Vivir: today's tomorrow. *Development* 54 (4):441-447. http://dx.doi.org/10.1057/dev.2011.86

Gunderson, L. H., and C. S. Holling, editors. 2002. *Panarchy: understanding transformations in human and natural systems*. Second edition. Island, Washington, D.C., USA.

Hallwass, G., P. F. Lopes, A. A. Juras, and R. A. M. Silvano. 2013. Fishers' knowledge identifies environmental changes and fish abundance trends in impounded tropical rivers. *Ecological Applications* 23(2):392-407. http://dx.doi.org/10.1890/12-0429.1

Herman-Mercer, N. M., E. Matkin, M. J. Laituri, R. C. Toohey, M. Massey, K. Elder, P. F. Schuster, and E. A. Mutter. 2016. Changing times, changing stories. *Ecology and Society* 21(3):28. http://dx.doi.org/10.5751/ES-08463-210328

Hill, M. O., and H. G. Gauch. 1980. Detrended correspondence analysis: an improved ordination technique. *Vegetation* 42 (1-3):47-58. http://dx.doi.org/10.1007/BF00048870

Hill, R., G. Nates-Parra, J. J. G. Quezada-Euán, D. Buchori, G. LeBuhn, M. M. Maués, P. L. Pert, P. K. Kwapong, S. Saeed, S. J. Breslow, M. Carneiro da Cunha, L. V Dicks, L. Galetto, M. Gikungu, B. G. Howlett, V. L. Imperatriz-Fonseca, P. O'B. Lyver, B. Martín-López, E. Oteros-Roza, S. G. Potts, and M. Roué. 2019. Biocultural approaches to pollinator conservation. *Nature Sustainability* 2(3):214-222. https://doi.org/10.1038/s41893-019-0244-z

Hinzman, L. D., N. D. Bettez, W. R. Bolton, F. S. Chapin, M. B. Dyurgerov, C. L. Fastie, B. Griffith, R. D. Hollister, A. Hope, H. P. Huntington, A. M. Jensen, G. J. Jia, T. Jorgenson, D. L. Kane, D. R. Klein, G. Kofinas, A. H. Lynch, A. H. Lloyd, A. D. McGuire, F. E. Nelson, W. C. Oechel, T. E. Osterkamp, C. H. Racine, V. E. Romanovsky, R. S. Stone, D. A. Stow, M. Sturm, C. E. Tweedie, G. L. Vourlitis, M. D. Walker, D. A. Walker, P. J. Webber, J. M. Welker, K. S. Winker, and K. Yoshikawa. 2005. Evidence and implications of recent climate change in Northern Alaska and other Arctic regions. *Climatic Change* 72(3):251-298. https://doi.org/10.1007/s10584-005-5352-2

Hölscher, K., J. M. Wittmayer, and D. Loorbach. 2018. Transition versus transformation: what's the difference? *Environmental Innovation and Societal Transitions* 27:1-3. https://doi.org/10.1016/j.eist.2017.10.007

Homann, S., B. Rischkowsky, J. Steinbach, M. Kirk, and E. Mathias. 2008. Towards endogenous livestock development. *Human Ecology* 36(4):503-520. https://doi.org/10.1007/s10745-008-9180-7

Horcea-Milcu, A.-I., D. J. Abson, C. I. Apetrei, I. A. Duse, R. Freeth, M. Riechers, D. P. M. Lam, C. Dorninger, and D. J. Lang. 2019. Values in transformational sustainability science: four perspectives for change. *Sustainability Science* 14(5):1425-1437. https://doi.org/10.1007/s11625-019-00656-1

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). 2019. *Next work programme of the platform*. IPBES/7/6. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. [online] URL: https://ipbes.net/event/ipbes-7-plenary

Ives, C. D., R. Freeth, and J. Fischer. 2020. Inside-out sustainability: the neglect of inner worlds. *Ambio* 49:208-217. https://doi.org/10.1007/s13280-019-01187-w

Jandreau, C., and F. Berkes. 2016. Continuity and change within the social-ecological and political landscape of the Maasai Mara, Kenya. *Pastoralism* 6(1):1-15. https://doi.org/10.1186/s13570-016-0048-y

Kassam, K.-A. 2009. Viewing change through the prism of indigenous human ecology: findings from the Afghan and Tajik Pamirs. *Human Ecology* 37(6):677-690. https://doi.org/10.1007/s10745-009-9284-8

Kendrick, A., P. O. 'B. Lyver, and Lutsël K'é Dene First Nation. 2005. Denésôliné (Chipewyan) knowledge of barren-ground caribou (*Rangifer tarandus groenlandicus*) movements. *Arctic* 58 (2):175-191. https://doi.org/10.14430/arctic409

Kgosikoma, O., W. Mojeremane, and B. A. Harvie. 2012. Pastoralists' perception and ecological knowledge on savanna ecosystem dynamics in semi-arid Botswana. *Ecology and Society* 17(4):27. http://dx.doi.org/10.5751/ES-05247-170427

King, D. A. 2004. The scientific impact of nations. *Nature* 430:311-316. http://dx.doi.org/10.1038/430311a

Klein, J. A., K. A. Hopping, E. T. Yeh, Y. Nyima, R. B. Boone, and K. A. Galvin. 2014. Unexpected climate impacts on the Tibetan Plateau: local and scientific knowledge in findings of delayed summer. *Global Environmental Change* 28(1):141-152. http://dx.doi.org/10.1016/j.gloenvcha.2014.03.007

Köhler, J., F. W. Geels, F. Kern, J. Markard, E. Onsongo, A. Wieczorek, F. Alkemade, F. Avelino, A. Bergek, F. Boons, L. Fünfschilling, D. Hess, G. Holtz, S. Hyysalo, K. Jenkins, P. Kivimaa, M. Martiskainen, A. McMeekin, M. S. Mühlemeier, B. Nykvist, B. Pel, R. Raven, H. Rohracher, B. Sandén, J. Schot, B. Sovacool, B. Turnheim, D. Welch, and P. Wells. 2019. An agenda for sustainability transitions research: state of the art and future directions. *Environmental Innovation and Societal Transitions* 31:1-32. https://doi.org/10.1016/j.eist.2019.01.004

Kothari, A., F. Demaria, and A. Acosta. 2014. Buen Vivir, degrowth and ecological Swaraj: alternatives to sustainable development and the green economy. *Development* 57 (3-4):362-375. https://doi.org/10.1057/dev.2015.24

Lang, D. J., A. Wiek, M. Bergmann, M. Stauffacher, P. Martens, P. Moll, M. Swilling, and C. J. Thomas. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science* 7:25-43. https://doi.org/10.1007/s11625-011-0149-x

Leach, M., I. Scoones, and A. Stirling. 2007. *Pathways to sustainability: an overview of the STEPS Centre approach*. STEPS Centre. Brighton, UK. [online] URL: https://steps-centre.org/wp-content/uploads/final_steps_overview.pdf

Leonard, S., M. Parsons, K. Olawsky, and F. Kofod. 2013. The role of culture and traditional knowledge in climate change adaptation. *Global Environmental Change* 23(3):623-632. http://dx.doi.org/10.1016/j.gloenvcha.2013.02.012

Loorbach, D., N. Frantzeskaki, and F. Avelino. 2017. Sustainability transitions research: transforming science and practice for societal change. *Annual Review of Environment and Resources* 42(1):599-626. https://doi.org/10.1146/annurev-environ-102014-021340

Luederitz, C., M. Meyer, D. J. Abson, F. Gralla, D. J. Lang, A.-L. Rau, and H. von Wehrden. 2016. Systematic student-driven literature reviews in sustainability science - an effective way to merge research and teaching. *Journal of Cleaner Production* 119:229-235. http://dx.doi.org/10.1016/j.jclepro.2016.02.005

Mauser, W., G. Klepper, M. Rice, B. S. Schmalzbauer, H. Hackmann, R. Leemans, and H. Moore. 2013. Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Current Opinion in Environmental Sustainability* 5 (3-4):420-431. http://dx.doi.org/10.1016/j.cosust.2013.07.001

Mayring, P. 2014. Qualitative Inhaltsanalyse. Pages 468-475 *in* U. Flick, E. von Kardorff, and I. Steinke, editors. *Qualitative Forschung. Ein Handbuch*. Rowohlt Taschenbuch Verlag, Hamburg, Germany.

McCarthy, D. D. P., G. S. Whitelaw, S. Anderson, D. Cowan, F. McGarry, A. Robins, H. L. Gardner, C. D. Barbeau, N. A. Charania, Z. General, J. Liedtke, C. Sutherland, P. Alencar, and L. J. S. Tsuji. 2012. Collaborative geomatics and the Mushkegowuk Cree First Nations: fostering adaptive capacity for community-based sub-arctic natural resource management. *Geoforum* 43(2):305-314. http://dx.doi.org/10.1016/j.geoforum.2011.07.015

Metz, T. 2011. Ubuntu as a moral theory and human rights in South Africa. *African Human Rights Law Journal* 11(2):532-559. [online] URL: http://www.scielo.org.za/pdf/ahrlj/v11n2/11.pdf

Mistry, J., and A. Berardi. 2016. Bridging indigenous and scientific knowledge. *Science* 352(6291):1274-1275. http://dx.doi.org/10.1126/science.aaf1160

Monni, S., and M. Pallottino. 2015. A new agenda for international development cooperation: lessons learnt from the *Buen Vivir* experience. *Development* 58(1):49-57. http://dx.doi.org/10.1057/dev.2015.41

Moore, M.-L. 2017. Synthesis: tracking transformative impacts and cross-scale dynamics. Pages 218-238 *in* F. R. Westley, K. McGowan, and O. Tjörnbo, editors. *The evolution of social innovation*. Edward Elgar, Cheltenham, UK. http://dx.doi.org/10.4337/9781786431158.00017

Moshy, V. H., and I. Bryceson. 2016. Seeing through fishers' lenses. *SAGE Open* 6(2):1-18. http://dx.doi.org/10.1177/2158244016641716

O'Brien, K. 2012. Global environmental change II: from adaptation to deliberate transformation. *Progress in Human Geography* 36(5):667-676. http://dx.doi.org/10.1177/0309132511425767

O'Brien, K. L. 2016. Climate change and social transformations: is it time for a quantum leap? *Wiley Interdisciplinary Reviews: Climate Change* 7(5):618-626. http://dx.doi.org/10.1002/wcc.413

Olsson, P. 2017. Synthesis: agency and opportunity. Pages 58-72 *in* F. R. Westley, K. McGowan, and O. Tjörnbo, editors. *The evolution of social innovation*. Edward Elgar, Cheltenham, UK. https://doi.org/10.4337/9781786431158.00009

Olsson, P., V. Galaz, and W. J. Boonstra. 2014. Sustainability transformations: a resilience perspective. *Ecology and Society* 19 (4):1. http://dx.doi.org/10.5751/ES-06799-190401

Olsson, P., M.-L. Moore, F. R. Westley, and D. D. P. McCarthy. 2017. The concept of the Anthropocene as a game-changer: a new context for social innovation and transformations to sustainability. *Ecology and Society* 22(2):31. https://doi.org/10.5751/ES-09310-220231

Orlove, B., C. Roncoli, M. Kabugo, and A. Majugu. 2010. Indigenous climate knowledge in southern Uganda: the multiple components of a dynamic regional system. *Climatic Change* 100 (2):243-265. https://doi.org/10.1007/s10584-009-9586-2

Paré, S., P. Savadogo, M. Tigabu, J. M. Ouadba, and P. C. Odén. 2010. Consumptive values and local perception of dry forest decline in Burkina Faso, West Africa. *Environment, Development and Sustainability* 12(2):277-295. https://doi.org/10.1007/s10668-009-9194-3

Partelow, S., A. Schlüter, H. von Wehrden, M. Jänig, and P. Senff. 2018. A sustainability agenda for tropical marine science. *Conservation Letters* 11(1):e12351. https://doi.org/10.1111/conl.12351

Pascual, U., P. Balvanera, S. Díaz, G. Pataki, E. Roth, M. Stenseke, R. T. Watson, E. Başak Dessane, M. Islar, E. Kelemen, V. Maris, M. Quaas, S. M. Subramanian, H. Wittmer, A. Adlan, S. E. Ahn, Y. S. Al-Hafedh, E. Amankwah, S. T. Asah, P. Berry, A. Bilgin, S. J. Breslow, C. Bullock, D. Cáceres, H. Daly-Hassen, E. Figueroa, C. D. Golden, E. Gómez-Baggethun, D. González-Jiménez, J. Houdet, H. Keune, R. Kumar, K. Ma, P. H. May, A. Mead, P. O'Farrell, R. Pandit, W. Pengue, R. Pichis-Madruga, F. Popa, S. Preston, D. Pacheco-Balanza, H. Saarikoski, B. B. Strassburg, M. van den Belt, M. Verma, F. Wickson, and N. Yagi. 2017. Valuing Nature's contributions to people: the IPBES approach. *Current Opinion in Environmental Sustainability* 26:7-16. http://dx.doi.org/10.1016/j.cosust.2016.12.006

Patterson, J., K. Schulz, J. Vervoort, S. van der Hel, O. Widerberg, C. Adler, M. Hurlbert, K. Anderton, M. Sethi, and A. Barau. 2017. Exploring the governance and politics of transformations towards sustainability. *Environmental Innovation and Societal Transitions* 24:1-16. http://dx.doi.org/10.1016/j.eist.2016.09.001

Pearce, T., J. Ford, A. Cunsolo Willox, and B. Smit. 2015. Inuit traditional ecological knowledge (TEK), subsistence hunting and adaptation to climate change in the Canadian Arctic. *Arctic* 68 (2):233-245. http://dx.doi.org/10.14430/arctic4475

Pelling, M. 2010. *Adaptation to climate change: from resilience to transformation*. Routledge, New York, New York, USA. https://doi.org/10.4324/9780203889046

Pelling, M., K. O'Brien, and D. Matyas. 2015. Adaptation and transformation. *Climatic Change* 133(1):113-127. http://dx.doi.org/10.1007/s10584-014-1303-0

Pullin, A. S., and G. B. Stewart. 2006. Guidelines for systematic review in conservation and environmental management.

Conservation Biology 20(6):1647-1656. http://dx.doi.org/10.1111/j.1523-1739.2006.00485.x

Reid, W. V, F. Berkes, T. J. Wilbanks, and D. Capistrano, editors. 2006. *Bridging scales and knowledge systems: concepts and applications in ecosystem assessment*. Island, Washington, D.C., USA; Covelo, London, UK.

Rodriguez, I. 2017. Linking well-being with cultural revitalization for greater cognitive justice in conservation: lessons from Venezuela in Canaima National Park. *Ecology and Society* 22 (4):24. https://doi.org/10.5751/ES-09758-220424

Savo, V., D. Lepofsky, J. P. Benner, K. E. Kohfeld, J. Bailey, and K. Lertzman. 2016. Observations of climate change among subsistence-oriented communities around the world. *Nature Climate Change* 6(5):462-473. https://doi.org/10.1038/NCLIMATE2958

Scoones, I., M. Leach, and P. Newell, editors. 2015. *Pathways to sustainability: the politics of green transformations*. Routledge, Oxon, UK.

Smith, L. T. 2012. *Decolonizing methodologies: research and indigenous peoples*. Second edition. Zed, London, UK.

Sterling, E. J., C. Filardi, A. Toomey, A. Sigouin, E. Betley, N. Gazit, J. Newell, S. Albert, D. Alvira, N. Bergamini, M. Blair, D. Boseto, K. Burrows, N. Bynum, S. Caillon, J. E. Caselle, J. Claudet, G. Cullman, R. Dacks, P. B. Eyzaguirre, S. Gray, J. Herrera, P. Kenilorea, K. Kinney, N. Kurashima, S. Macey, C. Malone, S. Mauli, J. McCarter, H. McMillen, P. Pascua, P. Pikacha, A. L. Porzecanski, P. de Robert, M. Salpeteur, M. Sirikolo, M. H. Stege, K. Stege, T. Ticktin, R. Vave, A. Wali, P. West, K. B. Winter, and S. D. Jupiter. 2017. Biocultural approaches to well-being and sustainability indicators across scales. *Nature Ecology and Evolution* 1(12):1798-1806. https://doi.org/10.1038/s41559-017-0349-6

Taylor, R. B., M. A. Morrison, and N. T. Shears. 2011. Establishing baselines for recovery in a marine reserve (Poor Knights Islands, New Zealand) using local ecological knowledge. *Biological Conservation* 144(12):3038-3046. https://doi.org/10.1016/j.biocon.2011.09.009

Tengö, M., E. S. Brondizio, T. Elmqvist, P. Malmer, and M. Spierenburg. 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. *Ambio* 43(5):579-591. https://doi.org/10.1007/s13280-014-0501-3

Tengö, M., R. Hill, P. Malmer, C. M. Raymond, M. Spierenburg, F. Danielsen, T. Elmqvist, and C. Folke. 2017. Weaving knowledge systems in IPBES, CBD and beyond-lessons learned for sustainability. *Current Opinion in Environmental Sustainability* 26-27:17-25. http://dx.doi.org/10.1016/j.cosust.2016.12.005

Timoti, P., P. O.'B. Lyver, R. Matamua, C. J. Jones, and B. L. Tahi. 2017. A representation of a Tuawhenua worldview guides environmental conservation. *Ecology and Society* 22(4):20. https://doi.org/10.5751/ES-09768-220420

Vinyeta, K., and K. Lynn. 2013. *Exploring the role of traditional ecological knowledge in climate change initiatives*. United States Department of Agriculture, Portland, Oregon, USA. https://doi.org/10.2737/PNW-GTR-879

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* 9(2):5. https://doi.org/10.5751/ES-00650-090205

Weiss, K., M. Hamann, and H. Marsh. 2013. Bridging knowledges: understanding and applying indigenous and western scientific knowledge for marine wildlife management. *Society and Natural Resources* 26(3):285-302. https://doi.org/10.1080/08941920.2012.690065

Westley, F. R., O. Tjornbo, L. Schultz, P. Olsson, C. Folke, B. Crona, and Ö. Bodin. 2013. A theory of transformative agency in linked social-ecological systems. *Ecology and Society* 18(3):27. http://dx.doi.org/10.5751/ES-05072-180327

Whyte, K. P., J. P. Brewer, and J. T. Johnson. 2016. Weaving indigenous science, protocols and sustainability science. *Sustainability Science* 11(1):25-32. http://dx.doi.org/10.1007/s11625-015-0296-6

Wilson, N. J., M. T. Walter, and J. Waterhouse. 2015. Indigenous knowledge of hydrologic change in the Yukon River Basin: a case study of Ruby, Alaska. *Arctic* 68(1):93-106. http://dx.doi.org/10.14430/arctic4459

Appendix 1. *Search string inserted into the database Scopus*

1. Regarding transformations:
   a. TITLE-ABS-KEY (transform* OR transition* OR change*)

AND

2. Regarding indigenous and local knowledge:
   b. ("indigenous knowledge" OR "indigenous ecological knowledge" OR "indigenous environmental knowledge" OR "indigenous local knowledge" OR "local knowledge" OR "local ecological knowledge" OR "local environmental knowledge" OR "traditional knowledge" "traditional ecological knowledge" OR "traditional environmental knowledge" OR "local indigenous knowledge" OR "local traditional knowledge" OR "indigenous traditional knowledge" OR "traditional indigenous knowledge" OR "traditional local knowledge")

AND

3. Regarding document characteristics:
   a. (LIMIT-TO (DOCTYPE , "ar ")) AND (EXCLUDE (SUBJAREA , "EART ") OR EXCLUDE (SUBJAREA , " MEDI ") OR EXCLUDE (SUBJAREA , " BIOC ") OR EXCLUDE (SUBJAREA , " ENER ") OR EXCLUDE (SUBJAREA , " COMP ") OR EXCLUDE (SUBJAREA , " ENGI ") OR EXCLUDE (SUBJAREA , " NURS ") OR EXCLUDE (SUBJAREA , " PHAR ") OR EXCLUDE (SUBJAREA , " HEAL ") OR EXCLUDE (SUBJAREA , " CHEM ") OR EXCLUDE (SUBJAREA , " CENG ") OR EXCLUDE (SUBJAREA , " IMMU ") OR EXCLUDE (SUBJAREA , " MATH ") OR EXCLUDE (SUBJAREA , " NEUR ") OR EXCLUDE (SUBJAREA , " PHYS ") OR EXCLUDE (SUBJAREA , " VETE ")) AND (EXCLUDE (PUBYEAR , 2017) OR EXCLUDE (PUBYEAR , 1999) OR EXCLUDE (PUBYEAR , 1998) OR EXCLUDE (PUBYEAR , 1997) OR EXCLUDE (PUBYEAR , 1996) OR EXCLUDE (PUBYEAR , 1995) OR EXCLUDE (PUBYEAR , 1994) OR EXCLUDE (PUBYEAR , 1991) OR EXCLUDE (PUBYEAR , 1986) OR EXCLUDE (PUBYEAR , 1979))

Appendix 2. *Papers included in the literature review*

Author	Title	Year	Cluster
Alessa L., Kliskey A., Williams P., Barton M.	Perception of change in freshwater in remote resource-dependent Arctic communities	2008	Red
Altschuler B., Brownlee M.	Perceptions of climate change on the island of Providencia	2015	Green
Andrachuk M., Armitage D.	Understanding social-ecological change and transformation through community perceptions of system identity	2015	Blue
Apgar M.J., Allen W., Moore K., Ataria J.	Understanding adaptation and transformation through indigenous practice: The case of the Guna of Panama	2015	Blue
Aswani S., Lauer M.	Indigenous people's detection of rapid ecological change	2014	Blue
Beaudreau A.H., Levin P.S.	Advancing the use of local ecological knowledge for assessing data-poor species in coastal ecosystems	2014	Blue
Berkes F., Jolly D.	Adapting to climate change: Social-ecological resilience in a Canadian western arctic community	2002	Red
Boillat S., Berkes F.	Perception and interpretation of climate change among quechua farmers of bolivia: Indigenous knowledge as a resource for adaptive capacity	2013	Green
Boissière M., Locatelli B., Sheil D., Padmanaba M., Sadjudin E.	Local perceptions of climate variability and change in tropical forests of Papua, Indonesia	2013	Grey
Boll V.M.	Following Garkman, the frog, in north eastern Arnhem Land (Australia)	2006	Green
Brännlund I., Axelsson P.	Reindeer management during the colonization of Sami lands: A long-term perspective of vulnerability and adaptation strategies	2011	Blue
Bruegger R.A., Jigjsuren O., Fernández-Giménez M.E.	Herder observations of rangeland change in Mongolia: Indicators, causes, and application to community-based management	2014	Grey
Byg A., Salick J.	Local perspectives on a global phenomenon-Climate change in Eastern Tibetan villages	2009	Grey
Carothers C., Brown C., Moerlein K.J., Andrés López J., Andersen D.B., Retherford B.	Measuring perceptions of climate change in Northern Alaska: Pairing Ethnography with cultural consensus analysis	2014	Red
Carter B.T.G., Nielsen E.A.	Exploring ecological changes in Cook Inlet beluga whale habitat though traditional and local ecological knowledge of contributing factors for population decline	2011	Red
Chalmers N., Fabricius C.	Expert and generalist local knowledge about land-cover change on South Africa's Wild Coast: Can local ecological knowledge add value to science?	2007	Grey
Chaudhary P., Bawa K.S.	Local perceptions of climate change validated by scientific evidence in the Himalayas	2011	Grey
Chaudhary P., Rai S., Wangdi S., Mao A., Rehman N., Chettri S., Bawa K.S.	Consistency of local perceptions of climate change in the Kangchenjunga Himalaya landscape	2011	Grey
Clark D.A., Slocombe S.	Adaptive Co-Management and Grizzly Bear-Human Conflicts in Two Northern Canadian Aboriginal Communities	2011	Red
Codjoe S.N.A., Owusu G., Burkett V.	Perception, experience, and indigenous knowledge of climate change and variability: The case of Accra, a sub-Saharan African city	2014	Green

Crate S.A., Fedorov A.N.	A methodological model for exchanging local and scientific climate change knowledge in northeastern Siberia	2013	Red
de Almeida G.M.A., Ramos M.A., Araújo E.L., Baldauf C., Albuquerque U.P.	Human perceptions of landscape change: The case of a monodominant forest of Attalea speciosa Mart ex. Spreng (Northeast Brazil)	2016	Grey
Dinero S.C.	Indigenous perspectives of climate change and its effects upon subsistence activities in the Arctic: The case of the Nets'aii Gwich'in	2013	Red
Dowsley M., Wenzel G.	"The time of the most polar bears": A co-management conflict in Nunavut	2008	Red
Eisner W.R., Cuomo C.J., Hinkel K.M., Jones B.M., Brower Sr. R.H.	Advancing landscape change research through the Incorporation of Iñupiaq knowledge	2009	Red
Fernández-Giménez M.E., Fillat F.	Pyrenean pastoralists'observations of environmental change: An exploratory study in los Valles Occidentales of Aragón	2012	Grey
Fernández-Llamazares Á., Díaz-Reviriego I., Guèze M., Cabeza M., Pyhälä A., Reyes-García V.	Local perceptions as a guide for the sustainable management of natural resources: Empirical evidence from a small-scale society in Bolivian Amazonia	2016	Green
Fernández-Llamazares Á., Díaz-Reviriego I., Luz A.C., Cabeza M., Pyhälä A., Reyes-García V.	Rapid ecosystem change challenges the adaptive capacity of local environmental knowledge	2015	Green
Ford J.D., Smit B., Wandel J.	Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada	2006	Red
Frans V.F., Augé A.A.	Use of local ecological knowledge to investigate endangered baleen whale recovery in the Falkland Islands	2016	Blue
Giglio V.J., Luiz O.J., Gerhardinger L.C.	Depletion of marine megafauna and shifting baselines among artisanal fishers in eastern Brazil	2015	Blue
Gill H., Lantz T.	A community-based approach to mapping Gwich'in observations of environmental changes in the lower peel river watershed, NT	2014	Red
Golden D.M., Audet C., Smith M.A.	“Blue-ice”: framing climate change and reframing climate change adaptation from the indigenous peoples' perspective in the northern boreal forest of Ontario, Canada	2015	Red
Gómez-Baggethun E., Reyes-García V., Olsson P., Montes C.	Traditional ecological knowledge and community resilience to environmental extremes: A case study in Doñana, SW Spain	2012	Green
Hallwass G., Lopes P.F., Juras A.A., Silvano R.A.M.	Fishers' knowledge identifies environmental changes and fish abundance trends in impounded tropical rivers	2013	Blue
Hansen W.D., Brinkman T.J., Leonawicz M., Chapin III F.S., Kofinas G.P.	Changing daily wind speeds on Alaska's North Slope: Implications for rural hunting opportunities	2013	Red
Herman-Mercer N.M., Matkin E., Laituri M.J., Toohey R.C., Massey M., Elder K., Schuster P.F., Mutter E.A.	Changing times, changing stories: Generational differences in climate change perspectives from four remote indigenous communities in Subarctic Alaska	2016	Red
Homann S., Rischkowsky B., Steinbach J., Kirk M., Mathias E.	Towards endogenous livestock development: Borana pastoralists' responses to environmental and institutional changes	2008	Grey
Hopping K.A., Yangzong C., Klein J.A.	Local knowledge production, transmission, and the importance of village leaders in a network of Tibetan pastoralists coping with environmental change	2016	Green
Huntington H.P., Quakenbush L.T., Nelson M.	Effects of changing sea ice on marine mammals and subsistence hunters in northern Alaska from traditional knowledge interviews	2016	Red
Jandreau C., Berkes F.	Continuity and change within the social-ecological and political landscape of the Maasai Mara, Kenya	2016	Green

Janif S.Z., Nunn P.D., Geraghty P., Aalbersberg W., Thomas F.R., Camailakeba M.	Value of traditional oral narratives in building climate-change resilience: Insights from rural communities in Fiji	2016	Green
Kakinuma K., Ozaki T., Takatsuki S., Chuluun J.	How Pastoralists in Mongolia perceive vegetation changes caused by grazing	2008	Grey
Kassam K.-A.	Viewing change through the prism of indigenous human ecology: Findings from the afghan and Tajik pamirs	2009	Green
Kendrick A., Lyver P.O'B.	Denésǫliné (Chipewyan) knowledge of barren-ground caribou (Rangifer tarandus groenlandicus) movements	2005	Red
Kgosikoma O., Mojeremane W., Harvie B.A.	Pastoralists' perception and ecological knowledge on savanna ecosystem dynamics in semi-arid Botswana	2012	Grey
Klein J.A., Hopping K.A., Yeh E.T., Nyima Y., Boone R.B., Galvin K.A.	Unexpected climate impacts on the Tibetan Plateau: LOCAL and scientific knowledge in findings of delayed summer	2014	Green
Kokelj S.V., Lantz T.C., Solomon S., Pisaric M.F.J., Keith D., Morse P., Thienpont J.R., Smol J.P., Esagok D.	Using multiple sources of knowledge to investigate northern environmental change: Regional ecological impacts of a storm surge in the outer Mackenzie Delta, N.W.T.	2012	Red
Lauer M., Aswani S.	Indigenous knowledge and long-term ecological change: Detection, interpretation, and responses to changing ecological conditions in pacific island communities	2010	Blue
Leonard S., Parsons M., Olawsky K., Kofod F.	The role of culture and traditional knowledge in climate change adaptation: Insights from East Kimberley, Australia	2013	Green
Levine A., Sauafea-Le'Au F.	Traditional knowledge, use, and management of living marine resources in american samoa: Documenting changes over time through interviews with elder fishers	2013	Blue
Lyver P.O.B., Taputu T.M., Kutia S.T., Tahi B.	Tūhoe Tuawhenua mātauranga of kererū (Hemiphaga novaseelandiae novaseelandiae) in Te Urewera	2008	Green
Mallory M.L., Gilchrist H.G., Braune B.M., Gaston A.J.	Marine birds as indicators of arctic marine ecosystem health: Linking the Northern Ecosystem Initiative to long-term studies	2006	Red
Marin A.	Riders under storms: Contributions of nomadic herders' observations to analysing climate change in Mongolia	2010	Grey
McCarthy D.D.P., Whitelaw G.S., Anderson S., Cowan D., McGarry F., Robins A., Gardner H.L., Barbeau C.D., Charania N.A., General Z., Liedtke J., Sutherland C., Alencar P., Tsuji L.J.S.	Collaborative geomatics and the Mushkegowuk Cree First Nations: Fostering adaptive capacity for community-based sub-arctic natural resource management	2012	Red
McDowell J.Z., Hess J.J.	Accessing adaptation: Multiple stressors on livelihoods in the Bolivian highlands under a changing climate	2012	Green
McIntyre-Tamwoy S., Fuary M., Buhrich A.	Understanding climate, adapting to change: Indigenous cultural values and climate change impacts in North Queensland	2013	Green
McNamara K.E., Westoby R.	Local knowledge and climate change adaptation on erub Island, torres strait	2011	Green
Moshy V.H., Bryceson I.	Seeing Through Fishers' Lenses: Exploring Marine Ecological Changes Within Mafia Island Marine Park, Tanzania	2016	Blue
Muchagata M., Brown K.	Colonist farmers' perceptions of fertility and the frontier environment in eastern Amazonia	2000	Grey
Nichols T., Berkes F., Jolly D., Snow N.B.	Climate change and sea ice: Local observations from the Canadian western Arctic	2004	Red
Oteros-Rozas E., Ontillera-Sánchez R., Sanosa P., Gómez-Baggethun E., Reyes-García V., González J.A.	Traditional ecological knowledge among transhumant pastoralists in Mediterranean Spain	2013	Green

Oviedo A.F.P., Mitraud S., McGrath D.G., Bursztyn M.	Implementing climate variability at the community level in the Amazon floodplain	2016	Grey
Palframan A.	“In common nature”: an ethnography of climate adaptation in the Lesotho Highlands	2015	Green
Paré S., Savadogo P., Tigabu M., Ouadba J.M., Odén P.C.	Consumptive values and local perception of dry forest decline in Burkina Faso, West Africa	2010	Grey
Parlee B., Manseau M.	Using traditional knowledge to adapt to ecological change: Denésǫłiné monitoring of caribou movements	2005	Red
Parlee B.L., Geertsema K., Willier A.	Social-ecological thresholds in a changing boreal landscape: Insights from cree knowledge of the Lesser Slave Lake region of Alberta, Canada	2012	Red
Reedy D., Savo V., McClatchey W.	Traditional Climatic Knowledge: Orchardists' perceptions of and adaptation to climate change in the Campania region (Southern Italy)	2014	Grey
Roba H.G., Oba G.	Integration of herder knowledge and ecological methods for land degradation assessment around sedentary settlements in a sub-humid zone in northern Kenya	2008	Grey
Rodenburg J., Both J., Heitkönig I.M.A., van Koppen C.S.A., Sinsin B., van Mele P., Kiepe P.	Land Use and Biodiversity in Unprotected Landscapes: The Case of Noncultivated Plant Use and Management by Rural Communities in Benin and Togo	2012	Grey
Shackeroff J.M., Campbell L.M., Crowder L.B.	Social-ecological guilds: Putting people into marine historical ecology	2011	Blue
Shava S., Krasny M.E., Tidball K.G., Zazu C.	Agricultural knowledge in urban and resettled communities: Applications to social-ecological resilience and environmental education	2010	Green
Taylor R.B., Morrison M.A., Shears N.T.	Establishing baselines for recovery in a marine reserve (Poor Knights Islands, New Zealand) using local ecological knowledge	2011	Blue
Turner N.J., Clifton H.	"It's so different today": Climate change and indigenous lifeways in British Columbia, Canada	2009	Green
Venkatachalam A.J., Price A.R.G., Chandrasekara S., Senaratna Sellamuttu S., Kaler J.	Changes in frigate tuna populations on the south coast of Sri Lanka: Evidence of the shifting baseline syndrome from analysis of fisher observations	2010	Blue
Vogt N., Pinedo-Vasquez M., Brondízio E.S., Rabelo F.G., Fernandes K., Almeida O., Riveiro S., Deadman P.J., Dou Y.	Local ecological knowledge and incremental adaptation to changing flood patterns in the Amazon delta	2016	Grey
Voorhees H., Sparks R., Huntington H.P., Rode K.D.	Traditional knowledge about polar bears (Ursus maritimus) in northwestern Alaska	2014	Red
Weatherhead E., Gearheard S., Barry R.G.	Changes in weather persistence: Insight from Inuit knowledge	2010	Red
Wilson N.J., Todd Walter M., Waterhouse J.	Indigenous knowledge of hydrologic change in the Yukon river basin: A case study of Ruby, Alaska	2015	Red
Wolfe B.B., Armitage D., Wesche S., Brock B.E., Sokal M.A., Clogg-Wright K.P., Mongeon C.L., Adam M.E., Hall R.I., Edwards T.W.D.	From isotopes to TK interviews: Towards interdisciplinary research in Fort Resolution and the Slave River Delta, Northwest Territories	2007	Red
Ziembicki M.R., Woinarski J.C.Z., Mackey B.	Evaluating the status of species using Indigenous knowledge: Novel evidence for major native mammal declines in northern Australia	2013	Green

Appendix 3. *Coding scheme*

Category	Subcategory	Description	Variables
Paper ID			
Cluster Number			
Paper charcteristics	Author		
	Title		
	Publication Year		
	Journal		
	Citation (complete)		
	Citation/Year		
	Continent of first authors' affiliation	In which continent lies the first authors affiliation?	Africa, Asia, Europe, North America, Oceania, South America
	Country of first authors' affilitation	In which country lies the first authors affiliation?	own words, e.g. Norway, Sweden, etc., multiple entries possible and seperated with "/"
Methodological approach	Data collection	How was the data assessed?	qualitative, quantitaive, mixed, na
	Data collection: specific methods	Which method was used to collect data?	own words, e.g. interview, questionaire, observation, etc., if not clear na
	Data analysis	How was the data assessed?	qualitative, quantitative, mixed, na
	Data analysis: specific methods	Which method was used to analyse data?	own words, e.g. statistical analysis, content analysis, GIS, etc., na
Location	Continent of case study	In which continent is the observed case study located?	Africa, Asia, Europe, North America, Oceania, South America
	Country of case study	In which country is the observed case study located?	own words, e.g. Norway, Sweden, etc., multiple entries possible and seperated with "/"
	Specific location, region of case study	In which region is the case study located?	own words, e.g. Lappland, Amazonas, also cities, etc., multiple entries possible. Seperate specific location and region with "," and different locations with "/"

Stakeholder in focus	Kind of group	Which kind of group is observed or worked with in the case study?	local, indigenous, local and indigenous, na
	Name of community	Which explicit community is observed or worked with in the case study?	own words, e.g. Sami, Inuit, etc., multiple entries possible, if no community name mentioned na. Seperate different communities with "/" and put further description of cummunity in "(…)".
	Explicit stakeholder	Which explicit stakeholder group is worked with in the case study?	own words, e.g. fisher, hunter, households, community, etc., multiple entries possible
Transformation/ Transition/ Change	Use of words in the paper	Which terms are used in the paper?	transformation, transition, change; multiple entries possible. If there is a strong focus on only one of the words, put the number of mention of the other not focused words in "(…)"
	Application	In which context is the term used?	own words: e.g. social-ecological transformation, environmental change, etc.
	Category	Which category describes the context of the term 'change'?	environmental, climate, social-ecological, species
	Definition	Is there a definition of transformation/ transition/ change mentioned?	0 (no), 1 (yes)
		Which definition is mentioned?	quote of the definition, if not mentioned na
	Reference	Is the definition connected to a specific reference?	0 (no), 1 (yes)
		Which reference is used?	complete reference, multiple entries possible, if not mentioned na
ILK	Use of words in paper	Which terms are used in the paper?	indigenous, traditional, local (environmental/ ecological) knowledge, multiple entries possible
	Definition	Is there a definition of ILK mentioned?	0 (no), 1 (yes)
		Which definition is mentioned?	quote of the definition, if not mentioned na
	Reference	Is the definition connected to a specific reference?	0 (no), 1 (yes)

		Which reference is used?	complete reference, multiple entries possible, if not mentioned na
Connection of ILK and transformation/ transition/ change		How is ILK used in context of transformation/ transition/ change?	own words, e.g. interpretation of environmental change, adaptation, etc.
Scaling of ILK	Spatial scale	Is ILK used only on a local scale or on higher scales?	local, sub-national, national, supra-national, continental
	Multi-scale approach	Is there e.g. more than one case study in the paper which demonstrates a regional understanding?	0 (no), 1 (yes)
	ILK to global sustainability (Balvanera et al. 2017)	Are there insights from place-based ILK research mentioned to inform global sustainability?	0 (no), 1 (yes)
		If yes, put quote.	qoute from the text
	Scaling of an ILK-initiative (Lam et al. Unpublished)	Does the paper mention an impact of sustainability initiatives and a scaling process of the initiative?	0 (no), 1 (yes)
	Scaling process	How does the scaling process into another context look like?	stabilizing, speeding up, growing, replicating, transferring, spreading, scaling up, scaling deep

Appendix 4. *Papers mentioning the terms "transformation" and "transition"*

Paper	Use of 'transformation'	Use of 'transition'
Andrachuk and Armitage (2015)	x *	x
Apgar et al. (2015)	x *	x
Aswani and Lauer (2014)	x	
Brännlund and Axelsson (2011)	x	
Bruegger et al. (2014)		x
Carter and Nielsen (2011)		x
Chalmers and Fabricius (2007)	x	x
Clark and Slocombe (2011)	x	
Codjoe et al. (2014)		x
Crate and Fedorov (2013)	x	
de Almeida et al. (2016)	x	
Dowsley and Wenzel (2008)	x	
Fernández-Llamazares et al. (2015)	x	
Ford et al. (2006)	x	x
Golden et al. (2015)	x	
Gómez-Baggethun et al. (2012)		x
Hallwass et al. (2013)	x	
Hansen et al. (2013)		x
Herman-Mercer et al. (2016)	x	x
Homann et al. (2008)		x
Jandreau and Berkes (2016)	x *	x
Kassam (2009)	x *	
Kendrick and Lyver (2005)	x	
Klein et al. (2014)		x
Kokelj et al. (2012)		x
Leonard et al. (2013)		x
Nichols et al. (2004)		x
Oviedo et al. (2016)		x
Shava et al. (2010)		x
Turner and Clifton (2009)		x
Vogt et al. (2016)		x
Ziembicki et al. (2013)		x

Papers marked with * use the term ‘transformation’ in the sense of a social-ecological transformation. All 81 papers contain the term ‘change’, therefore only the papers containing the terms ‘transformation’ and/or ‘transition’ are listed here.

Appendix 5. *List of most important indicator words for each research cluster*

Research in arctic environments (red)	**Research in terrestrial environments (green)**	**Research in coastal environments (blue)**	**Research in grass- and rangelands (grey)**
aboriginal	adaptation	anecdotal	agriculture
accessible	adaptive	anecdotes	agroforestry
anchorage	adults	anthropogenic	alternate
arctic	animal	applicable	arid
art	anthropology	aquatic	burning
bay	authorities	archipelago	cattle
boating	belief	artisanal	crop
changed	beliefs	biology	cultivated
chipewyan	capacity	biomass	cultivation
cold	century	boat	degraded
complex	conversation	boats	desertification
cree	culturally	coast	desirable
elder	culture	coastal	droughts
eskimo	customary	cognitive	ethnic
experienced	desire	collapse	exotic
frozen	disaster	coral	farming
geophysical	dynamic	corals	fertility
harvesting	eating	crisis	forest
hunt	economy	degradation	forested
hunted	education	endangered	forests
hunter	educational	expertise	grass
hunters	experiences	fisher	grasses
hunting	fire	fisheries	grassland
ice	flowers	fishermen	grasslands
inland	foods	fishers	grazing
inuit	generation	fishery	herd
inupiat	globalization	fishing	herder
inuvialuit	god	gulf	household
lake	government	habitats	households
lakes	governments	integrating	integrated
mammals	histories	islands	livelihood
meat	huanca	lagoon	livestock
melts	integration	lek	mitigation
moss	islander	marine	mountain
nunavut	language	memory	participatory
oil	languages	nearshore	pastoral
participants	leader	oceanic	perception
permafrost	male	opinions	places
polar	medicine	overfishing	plantations
regionally	men	pacific	planted
regions	mountainous	periods	planting
relationship	oral	perspective	poverty
renewable	parents	practical	precipitation
scales	participant	predator	rainy
snow	participate	predatory	ranching
snowmobile	pastoralism	protected	rangeland
subarctic	plateau	recreational	rangelands
territories	policies	reef	relation
timing	political	reefs	savanna
tribal	power	seas	shrub
tundra	properties	shifting	shrubs
wildlife	rain	territorial	smallholder
	rainforests	tourism	soil
	restore	transformability	timber
	rock	tropical	transhumance
	sacred	villages	tree
	school	waters	vegetation
	seed		weeds
	societies		
	spiritual		
	story		
	technology		
	traditionally		
	traditions		
	tropics		
	urban		
	valley		
	valued		
	women		
	young		
	younger		

Appendix 6. *Differing characteristics of the individual research clusters*

Characteristics \ Cluster		Research in arctic environments (26 papers, red)	Research in terrestrial environments (22 papers, green)	Research in coastal environments (14 papers, blue)	Research in grass- and rangeland environments (19 papers, grey)
Continental distribution	Authors' affiliation	North America (26)	North America (9), Oceania (7), Europe (6), Africa (2)	North America (5), Europe (3), South America (3), Africa (2), Asia (1), Oceania (1)	Europe (8), North America (6), South America (3), Africa (3), Asia (1)
	Case studies	North America (25), Asia (1)	Oceania (7), South America (5), Africa (4), Asia (3), Europe (2), North America (2)	North America (4), Oceania (3), Asia (2), South America (2), Europe (2), Africa (1)	Asia (7), Africa (6), South America (4), Europe (2)
Stakeholder		indigenous communities (23), local groups (3)	indigenous communities (12), local groups (10)	local groups (12), indigenous communities (2)	local groups (18), indigenous communities (1)
Key research aspect		observation and perception of climatic and environmetal changes in arctic regions	perception of climate changes and adaptive capacity of communities, inclusion of societal and cultural aspects	environmental changes in aquatic ecosystems, endangered fish and plant species, management strategies	environmental changes of grass- and rangelands and following consequences for farming and herding

The numbers in brackets indicate the frequency of occurrence of the viewed characteristics of the individual research cluster. Note that one author can have more than one institutional affiliation and one paper can observe multiple case studies in different countries and continents.