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Global environmental change: local perceptions, understandings, and explanations

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ABSTRACT. Global environmental change (GEC) is an increasingly discussed phenomenon in the scientific literature as evidence of its presence and impacts continues to grow. Yet, while the documentation of GEC is becoming more readily available, local perceptions of GEC— particularly in small-scale societies—and preferences about how to deal with it, are still largely overlooked. Local knowledge and perceptions of GEC are important in that agents make decisions (including on natural resource management) based on individual perceptions. We carried out a systematic literature review that aims to provide an exhaustive state-of-the-art of the degree to and manner in which the study of local perceptions of change are being addressed in GEC research. We reviewed 126 articles found in peer-reviewed journals (between 1998 and 2014) that address local perceptions of GEC. We used three particular lenses of analysis that are known to influence local perceptions, namely (i) cognition, (ii) culture and knowledge, and (iii) possibilities for adaptation.We present our findings on the geographical distribution of the current research, the most common changes reported, perceived drivers and impacts of change, and local explanations and evaluations of change and impacts. Overall, we found the studies to be geographically biased, lacking methodological reporting, mostly theory based with little primary data, and lacking of indepth analysis of the psychological and ontological influences in perception and implications for adaptation. We provide recommendations for future GEC research and propose the development of a "meta-language" around adaptation, perception, and mediation to encourage a greater appreciation and understanding of the diversity around these phenomena across multiple scales, and improved codesign and facilitation of locally relevant adaptation and mitigation strategies.

Key Words: *adaptive strategies; cognitive psychology; local knowledge; ontologies; small-scale societies*

INTRODUCTION

Global environmental change (GEC) is an increasingly discussed phenomenon in the scientific literature as evidence of its presence and impacts continues to emerge from different corners of the world (Turner et al. 1990, Vitousek 1994, Steffen et al. 2004, 2011, Zalasiewicz et al. 2011) The notion of GEC refers to a set of planetary-scale changes in the Earth System (Vitousek 1994, Zalasiewicz et al. 2011, Dirzo et al. 2014), spanning from large-scale changes related to the global geosphere and biosphere systems (e.g., nitrogen and carbon cycles, biodiversity loss) to changes at the local or regional scale and related specifically to human activities (e.g., waste production, extirpation of species, land use changes). The processes driving GEC result from complex articulations of human actions (IGBP 2004, IPCC 2007) as well as from biological and physical processes, sometimes resulting from the accumulation of even multiple localized processes (Turner et al. 1990). Concerns and evidence are growing for the possible implications of a major state shift in the Earth's biosphere (Barnosky et al. 2012), and according to some, we are now living in a new geological epoch, the Anthropocene, in which human actions dominate Earth's systems (Crutzen 2002, Crutzen and Steffen 2003, Zalasiewicz et al. 2008, Ruddiman 2013).

In general, environmental change has been described by scholars as an integrative, all-encompassing, and even cyclical process (Sánchez-Cortés and Chavero 2011, Habiba et al. 2012, Boillat and Berkes 2013), with significant social dimensions (Byg and Salick 2009, Petheram et al. 2010). Despite this, most of the research examining local aspects of GEC has applied a top-down perspective (Wilbanks and Kates 1999). Using global modeling techniques, the normative aim has been to assess and predict impacts at highly localized scales and in specific settings (Schneider and Root 1996). However, due to the low resolution of global models at the local scale, some authors are starting to untangle the complex interconnection of GEC processes using a bottom-up approach, from the local to the global (Cox 1997, Byg and Salick 2009). Yet, while causes of GEC are better studied at the local level, GEC dynamics are observed mostly at the global scale but with responses and adaptations occurring at all levels (Wilbanks and Kates 1999, Adger et al. 2005, Wiens and Bachelet 2010).

While the documentation of GEC is becoming more readily available, with ever more sophisticated devices capable of capturing large-scale biophysical changes, local accounts of the impacts of GEC are still relatively overlooked. Indeed, most research to date has focused on the biophysical aspects of GEC, and it is only recently that the social sciences and the humanities have started to make their contribution. Social scientists concerned with GEC have tended to center on vulnerability and adaptation (Burton et al. 2002, Agrawal 2008, Thornton and Manasfi 2010) and risk perceptions (Tàbara et al. 2010) with regard to climate change, with the aim of measuring and modeling the relative vulnerability of particular regions, communities, or resources to predicted changes (e.g., Brooks et al. 2005, Erlandson 2012). This is a critical gap in global environmental science, as GEC has the potential to reduce the well-being and security of people locally and around the world, especially when exacerbated by social, political, and economic unrest.

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Recent calls for more social science research on GEC have come from a number of scholars (Monastersky 2009, Hulme 2011, Turnhout et al 2012, Barnes et al. 2013, Castree et al 2014, Victor 2015). There are a number of reasons why understanding local perceptions of change is important. Firstly, an insight into local perceptions can improve our understanding of GEC in its various manifestations and impacts on human populations. As an example, discrepancies between local perceptions of change and instrumental records (Marin 2010) illustrate the potential contribution that these can make in discovering new elements of GEC. Secondly, people's perceptions may well determine their behavior toward mitigation and adaptation actions (Stern 2000, Vignola et al. 2010, Engels et al. 2013), and are therefore a key ingredient in the design, planning, and implementation of successful GEC adaptation strategies that are adequate for local realities, be they social, cultural, or environmental (Patt and Weber 2014). Local perceptions are thus of direct relevance to any initiatives aiming for sustainable natural resource management, biodiversity conservation, or climate change adaptation and mitigation.

Given this situation, a handful of scientists have begun to undertake research on local understandings of environmental change among indigenous and local communities and other small-scale societies (e.g., Lykke et al. 2004, King et al. 2007, Green et al. 2010, Boillat and Berkes 2013, Kansiime et al. 2013), demonstrating the potential of local peoples' observations for the understanding of the local expressions of GEC (Byg and Salik 2009). We set out to review this literature to critically review the ways in which local understandings are captured and presented in the research. We approach this study from multiple perspectives, exploring aspects such as scale, geographic distribution, cognitive mechanisms, cosmologies, and values, and to what degree studies of GEC and local perceptions take into account these factors that might well be influencing the results. In addition, we review the literature with an interest in understanding why researchers study local perceptions of GEC, for what purpose or end.

To guide us through this, we framed our study in relation to three particular thematic foci. We questioned to what extent GEC research takes into account (1) the influences that cognitive psychology may have on local perceptions, (2) the role that local cosmologies, epistemologies, and ontologies play, and (3) whether and how local small-scale societies might be taking measures to adapt to environmental change. By "small-scale societies" we mean societies of a few dozen to several thousand people who live by foraging wild foods, herding domesticated animals, or conducting nonintensive horticulture at the village level. To contextualize our review, we present some general findings on the geographical and thematic foci of the literature, and how it reports (a) the types of environmental change perceived, (b) local explanations of the change occurrence and manifestation, including in time and scale as well as in terms of drivers and impacts, and (c) local evaluations of the change and its impacts. Our study is innovative in that it is the first—to our knowledge—that undertakes a comprehensive review of the existing research on local perceptions of GEC while using a critical perspective.

We present a theoretical background to our research design and analysis, touching upon elements of scale and causation, cognition, culture and knowledge, and adaptation. We then present a descriptive overview of our results, followed by a more comprehensive analysis around the three overarching themes of the paper, namely cognition, ontologies, and adaptation. We discuss the implications of our findings for the broader research on GEC, and the repercussions these might have for planning local adaptation and mitigation strategies.

THEORETICAL BACKGROUND

The purpose of this research was to undertake a systematic literature review with the aim of providing an exhaustive state-of-the-art of the extent to and manner in which GEC research addresses local perceptions in small-scale societies. To do so, we used three particular lenses of analysis that are known to influence local perceptions, namely (i) cognition, (ii) culture and knowledge, and (iii) possibilities for adaptation. We present and elaborate on each of these three thematic strands.

Cognition in global environmental change perception

In addition to scale and causation, equally important to local perceptions is cognition: the rates of temporal change in local perceptions (e.g., Deryungina 2012), perceptibility itself (e.g., Weber 2013), and the role that the reception of external scientific information may play in influencing local perceptions (e.g., Marin and Berkes 2012, Fernández-Llamazares et al. 2015*a*). Understanding the role that cognition plays in GEC perceptions is important for at least three main reasons. First, studies indicate that different psychological processes play a key role in shaping individual framings of environmental change (e.g., Stamm et al. 2000, Helgeson et al. 2012, Howe and Leiserowitz 2013). Examples of such processes include memory illusions, change blindness, and the Shifting Baselines Syndrome. Memory illusions refer to exaggerations of the extent of trends, which may also have been caused by the influential memory of extreme events (Roediger 1996, Kahn 2002, Daw 2010). Change blindness refers to the failure to observe local indicators of climate change; that is, the desensitization to change (e.g., Simons and Rensik 2005, Alessa et al. 2008). Shifting Baselines Syndrome refers to a type of change in how a system is measured or perceived, usually against previous reference points (baselines), which themselves may represent significant changes from an even earlier state of the system (see e.g., Papworth et al. 2009, Fernández-Llamazares et al. 2015*b*). Second, many works describe how experiential knowledge acquired through daily observation of the environment—accurate or not—generally overrides descriptive knowledge gained through the uptake of scientific information (Myers et al. 2013, Egan and Mullin 2014, Zaval et al. 2014, Yeh 2015). In other words, agents make decisions (e.g., on the use of natural resources) based on individual perceptions rather than on measured variables or more diagnosed criteria (Oba and Kotile 2001, Maule and Hodgkinson 2002, Voyer et al. 2012). And third, the research to date suggests that the way in which people perceive environmental changes influences how they respond to them (Weber and Johnson 2009, Vignola et al. 2010, Spence et al. 2011).

Yet, human perceptibility of GEC (particularly climate change) has been somewhat disputed in the last decades (see Rudiak-Gould 2013). While some argue that global changes are beyond the threshold of human perception over the course of a lifetime (Mormont and Dasnoy 1995, Doyle 2009, Spence et al. 2011), others claim that the effects of GEC are visible to the naked eye

(Riedlinger and Berkes 2001, Green et al. 2010). Responses to this debate are blurred by the meagre empirical research on the topic and partially explain the increasing interest in understanding the way in which people frame environmental changes from a psychological point of view (Swim et al. 2009, Howe et al. 2012, ISSC and UNESCO 2013). Nevertheless, our current understanding of psychology in GEC remains poor and biased, the latter in that the cognitive science that has been carried out to date has been limited largely to climate change perceptions and to what Henrich et al. (2010) term as "WEIRD" (Western, Educated, Industrialized, Rich, and Democratic) societies (Capstick et al. 2014). Such biases are of concern, especially as local knowledge and individual perceptions often form the basis upon which many small-scale societies monitor availability and thus manage natural resources (Maule and Hodgkinson 2002). In other words, local perceptions are critical in designing successful and sustainable natural resource management schemes among small-scale societies wherever they may be (Oldekop et al. 2012).

Culture and knowledge

Beyond the psychological and socioeconomic considerations that GEC entails, there is also a need to understand how GEC is converted into a culturally relevant form at the local level (ISSC and UNESCO 2013). Research already shows the importance of existing epistemic frameworks, local systems of knowledge, and vernacular systems of classification in studying local perceptions of environmental change (Gupta 1999, Lakoff 2010). This body of research relies mainly on concepts and ideas developed in environmental anthropology and ethnoecology (e.g., Brosius 1999, Kottak 1999, Nazarea 1999), and focuses on the study of systems of local knowledge (hereafter LK) (Berkes 1999, Davis and Wagner 2003) and stresses the fact that, beyond psychological aspects, such systems also include theoretical, practical, and symbolic dimensions (Nadasdy 2007, Reo and Whyte 2012).

As Berkes (2009) has already put forth, local perceptions of environmental change need to be understood as part of larger systems of knowledge that have been developed locally, through repeated interactions with the environment, and that have been handed down over generations. In addition, local perceptions may also integrate with local values (including economically driven commodification and utility values), as well as with hybridized knowledge coming from external sources such as NGOs, governmental agencies, or media channels (Dove et al. 2007, Li 2007, Leonti 2011, Rudiak-Gould 2014). Therefore, the way in which people perceive and experience environmental change will most likely be shaped at least partly by the existing vernacular conceptions of the environment, be it referred to or theorized as local cosmologies, local classification systems, or ontological regimes (Orlove et al. 2002, Descola 2005).

Adaptation to global environmental change

All the above-mentioned perceptual differences have implications for people's cultural representations of the environment, which in turn, largely define the possible strategies for coping with—and enacting with—change (Manandhar et al. 2011, Boissière et al. 2013, Yu et al. 2014). For example, differences in perceptions of climate change across gender and age groups in Ethiopia have been found to affect local adaptation preferences (Deressa et al. 2009). Not surprisingly then, adaptation has become an increasing focus in GEC literature, and particularly climate change literature, as human vulnerabilities to the impacts of change (regardless of mitigation efforts) have become manifest and irreversible. Some studies have already begun to highlight the importance of local understandings of GEC for adaptation policies in particular, especially as they can compensate for the lack of formal scientific data on local effects of environmental change, and to inform locally sound resource governance (Laidler 2006, Bunce et al. 2008, Newsham and Thomas 2011, Robbins 2012). However, a problem with the literature to date on climate and GEC adaptation is the difficulty to isolate precisely what drivers and impacts people are responding to. Locally experienced stress and vulnerability likely arise from multiple sources, among which GEC drivers and impacts may be secondary to more proximate ones; e.g., socioeconomic trends. In our review, we therefore use a multifaceted approach to assessing how adaptation has been addressed in the GEC literature.

METHODS

In order to access articles that address local perceptions of GEC, we used the search engine Web of Science (http://wokinfo.com/) to run our search. We inserted the following keyword phrases: "Local Perceptions Global Environmental Change," "Local Perceptions Climate Change," "Indigenous Climate Change," "Indigenous Perceptions Climate Change," "Indigenous Local Environmental Change," and "Small-scale Society Environmental Change." First, we compiled all relevant articles published up to mid-2014, which gave us a total of 176 articles. We did a general but careful review of all of these to filter out any articles that might not fit our criteria; i.e., they had to be case studies that substantially addressed local perceptions or contemporary environmental change with actual data, rather than general theoretical papers or compilations of many cases. Through this initial scan, we eliminated 50 articles, which left us with a total of 126 articles—all published in peer-reviewed journals between 1998 and mid-2014 (see Appendix 2 for the full list of articles reviewed).

We then designed a database matrix framed according to our key research questions and the variables that would help us answer them. We pilot tested the matrix by initially reviewing 13 randomly selected articles from our first sample set, and made the necessary adjustments to the matrix to maximize quantitative data entry and applicability across a variety of case studies while maintaining the level of detail we sought to have. We then decided on a final template for the matrix (see Appendix 1), and set up a database in which to enter our data. Responses to GEC were analyzed using a meta-language of adaptation processes developed by Thornton and Manasfi (2010) (see also Agrawal 2010). For a more detailed explanation of our methodology and analysis, see Appendix 1. Table 1 lists those variables for which we present findings. Appendix 3 contains the full matrix of the results presented here.

RESULTS

Descriptive results

Thematic and geographical foci

The 126 articles we reviewed spanned more than 56 journals, mostly from the following: *Global Environmental Change*, *Climatic Change*, *Arctic*, *Indian Journal of Traditional Knowledge*, *Ecology and Society*, *Environmental Management*, *Land*

Table 1. Variables for which data were collected, with scales and categories of analysis.

Variable	Description (including codes and categories)
Geographical focus of study	(i) Continent (pre-coded into seven categories), and (ii) region (pre-coded into 28 categories)
Goals of article	Whether (a) documenting change and (b) comparing scientific data with local perceptions were the main goal (1), one of many goals (2), or not a goal (3) of the article
Methods of data collection	Whether quantitative (1), qualitative (2), or both (3)
Type of change perceived	Pre-coded into 16 categories: temperature change, rainfall change, drought, erosion, floods, sea level rise, deforestation, biodiversity change, invasive species, permafrost/ice/glaciers, fire, winds (excluding tornadoes/cyclones), storms, extreme events (including tornadoes/cyclones/tsunamis/earthquakes), phenology/seasonality, or other. This was recorded for up to seven different types of environmental change per article.
Perceived driver of change	Whether perceived as human-induced (1), a natural phenomena (2), induced by supernatural/religious/cosmological forces (3), or other (4)
Perceived spatial impact of change	Whether local (1), regional (2), global (3), or locally not perceived (4)
Evaluation of change	Whether change was seen as positive (1), negative (2), or both (3)
Visibility of change	Whether change was perceived by the naked eye (1), only by use of technological instruments (0), or by both (2)
Psychology	Whether the article took into account (1) or not (0) local psychological dimensions of the environmental perceptions (e.g., shifting baselines, change blindness, amnesia, media effects)
Conceptualizations of change	Whether the article took into account (1) or not (0) local ethnological explanations of change (e.g., any local epistemology, ontology, cosmology, cultural meaning, or other)
Response and adaptation	Whether the article mentioned any local responses or adaptation measures to change (yes = 1, no = 0), and if so, whether these were (a) based on local knowledge (1), based on modern technology (2), or both (3), (b) locally driven (1), externally driven (e.g., by NGOs, development aid, scientists, government) (2), or both (3)

Degradation and Development, and *Regional Environmental Change*. Overall, we found great variation in both the thematic foci and types of GEC that the articles covered. The most common topics were vulnerability assessment, local weather, adaptive strategies, LK systems, and local observations of environmental change. However, even within the same thematic area, articles varied in terms of focus. For instance, some authors addressed specifically socioeconomic vulnerability (increasing poverty, unemployment, disease), while others focused more on cultural vulnerability (e.g., local traditions). Most case studies were from Africa, followed by North and Central America, and thirdly Asia. Table 2 outlines the geographic distribution of the studies in relation to continent and region.

Table 2. Geographic representation of articles reviewed.

Continent	No. of Articles	Region	No. of Articles
Africa	36	Southern Africa	8
		Horn of Africa	8
		East Africa	7
		Sahel	7
		Western Africa	5
		North Africa	1
North and Central America	37	Arctic	33
		Mexico	3
		Other	1
Asia	29	South-Central Asia	16
		Eastern Asia	8
		South-East Asia	5
South Pacific	13	Australia	6
		South Pacific Islands	6
		New Zealand	1
South America	6	Amazon Basin	4
		Andean Region	2
Europe	3		3
Total	124		124

Goals and methods

For more than half the cases, studying local perceptions of change was only one of several goals of the research; for approximately one-third of the cases, this was the primary goal of the article. In only a handful of articles was the actual documentation of change (i.e., using scientific methods for change documentation) the main goal of the study. About one-third of the studies had change documentation as one of several goals, but it was not the primary goal. Meanwhile, the methods of data collection varied between quantitative only, qualitative only, and both. Many of the articles lacked methodological details; e.g., descriptions of precisely (a) what was asked of respondents, (b) to whom specifically it was asked, (c) how it was asked (i.e., exact wording, approach), and (d) when it was asked (timing and context). Less than one-third of the articles reported on sample size of the group studied, let alone sampling strategy. Approximately half the articles reported either the year(s) for which data were recorded, or the decade since change had been recorded or perceived.

Types of global environmental change, drivers, and impacts

The most commonly documented types of environmental change that were reportedly perceived by the peoples studied were phenology/seasonality, rainfall change, temperature change, and biodiversity change. For the full list of findings, see Table 3. In those articles that reported on drivers and impacts, the driver of change was perceived to be local (e.g., most commonly related to temperature change, followed by biodiversity change) in most of the cases, followed by global (mostly biodiversity then temperature change related); the least commonly reported drivers of change were regional (mostly deforestation then biodiversity change related) or were locally not perceived at all. The drivers of change were seen in most cases to be human-induced, and only in very few cases as natural phenomena, supernatural/religious/cosmological driven, or a combination of both human and supernatural. In those articles that reported local perceptions of the spatial impacts of GEC, the change was perceived to be mainly global in most of the cases, followed by local; perceived impacts

at regional scale were reported in only one case. The impacts were perceived to be mostly on (i) livelihoods, (ii) culture and social norms, and/or (iii) the environment. Overall, change was evaluated by local peoples (and reported in more than half the articles) as negative in most cases, or as both negative and positive in a few cases. In no cases was the change perceived by the local society as entirely positive. We discuss the possible reasons for these results further in this article.

Table 3. Types of locally perceived global environmental change reported in articles reviewed.

Type of Change	No. of Articles
Phenology/seasonality	71
Rainfall change	70
Temperature change	69
Biodiversity change	63
Permafrost/ice/glaciers	42
Unusual/unpredictable weather patterns	42
Extreme events (including tornadoes/cyclones/tsunamis/ earthquakes)	39
Drought	38
Deforestation	28
Winds (excluding tornadoes/cyclones)	25
Erosion	23
Floods	23
Storms	23
Fire	19
Invasive species	17
Sea level rise	14

Cognitive psychology and perceptions of change

Approximately half our sample reported cognitive aspects related to perceptions of change, and made direct links between the local observations of change and different psychological aspects. Cognitive processes influencing change perceptions that were given particular attention included the endowment effect (Patt and Schröter 2008), availability heuristics (Meze-Hausken 2004), change blindness (Alessa et al. 2008), and Shifting Baselines Syndrome (Ainsworth et al. 2008). Some of the articles drew on individual and group mental models to clarify the synergies and feedbacks in the linkages between change perceptions and other likelihood stressors (Bunce et al. 2009, 2010), while others showed, with the help of mental models, that people recognize linkages and feedbacks between events, processes, and causes, interwoven both at local and global scales (Bunce et al. 2010, Rai 2010).

Change was reported as able to be perceived by the naked eye (without any recording devices) in about one-third of the cases, whereas in more than half the cases the change was reportedly perceived by the naked eye and recorded with technological equipment or measurements. Some articles explored the role of visualization and sight in environmental change perception (e.g., Rudiak-Gould 2012, Li et al. 2013, Nkomwa et al. 2014), while others examined how climate change perceptions differ due to age differences (Alessa et al. 2008) or gender (Boissière et al. 2013, Li et al. 2013), both of which could be linked to age and gendered distribution of labor and environmental engagement. For example, men of a certain age who hunt (compared to men or women who do not hunt) would be more likely to perceive more changes in animal populations.

Most of the studies used an epistemological approach of constructivism, in which it is held that people construct knowledge and meaning from their social interactions and personal experiences of change (Petheram et al. 2010, Rudiak-Gould 2014). For instance, Ignatowski and Rosales (2013) reported that local peoples are particularly perceptive of biophysical factors related to safety and security. Several other authors explored local change perceptions by undertaking a risk perspective (Anik and Khan 2012, Below et al. 2012, Combest-Friedman et al. 2012), and argued that perceptions of increased risk due to uncertain and complex environmental changes are highly contingent on the social, economic, and cultural conditions within which people experience these risks (West et al. 2008, Bridges and McClatchey 2009, Ignatowski and Rosales 2013).

Local cosmologies, epistemologies, and ontologies

Almost half the articles in our sample addressed local conceptualizations of change in one way or another. Of these, very few touched on cosmology or ontology, while many more addressed epistemology. While a handful of papers touched on cosmology, they did so merely by giving some examples of perceived causality (e.g., environmental changes linked to spirits or deities) and myths (Byg and Salick 2009, Marin 2010, Lauer and Aswani 2010, Cruickshank 2011). A few papers talked more generally about other conceptualizations of nature—e.g., as personal or social relationships or something that continues to be created continuously—or mentioned the way some practices are rooted in cosmological principles as well as in practical considerations (e.g., sharing food).

As for epistemologies, the articles that addressed this mostly (e.g., Laidler 2006, Roturiera and Roue 2009, Speranza et al. 2010, Cruikshank 2001) did so when comparing what characterizes LK in contrast to Western science, and stressed the importance of the former and how it should be taken into account, although the reasons given differed. While some of the authors highlighted LK as a means to help confirm scientific observations (Ignatowski and Rosales 2013), others suggested that LK can provide additional information for scientists by supplementing scientific data (e.g., for places, time scales, or parameters that scientists have not yet measured or taken into account [cf. Roncoli 2006]). Some of the articles (e.g., Marin 2010) showed how LK can point toward areas that need more research—e.g., where there is disagreement between LK and Western science (Gearheard et al. 2010, Weatherhead et al 2010)—or highlighted the importance of LK as an asset of resilience for smallholders to respond to climate change and other social-ecological shifts (von Glasenapp and Thornton 2011, Ruiz-Mallén and Corbera 2013).

A few papers reflected on the ways in which Western science conceptualizes LK, and how the latter is used or abused (e.g., Leduc 2006). The difficulties of translation between different epistemologies (Rudiak-Gould 2012), the ways in which different kinds of knowledge become authorized (Cruikshank 2001), and how such processes constitute power (Veland et al. 2013) are some of the important points that came up in the literature. Furthermore, some of the literature acknowledged how Western science is influenced by factors other than just empirical properties

Table 4. Adaptation processes addressed in the reviewed articles.

Adaptation Process	Definition†	No. of Articles (n = 64)	Examples
Mobility	Seasonal movement or permanent migration to avoid risk or in search of better circumstances	54	Hunter mobility on Arctic sea ice; pastoralist seasonal migrations; crop siting
Exchange	Flow of material and symbolic goods and services	52	Knowledge exchange programs
Rationing	Controlling the circulation or consumption of limited or critical resources	50	Water conservation or recirculation in rain-fed agricultural schemes
Pooling	Sharing or linking of assets (wealth, labor, knowledge)	39	Improved risk management through sharing of information and technology assets
Diversification	Changing the portfolio of food, income sources, etc. to enhance livelihoods	64	Changing crops, livestock, prey choices
Intensification	Increasing the availability of resources by boosting their yield within a certain space or time	56	Intensifying planting or harvesting in places with higher capacity
Innovation	New method or technique that arises to address a certain need	41	New seed varieties or inputs to maintain or improve agricultural yields
Revitalization	Organized reconfiguration of traditional knowledge and practices to reduce stress	23	Re-evaluating traditional weather forecasting techniques in light of climate change impacts

†cf. Thornton and Manasfi (2010)

of the phenomena studied (Gearheard et al. 2010, Veland et al. 2013). Many papers mentioned changes in knowledge systems due to changes in lifestyle, influence from other knowledge systems, or because of environmental changes which invalidate traditional knowledge (e.g., Ford et al. 2006).

A conceptually interesting paper by Orlove et al. (2010) differentiated between several components of LK related to climate (components of LK being somehow equivalent to domains of knowledge). The study identified four components to which people refer when dealing with climatic events: (a) historical patterns, (b) signs (i.e., symbolic or religious dimension), (c) actual weather observations, and (d) regional media information (radio, news). In contrast to most of the papers that emphasized epistemological differences between LK and scientific knowledge, Orlove et al. (2010) showed that information coming from different domains ("components") is actually used by people while interpreting ongoing climatic events. According to the authors, local people show a clear openness in selecting the information they use, and there is no apparent opposition between the different epistemologies at play; rather, they are seen to complement one another. Why local people in these cases choose to transcend epistemic boundaries is unclear, and may be linked to how different information is accessed, by whom, and in what form.

Local responses and adaptation strategies to global environmental change

Local responses to GEC were reported in more than half the papers reviewed. Such responses were based on LK in about one-quarter of the articles, and relied on both LK and modern technology in a similar number of cases. Very few articles reported responses based only on technological knowledge and practices. In general, responses were locally driven (for the most part) or both locally and externally promoted, whereas those driven only by external institutions (NGOs, scientists, and government) were reported in only a handful of articles. Some articles did not include enough data to identify the type of knowledge and origin of the response.

Responses to GEC that consisted of diversification, or the process of increasing the variety of income production strategies and food, were the most frequently reported as adaptation strategies (in about half the articles) (see Table 4). Less than half the articles reported adaptation strategies based on mobility (i.e., temporary or permanent migration to avoid risk), rationing (i.e., controlling and limiting critical resources consumption or circulation), and exchange processes (i.e., increasing revenue flows). Intensification strategies aimed at increasing the utilization of resources in a certain period and location were reported in about one-third of the articles. Responses based on innovation were included in one-third of the articles, as were pooling, or the sharing of assets across social groups. Adaptation consisting of revitalization processes, or the restructuring of society cultural practices, ideology, and organization to deal with stress, were identified in about one-quarter of the articles.

We also found that about one-tenth of the articles, particularly those focused on Arctic indigenous peoples, reported adaptation strategies related to forecasting, such as the observation of snowing by Saami reindeer herders to decide when to move animals (Tyler et al. 2007). Here, the emphasis on forecasting was concerned mainly with re-evaluating and aligning traditional knowledge and techniques for weather forecasting in light of changing conditions, and thus arguably could be considered a revitalization process. Hardly any articles mentioned any responses based on flexibility (e.g., in terms of when to travel on sea ice, plant crops, graze animals in certain areas). Two articles also mentioned praying as an adaptation strategy, again perhaps reflecting revitalization or revalorization of a traditional technique. One article reported strategies based on selectivity (classed as rationing), and another one identified "policy" itself as an adaptation pathway (classed as innovation, given the emphasis on new policies).

DISCUSSION

Firstly, and as mentioned in the Introduction, it is surprising how many articles in the broader GEC literature do not deal with local perceptions at all. Several reasons may explain this. First, it is

often difficult for local people to perceive certain aspects of GEC; e.g., in the case of changes in temperature over time (a fluctuating process in itself), especially if adequate measuring instruments are not available (see Rudiak-Gould [2013] for some examples). Second, local people may face a challenge in understanding the drivers and impacts of environmental changes at the local and global scales. For instance, Wilbanks and Kates (1999) stress the difficulty local people have in drawing causal links between their daily activities and the global-level impact these have, as indirect processes are simultaneously at work in GEC induction. Third, there is the ongoing debate about what counts as knowledge with regard to valid data and science (Adams 2007). The most fundamental and consequential effect of this is that those (often mistakenly) considered "nonspecialists" are rarely given the opportunity to contribute to the GEC debate, even when they are directly affected by it.

Of those studies that looked at GEC and local perceptions of small-scale societies (i.e., the 126 articles reviewed here), there is firstly a geographical bias, particularly to Africa, the Arctic, and Asia, with very few studies for instance from Europe or South America. There may be some association between geographic representation and the patterning of goals in the articles due to scientific data availability at the scales necessary to evaluate it against local knowledge and perceptions. This geographical bias may also be linked to the more prominent presence of small-scale societies in Africa, Asia, and the Arctic, although this does not explain the relatively numerous studies in South America. The Arctic, in turn, plays an interesting role as it represents one of the few areas where indigenous peoples and local resource-dependent communities exist within highly developed countries with capacity to perform high quality interdisciplinary and transdisciplinary studies.

There may also be a link to why researchers go about studying local perceptions of GEC in the first place. While some researchers may undertake such studies with the main purpose being to fill data gaps (assuming that LK has a certain validity, at least concerning local, observational data), others may have the primary aim of testing or proving the validity of LK. Another reason may be the aim of identifying new research areas or questions, which implies that LK is seen as valid per se. That said, many scholars might intentionally dismiss LK precisely because it is integrative, and thus difficult for disciplinary thinkers to understand and manage. While there may be good reasons to undertake coproduction of knowledge and transdisciplinary studies (e.g., more suited to address complex systems, more democratic knowledge production, better-placed solutions), the disciplinary structure of academic knowledge production, the lack of resources, and closed and competitive career paths for scientists all act as barriers to perform more integrative research (Nowotny et al. 2001, Hirsch Hadorn et al. 2006, Cornell et al. 2013). Finally, there may be practical considerations such as improving adaptation, mitigation, or communication strategies in relation to GEC, in which case the validity of LK might not be of prime importance, but rather the assumption that LK influences people's behavior and therefore needs to be taken into account. This might explain why, of our three thematic foci, adaptive strategies were more commonly addressed in the reviewed articles than were factors of cognitive psychology or ontologies.

Philosophical questions

This brings us to the complexity of GEC research: both scale and causality are hugely complex phenomena that scientific research continues to be challenged by. Yet, the concept of scale might be over-dichotomized, especially when categorized as simply "local" or "global," and as largely portrayed in the current GEC discourse. As our findings illustrate, there are a number of gaps in the current GEC research in terms of scale and causality, resulting in little evidence of how local societies perceive concepts of scale (e.g., "global" or "local") and the possible interactions between scales.

Scale is also strongly linked with models of causation (i.e., to cultural perceptions of drivers of change), as there is undoubtedly a feedback continuum across scales and perceptions. Aspects of GEC might well be changing ways of life and associated value, which might in turn influence local perception (Turner et al. 2008, Byg and Salick 2009). One might also ask to what extents are changing values simply adaptations to change, especially in intergenerational time frame? Similarly, it is extremely difficult to tease apart the political, cultural, social, and economic factors that influence perception, and how these factors might influence what people perceive (or state) as the reasons for change. The same can be said for psychological factors, although studies in phenomena such as the Shifting Baselines Syndrome have already shed some light on how these impact local perceptions of environmental change (see Fernández-Llamazares et al. 2015*b*).

The concept of change is also something that we argue needs to be considered from a cultural and ontological perspective (Barnes et al. 2013). In many cosmologies, the world is not seen as static, and longer cycles may be recognized and passed on in oral tradition over generations. The implications of this are related to those of psychological phenomena in that perceptions captured at the individual and time-specific levels may vary greatly depending on the positioning against larger perceived cycles and/or the knowledge held of broader patterns of change. Such change is not necessarily associated with "climate change" or other scientific phenomena as Western science frames them, but rather explained according to spiritual beliefs. Similarly, if a local population is experiencing the same environmental phenomena but with more frequency or extremes, it may not necessarily change its beliefs or perceptions of the drivers of these. Further research—especially from more interpretive rather than positivist disciplines (see Hulme 2011)—could shed light on the multiple nonscientific ways in which people perceive and interpret change.

As for the impacts of GEC, and whether they are seen as positive or negative, our results gave no cases of changes that were seen as solely positive. While it may well be that local small-scale communities really are the net losers of GEC (hence, their attitudes), there may also be a tendency of local people to emphasize the negative; e.g., in the hope of receiving assistance, even when livelihoods have actually improved. The negative perceptions may also be related to the ever more unpredictable nature of GEC; hence, a source of insecurity. Whatever the reasons, they are unlikely to be so clear-cut. For instance, the perception of negative effects linked to environmental change may in some cases be partially offset by the benefits that may result from certain change, as seen in the case of oil exploitation in northwestern Siberia providing new market opportunities for

reindeer herders, despite environmental degradation (Forbes et al. 2009). Therefore, while scientists tend to focus on negative impacts of GEC, local populations' perceptions may be very different when it comes to impacts on their livelihoods. This calls for a deepened ontological approach to understanding the concept of change; e.g., through more indepth qualitative studies and opening of knowledge systems. As Denzin and Lincoln (2000) concur, contemporary research is becoming more inclusive of different worldviews, and other "ways of knowing" are central to this evolving qualitative discourse.

That said, there are many challenges related to gathering and presenting LK and integrating it into Western scientific research. These can be seen as trade-offs or even inherent tensions between (i) a commitment to ethical principles and performing "decolonized" science (e.g., Tuhiwai Smith 1999) on the one hand, and (ii) following the expectations or established rules imposed by academia on the other. These relate not only to research design and methods, but also to the eventual distribution of benefits of the research findings. Similarly, the ontological and epistemic characteristics of both local and scientific knowledge can become an impediment to a common and merged body of theory, especially if practical use of knowledge by local people is to be enabled. As mentioned, agents make decisions (e.g., on the use of natural resources) based on individual perceptions rather than on measured variables or more diagnosed criteria (Oba and Kotile 2001, Maule and Hodgkinson 2002, Voyer et al. 2012). Moreover, small-scale societies often rely on many different kinds and systems of knowledge in their daily interactions with the environment (Brant-Castellano 2000). This has important implications on the relationships between local and scientific knowledge (Agrawal 1995, Ingold 2000), especially if and when LK cannot be measured or quantified, and thus continues to be largely dismissed by Western researchers, stemming from a different appreciation regarding the truthful representation of the world by these two epistemological systems (Johnson and Murton 2007).

Methodological caveats

There are a number of methodological challenges and limitations to our study that are important to point out. Already in the actual material reviewed, there are potential sources of bias derived from having included only journal articles in our sample—as opposed to books or book chapters—particularly as the latter tend to be of a more ethnographic nature, which arguably is what accounts of LK entail. Another significant limitation is that, in general, the articles we reviewed gave very little methodological explanation or description, which makes it difficult for readers to discern between what is reported by each study as being a local perception and what the individual's (or community's) actual perceptions are. This is an important methodological caveat given that how questions are designed may have significant effects on the answers given.

This brings us to a question of unit and representation; i.e., whether the results presented in the studies reviewed really can be generalized as "local," or whether there might be significant heterogeneity in response (and perception) within a community. This question of possible heterogeneity in local perceptions remains for the most part unacknowledged in the literature on GEC, while the literature on intracultural variations of LK suggests that such a heterogeneity is very likely (Begossi et al. 2002, Ghimire et al. 2005). There may also be a tendency for scientists to use hegemonic approaches and skew their results in an attempt to force a certain logic; e.g., to report more homogenous views on local perceptions in order to make their scientific arguments come across as more solid or credible. Additionally, there is the possibility that what external scientists understand as "local" or "global" (be it knowledge, responses, strategies, for example) may not necessarily be seen or self-perceived as such by local people themselves.

There are also possible confirmation biases and gaps in understanding causation when people are asked questions based on external (predefined) terms and frameworks. Simply the asking of change from people who may or may not perceive any change may create a bias in the results. Hence, there may be some bias in the results due to local respondents having given strategic answers. In general, studies like the ones we have reviewed here are almost always framed according to Western scientific logic, meaning that even the use of categories (such as "local" versus "global") are predefined and may go contrary to local framings and epistemologies (Aswani and Lauer 2014). This might not only influence the responses given, but may also leave out important and relevant aspects of research that go unnoticed as scientists remain limited by their own epistemological thinking. What we draw from these limitations is a call for more indepth, qualitative studies to better complement the more common inbreadth, quantitative ones.

Suggestions for future research

The current literature begs for a conjunction of research on livelihoods and GEC (although these may be more common in the vulnerability literature). For instance, studies on whether groups with different livelihood strategies perceive change differently are called for, as are studies that addres the universality of GEC perceptions and cognition, and whether these might be useful in distinguishing diversity. With regard to appropriate units of scale, and addressing the above-mentioned questions on possible intracommunity heterogeneity in the evaluation of a change, association of a change with a cause, and preferences for responses, future research would do well in considering a shift in the focus of unit of analysis. For instance, a shift from community-level analysis down to the household level could be more appropriate. As demonstrated by von Glasenapp and Thornton (2011), the household is a suitably "small flexible unit" (Netting 1993, as cited in von Glasenapp and Thornton 2011) and a repository of LK and components of resilience.

Finally, more cross-cultural research is needed, as is the need to include a much more embedded perspective that encompasses embodied experiences in the study of knowledge and perception. Measuring (or discovering) perception can be resource costly. One way to overcome this is to look at the responses and ask—in hindsight—what made people do what they chose to do, or say what they said, or perceive what they reported to perceive. We agree with Ribot (2011) and others (cf. Cameron 2012) who argue that current approaches used in GEC research are far too narrow to encompass the complexity they involve, as research must not simply identify who and what is vulnerable to environmental change, but also why. When designing protocols on what to ask and how, and what kind of knowledge to capture (such as

experiential knowledge in relation to certain kinds of change), the value of questions that address the "why" behind local perceptions and explanations should not be underestimated.

CONCLUSION

Our study confirms previous studies (Barnes et al. 2013, Castree et al. 2014), suggesting that most research on GEC has not to date relied on local perceptions and understandings, despite their importance as a resource for adaptive capacity (Naess 2013). The relatively little research that does exist remains fragmentary, geographically scattered, and mainly qualitative (ISSC and UNESCO 2013). We also found that researchers integrate vernacular understandings of environmental change in very heterogeneous ways due to the absence of clear standards on how to do so. The use of categories based on formal science—while collecting data on local perceptions of environmental change—is prevalent in the literature, which runs the risk of biasing the actual perceived changes at the local level with imposed Western epistemological frameworks that are disconnected from particular cultural contexts. We as researchers should therefore be aware of the effects that enforcing our own hegemonic logical frameworks and epistemologies may have on the responses and results we obtain, especially when carrying out cross-cultural research. The same applies to preconceived responses or results, even when it implies compromising on clarity or strength of our scientific arguments. If we wish to inform and engage in the facilitation of adaptive processes to better mitigate and cope with GEC, then the different (including moral) causations held by local peoples may be critical in defining success. Our work as external researchers also calls not only for community-specific validation of results and knowledge, but for increased coproduction of hybrid knowledge, if we are to decolonize what remains as a highly top-down system of scientific practice in framing GEC research.

In attempting to decolonize research—e.g., by means of codesign and increased facilitation—problems may well arise if simultaneously trying to standardize approaches more broadly. These challenges are not new to researchers, as already noted by several scholars (Agrawal 1995, Ingold 2000, Nowotny et al. 2001, Hirsch Hadorn et al. 2006, Cornell et al. 2013), who point out that, in addition to bridging knowledge systems and decolonizing scientific methods, there is a need to complement quantitative-breadth-type studies (which enable comparability) with qualitative-depth ones (for increased acknowledgment and respect for the cultural diversity of concepts and interpretations). Whether and how these seemingly contradictory objectives can be successfully merged remains to be seen, and certainly calls for further research in itself. In the meantime, introducing local worldviews into the theoretical process can provide for a more inclusive perspective on the concept of knowledge and its production. Similarly, the encounter of seemingly contrasting worldviews can be used to create an "ethical space" (Poole 1972): a place between worldviews where the intentions of each are submitted for negotiation. This in turn can open up the possibility for configuring new models of research and knowledge production that are mutually developed through negotiation and respect in cross-cultural interaction (Ermine et al. 2004). Such processes are by no means easy, and may well entail a ceding of control and re-orientation in thinking (Nicholls 2009, Coram 2011) or a shift altogether in paradigmatic approach, thereby allowing for a much closer attention to the vernacular, and dynamic understanding of scale and context (Grandia 2015).

While we do not have all the answers on how to go about improving GEC research on local perceptions, what is clear is that both the qualitative indepth and the quantitative inbreadth approaches play a critical and complementary role in research on local perceptions of GEC. Despite this, our study found that (i) very few studies in the broader GEC research deal with local perceptions overall, (ii) the methods employed in GEC research remain largely underreported and inconsistent, and (iii) very few studies go into sufficient depth in addressing issues of knowledge coproduction, or ontological/epistemic aspects of GEC perceptions. We therefore call for the further development of a meta-language around adaptation, perception, and mediation so that we can begin to appreciate and understand the diversity around these phenomena across multiple scales. We urge future researchers to consider their possible contribution toward such a meta-language when designing their studies in order to improve comparability among cases and broader understandings of the interaction of perception and adaptation processes and pathways among human societies. Again, combining standardized approaches with decolonized ones brings with it new challenges, but by following the road maps already laid out by scholars in this area (e.g., Cornell et al. 2013), it may well be feasible.

Incorporating and better understanding local perceptions of GEC requires addressing the "why?" behind perceptions and explanations. Only in getting a deeper understanding can we perhaps begin to explain why people react to environmental changes the way they do, and thereby be better placed to work on longer term adaptation and mitigation strategies to GEC, among other alternative solutions to current environmental problems. Such analysis would also improve communication, relations, and deliberative processes among actors, and provide support for suitable adaptation measures at appropriate scales.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/8482

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Appendix 1: Database Matrix

In reviewing each article, we inserted the data for each variable listed below into the ready-formulated Excel database. Where information was not provided or not clear, the data cells were left blank. Answers were mostly quantitative, pre-coded and categorized (as shown in Table A1 and A2 below) to ease subsequent data analysis. Similarly, as seen in Table 3, we used pre-defined categories (Mobility, Exchange, Rationing, Pooling, Diversification, Intensification, Innovation, Revitalization, and Other) to analyze adaptation type. We used basic statistics in Excel to analyze our results. Throughout, we critically examined data collection procedures and analytical methods used to support the information provided in the studies.

Part I:

Table A1. Descriptive characteristics

Variable	Description	Format	Categories
Num	Number of article (assigned by us: from 1 onwards)	Number	---
Ref	Full scientific reference, eg: Author et al. (Year) Title, Journal, vol: (issue), pgs.	Text	---
Year	Year that article published	Number	---
Jour	Journal title	Text	---
Auth	Lead author affiliation country	Text	
Group	Group studied	Text	Coded later into the following:
Data year	Year(s) that data were collected	Number	
Cont	Continent (classification of Encyclopedia Britannica 2006)	Number	1 = Africa 2 = Europe 3 = Asia 4 = North America (*including Central America*) 5 = South America 6 = Australia 7 = Antarctica
Region	Region	Number	101 = Northern Africa (Maghreb) 102 = Sahel 103 = Rest of Western Africa 104 = East Africa (excluding the Horn of Africa) 105 = Central Africa 106 = Southern Africa 107 = Horn of Africa (Eritrea, Djibouti, Ethiopia and Somalia) 107 = African islands --- 201 = Eastern Europe 202 = Western Europe (excluding Nordic countries) --- 301 = Western Asia and Middle East 302 = South-East Asia (Pacific) 303 = South-Central Asia (including India and the Himalayas) 304 = Eastern Asia (including Mongolia and Taiwan) 305 = North Asia (Russia, excluding Siberia) --- 401 = United States and Canada (excluding Arctic regions) 402 = Mexico 403 = Rest of Central America

			404 = Caribbean Islands --- 501 = Andean region (including Altiplano) 502 = Amazon Basin 503 = Atlantic littoral 504 = Cerrado and Pampa 505 = The Guyana 506 = Southern South America (mainly Patagonia and Tierra de Fuego) --- 601 = Australia 602 = New Zealand 603 = South- Pacific islands --- 801 = Arctic (including Alaska, Siberia and Lapland)
Country	Country/ies of study	Text	---
Climate	Type of climate (Köppen climate classification)	Number	10= tropical/megathermal 20= dry (arid and semiarid) 30= temperate/mesothermal 40= continental/microthermal 50= polar and alpine
Livelihood_1	Main livelihood strategy / subsistence activity	Number	1= hunter-gatherer 2= small-scale agriculture 3= intensive agriculture 4= fishing 5=NTFP collection 6=Pastoralism/animal husbandry 7=wage labour 8=other
Livelihood_2	Secondary livelihood strategy / subsistence activity	Number	1= hunter-gatherer 2= small-scale agriculture 3= intensive agriculture 4= fishing 5=NTFP collection 6=Pastoralism/animal husbandry 7=wage labour 8=other
Livelihood_3	Tertiary livelihood strategy / subsistence activity	Number	1= hunter-gatherer 2= small-scale agriculture 3= intensive agriculture 4= fishing 5=NTFP collection 6=Pastoralism/animal husbandry 7=wage labour 8=other
Sample	Sample size studied (number of individuals studied/interviewed/surveyed)	Number	---
Method	Method for data collection	Number	1= quantitative 2= qualitative 3= both quantitative and qualitative
Goal_perc	Local perceptions of change as goal of article	Number	Was the primary goal of the article to collect local perceptions of change? 1 = Main goal 2 = one among several goals 3 = not a goal, perceptions appear only in a tangent way
Goal_chang	Documenting change as goal of article	Number	Was one of the goals of the article to collect actual documentation of change? 1 = Main goal 2 = one among several goals 3 = not a goal, documentation

			appears only in a tangent way
Goal_sci	Comparing scientific data with local perceptions as goal of article	Number	Was one of the goals of the article to compare local perceptions with scientific evidence? 1 = Main goal 2 = one among several goals 3 = not a goal, comparison appears only in a tangent way
Notes	Notes (be as brief and to the point as possible)!	Text	---

Note: For all the above, code "-9" for "Not mentioned/not clear"

Table A2. Perceptions and understandings of Global Environmental Change

This Table is intended to compile all the information on the perceptions, understandings and manifestations of Global Environmental Change in the publications referred to in Table 2. If some information is missing, not available, or not mentioned, code as " -9".

Variable	**Description**	**Format**	**Categories**
Num	Number	Number	---
Type_chang_1 Type_chang_2 Type_chang_3 Type_chang_4 Type_chang_5 Type_chang_6 Type_chang_7	Type of perceived contemporary change	Number	1= temperature change 2= rainfall change 3= drought 4 = erosion 5 = floods 6= sea level rise 7= deforestation 8= biodiversity change 9= invasive species 10= permafrost/ice/glaciers 11= fire 12= winds (excl. tornadoes/cyclones) 13 = storms 14= extreme events (incl. tornadoes/cyclones/tsunamis/earthquakes) 15 = phenology/seasonality 16=other (name what)
Length	Decade	Number	Decade since change is recorded/perceived (e.g. 1980s)
Spat_imp	Spatial impact	Number	Is the change perceived to be only local, or also regional, or even global? 1= local 2= regional 3= global 4= locally not perceived as change
Spat_driver	Spatial driver of change	Number	Is the perceived main driver of change perceived to be local, regional, or global? 1= local 2= regional 3= global 4= locally not perceived as change
Driver	Perceived driver of change	Number	Perceived driver of change? 1 = human-induced; 2= natural phenomena; 3=supernatural/religious/cosmological

			4= other
Change_eval	Change perceived as positive or negative	Number	Change perceived as positive or negative? 1=Positive 0=Negative 2=Both positive and negative
Change_inv	Invisibility of change	Number	Is the change perceived by the naked eye (=1)? Has it been recorded only through the use of technological equipment/measurement (=0)? Or both (=2)?
Imp_liv	Explicitly stated direct impact on livelihood	Number	Are there direct impacts of the change on local livelihoods? Yes=1 No=0
Imp_cult	Explicitly stated direct impact on culture/social norms	Number	Are there direct impacts of the change on culture/social norms? Yes=1 No=0
Imp_envir	Explicitly stated direct impact on the environment	Number	Are there direct impacts of the change on the environment? Yes=1 No=0
Local_conc	Local epistemology, ontology, cosmology, cultural meaning, conceptuatlisation, etc	Number	Do the authors take into account local conceptions of the environment in their study? (i.e. do they rely -even partly- on local ethnological explanations?) Yes=1 No=0
Local_psy	Local psychology and processes that shape perceptions of change	Number	Do the authors take into account psychological dimensions of the environmental perceptions? (e.g. shifting baselines, change blindness, amnesia, media effects, etc.) Yes=1 No=0
Conc_sci	Report/perceptions concordant or not with scientific data/info?	Number	1=Yes, local=scientific reports 0=No, local differs from scientific 2= Both yes and no -9= not reported
Own_sci	Self-measured scientific data	Number	Does the article contain primary scientific data, measurements, records on the change apart from local perceptions? 1=Yes 0=No
Loc_resp	Local response to change	Number	Does the article mention any local responses to change? 1=Yes 0=No
Loc_adapt	Local adaptation to change	Number	If there are responses/adaptation measures to change, are these: 1= based on local knowledge 2= based on modern technology 3= both

Loc_init	Externally or locally driven adaptation strategies	Number	If there are responses/adaptation measures to change, are these: 1= only locally driven 2= externally driven (ex. NGOs, development aid, scientists, government) 3= both
Notes	Notes	Text	---

Appendix 2. Articles reviewed (n=126)

#	Reference
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Appendix 3. Original Data Matrix

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