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A tool for measuring ecological literacy: coupled human-ecosystem interactions*

Anne Marie A. Casper [a,b], María E. Fernández-Giménez [a,c] and Meena M. Balgopal [a,b]

[a]Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO, USA; [b]Department of Biology, 1878 Campus Delivery, Colorado State University, Fort Collins, CO, USA; [c]Department of Forest and Rangeland Stewardship, 1472 Campus Delivery, Colorado State University, Fort Collins, CO, USA

ABSTRACT

Purpose: Ecological and natural resource management (NRM) decisions have far-reaching implications for global ecological change. Because beliefs influence behaviors, it is vital that decision-makers' beliefs reflect the shift to include humans as an integrated component of ecosystems. Our study, grounded in socio-cultural theory, analyzed how undergraduate participants situated humans in relation to ecosystems and describes the continuum we developed to characterize individuals' conceptions.

Design/Methodology/Approach: To develop a grounded theory we analyzed participants' perceptions of human-environment relationships through semi-structured interviews. We used both triangulation of codes through student course artifacts and inter-rater coding to establish trustworthiness of findings.

Findings: We present a continuum of coupled human-ecosystems conceptions developed from the participants' conceptions: (i) exclusion, (ii) uncertain-exclusion, (iii) uncertain, (iv) uncertain-inclusion, and (v) inclusion.

Practical Implications: Our tool is useful for NRM educators and professionals to assess how people perceive human-environment relationships and to study shifts in ecological literacy.

Theoretical Implications: If people believe that humans are independent from ecosystems, their decisions about interacting with the environment will reflect this. Each individual contributes to societal practices through the officials, policies, and causes they support, and their consumption and land management decisions. Without a conception of ecosystems that includes humans, future NRM professionals may select policies and practices that result in ineffective or destructive management.

Originality/Value: Our study responds to the need for an instrument that measures how people situate humans in relationship to ecosystems that is open-ended, can be used across a variety contexts, and does not require specialized statistical knowledge.

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CONTACT Anne Marie A. Casper aramaticasper@gmail.com Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO 80523, USA; Department of Biology, 1878 Campus Delivery, Colorado State University, Fort Collins, CO 80523 USA

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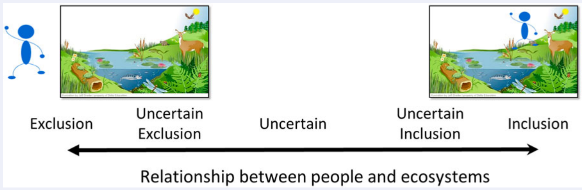

Introduction

In the midst of current global change, natural resource (NR) managers make decisions that can have far-reaching ramifications for future environmental change (Rockstrom et al. 2009). A recent conceptual shift within NR management (NRM) research and management reflects an understanding of ecosystems as dynamic, interconnected, and inclusive of humans, rather than as static, 'pristine,' 'natural' systems, devoid of humans (Meffe 2002; Walker and Salt 2006). This paradigm shift is similar to the broader perspective of ecological literacy that includes people's roles in changing environments (Chapin, Matson, and Vitousek 2011) and has been supported by recent ecological research that demonstrates that long-term and persistent disturbance by humans is changing the diversity and stability of ecological systems (MacDougall et al. 2013).

If people believe that humans are independent from ecosystems, their decisions about how to interact with the environment will reflect this. In NRM, conceptualizations of ecosystems that exclude humans may result in ineffective or destructive management strategies (Meffe 2002; Alberti et al. 2003; Estes et al. 2011). Every individual influences management practices and societal practices through the officials they elect and policies and causes they support (Arbuthnott and Devoe 2014). Furthermore, the communication of complex ecological issues to community stakeholders as simple dichotomies can undermine the credibility of scientists and NR managers when systems do not respond as expected. For example, hydraulic fracturing may be presented in some media as a practice that either is unproblematic to watersheds or something that should be completely banned because of threats to watersheds, while the complexities of social-ecological concerns surrounding the issue are not always communicated (Hudgins and Poole 2014; Williams et al. 2017). In other words, the economic, ecological, and social concerns of residents in areas where hydraulic fracturing occurs may not be included in media discussions of this NRM practice.

Evaluating how people frame and conceptualize human-ecosystem relationships is important for NR and environmental educators who teach courses or lead workshops about the environment. A tool to assess such conceptions can promote self-reflection by teams working across ecological contexts. We developed a tool to assess individuals' conceptions of human-ecosystem conceptions that is adaptable to different teaching/learning contexts because we were not aware of an existing one. The tool has been tested in an undergraduate classroom (described in another manuscript; Casper and Balgopal 2018), and it is currently being tested by by one of the co-authors in K-12 settings to examine the perceptions of secondary science school teachers who teach environmental concepts and issues (Wright and Balgopal 2020). In formal classroom contexts many instructors use concept inventories (CI; multiple-choice assessments of knowledge and perceptions); however, these have limitations because they are often developed for a specific population of participants and are comprised of closed-response questions that may not reflect all participants' views (Smith and Tanner 2010).

While CIs typically measure content knowledge, other instruments, such as the connectedness with nature Implicit Association Test (IAT), the New Ecological Paradigm (NEP) scale, the Pro-Environmental Behavior Scale (PEBS), Image Analysis of Environmental Perception, and the Allo-Inclusive Scale assess individuals' beliefs about and implicit biases towards environmental issues (Dunlap et al. 2000; Schultz et al. 2004; Davis, Green, and Reed 2009; Howell et al. 2011; Markle 2013; Freitas et al. 2015). However, none of these explicitly address individuals' attitudes about society's roles in relationship to the environment while allowing for flexible, open-ended use (Dunlap et al. 2000; Schultz et al. 2004; Davis, Green, and Reed 2009; Howell et al. 2011; Markle 2013; Freitas et al. 2015). Likert-scale instruments that focus on responses to specific questions depend on an individual's nuanced reasoning and culturally and linguistically embedded interpretation of the question. Freitas et al. (2015) suggested prompts for different populations, which helps with, but does not solve, the context-dependent nature of specific prompts.

Our tool is a continuum that is applicable to a variety of written and oral forms of communications and, therefore, could be adapted for use across diverse contexts. While output from our tool could be used for statistical analyses, it can also show change over time on a case by case basis, without statistical analysis (e.g. see Casper and Balgopal 2018). Therefore, our tool has the potential to be used by a wide range of users across broad contexts.

Measuring ecological literacy

Several constructs describe relationships between knowledge, beliefs, and behaviors regarding human-environment interactions (McBride et al. 2013; Long et al. 2014), including ecological literacy. Since they were conceptualized, ecological and environmental literacy have included the integration and interaction of social and ecological systems (Risser 1986; Scholz and Binder 2011); however, other authors have not always adopted this position (Machlis, Force, and Burch 1997). Despite the importance of ecological literacy in the environmental education literature (Duailibi 2006; Balgopal and Wallace 2009; McBride et al. 2013; Lewinsohn et al. 2015), none of the metrics we found directly addressed a system-level conception of ecosystems that explicitly includes humans (Bogan and Kromrey 1996; Morrone 2001; Jordan et al. 2009; Pe'er, Goldman, and Yavetz 2009; Davidson 2010; Keynan, Assaraf, and Goldman 2014). In our research we used Balgopal and Wallace's (2009) definition, 'An ecologically literate person can recognize the relevance and application of ecological concepts to understanding human impacts on ecosystems' (14-15). In line with Balgopal and Wallace's (2009) definition, we assume that *ecosystem* refers to an 'integrated human-ecological system' (Chapin, Kofinas, and Folke 2009).

We sought to characterize the way people described their conceptions of *ecosystems* by drawing on socio-cultural theory, which describes that conceptions are developed through communication, observations of natural phenomena, and opportunities to assimilate and make meaning of new information (Lemke 2001). Because we interpret language and vocabulary through our background knowledge and contexts, different socio-cultural backgrounds lead to different world-views, which are reflected in the specific vocabulary used in communication (Nisbett 2003; Scholz and Binder 2011; Gee 2014; Druschke and McGreavy 2016). Therefore, it is important to elicit how individuals make meaning of specific concepts, rather than assuming that a group of individuals will make meaning in the same or similar ways or use the same words to describe their conceptions. Specifically, we explored the questions: *how* did participants describe ecosystems, and *how* did they situate humans in relation to the built environment and broader ecosystem?.

Methods

Study context

We conducted our study in an NRM capstone class (n=45) at a large land-grant university in the Western United States. Most of the participants enrolled in the course were NRM majors, and the non-NRM majors were all Rangeland Ecology majors. The course met weekly for two 75-minute lectures and one 100-minute lab. The course was taught by an NRM professor and an ecology graduate teaching assistant (GTA). It was the professor's ninth time teaching the course and the GTA's third time teaching the associated laboratory sections. The curriculum included a semester-long group project designing a management plan for a local social-ecological system (SES; ecosystem assessment, stakeholder analysis, and management strategies), guest speakers (diverse NRM professionals and local stakeholders), and readings from the primary literature.

All participants enrolled in the class were invited to participate in the study, and almost half (n = 20) consented. In addition, three participants from the prior semester who had maintained contact with the instructor on campus participated via interviews. A total of 23 participants consented to have their coursework analyzed and to participate in interviews at the beginning and end of the semester (see Appendix A; IRB #047-15; only pseudonyms are presented). Interview questions were informed by the literature describing challenges early-career NRM practitioners faced (Sample et al. 1999; LaChapelle, McCool, and Patterson 2003), and were grounded in socio-cultural theory, which explains that individuals make meaning based on their own social and cultural experiences and background (Gee 2014; Druschke and McGreavy 2016). As such, it is vital to elicit how students make meaning of commonly used terms. Consistent with grounded theory, our interview questions were broad in scope to allow for rich inductive analysis (Charmaz 2014).

Data collection and analyses

We collected the following data: (1) participants' written work (e.g. reading responses) produced during the course (Appendix B) and (2) semi-structured interviews of each participant (~1,600 min were transcribed) during the first and last weeks of the semester (Appendix A). Participants' weekly reading responses were a particularly relevant data source. We analyzed data following Charmaz's (2014) constructivist grounded theory approach, allowing us to ask inductive and deductive questions, and to use the data to guide the research process (Balogpal 2014). Categories, or codes, were used to describe characteristics of the data, while recognizing our own assumption that ecosystems do include humans. Our codes characterized (1) how participants described the relationship between humans and ecosystems, (2) what they thought were components of ecosystems, and (3) words or concepts they struggled with in their descriptions, or that had multiple meanings. These codes were used to construct our continuum of conceptions.

To assure reliability and validity of the analysis and to decrease the potential for bias we engaged in the following: analyses of multiple sources of data (triangulation); discussion of the analysis process and preliminary findings with other researchers involved in the project (peer debriefing); long term involvement with the course, participants, and data (prolonged engagement); discussion of the interpretation of the results with study participants (member checking); and the comparison of data coding by two independent coders (inter-rater reliability) (Merriam 2002; Charmaz 2014; Moon and Blackman 2014). A second coder (also an ecologist) coded 20% of the sections of the interviews focused on ecosystems. Inter-rater reliability was initially 87.5%, and after debriefing, was 100%.

Findings

Participants' foundational concepts of ecosystems remained stable, although their nuanced definitions of ecosystems varied (Table 1). The description of an ecosystem as a bounded system made up of biotic and abiotic factors was consistent among participants and remained unchanged for some individuals. Participants whose conceptions included human society as part of an ecosystem (Inclusion), as well as those who situated humans external to ecosystems (Exclusion), were easy to describe; however, others were more difficult to classify. Participants who were between the ends of the continuum struggled to describe their conceptions. Some people initially made a distinction between 'human-influenced' and 'natural' environments but had trouble defining a natural environment. Words that perplexed these participants included *natural*, *man-made*, and *infrastructure*, and confusing key ideas included the *type of influence* an action had on an ecosystem or the *intent* behind a management action. When participants who were unsure about how humans fit in ecosystems decided that humans were a part of an ecosystem in some way, they were classified as Uncertain-Inclusion, but if they decided that humans were excluded, they were classified as Uncertain-Exclusion. These last two categories captured individuals whose data (interviews and coursework) were inconsistent. If a participant was unable to commit to a description of ecosystems, they were classified as Uncertain. Most of the participants in the study had conceptions in either the Inclusion or Uncertain-Inclusion categories. The term, 'uncertainty,' was used in light of the conceptual change literature, which suggests that individuals are more likely to change an alternative conception if they harbor doubt about their original ideas (Posner et al. 1982; Chi and Roscoe 2002). In addition to the supporting examples, such as those presented in Table 1 and below, we also looked for, but did not find, counter-examples that would have challenged our interpretation of interviews as presented in the continuum. This lack of counter-examples is in part due to our methods; we developed codes and refined them until there were no uncoded data and our codes were saturated (Merriam 2002).

Written responses

Participants wrote about systems in varied ways. Some individuals wrote about human-environment interactions, whereas others selected examples that focused on either

Table 1. Continuum of conceptions of humans in ecosystems; conceptions were classified into five categories based on how they situated humans in relationship to ecosystems. A description and an example narrative are presented for each category.

Category	Description	Interview Example
Exclusion: Humans are definitely not part of an ecosystem	Describes ecosystems as distinct and separate systems from humans and human influences. There may be interactions between the two, but they are different.	*'I guess I'm just thinking of things that people didn't make, you know, like nature. I put people in a separate box … I think. I think we're set apart.'* – Rachel*
Uncertain Exclusion: Unsure, but final conclusion is that humans are not, or are probably not part of an ecosystem.	May use terms conveying uncertainty, or they may start out with a different idea and end with a final conclusion in the exclusion category.	*'I guess, humans are in it too, I'm thinking agricultural point, so they plough the fields and everything and they're changing it. … you know it's more social ecological system where humans influence nature. So that's where I'm going to, like ok no, ecosystems are just natural.'* – Jade
Uncertain: Unsure, no final conclusion.	Discusses uncertainty, may discuss possibilities of humans either excluded/included, but they have no clear final conclusion.	*'I think a lot of people try and separate human systems from ecosystems. I still don't know where I stand on that, whether or not you know there's this big, like, we're all interconnected sort of thing, or if we're separate.'* – Tyler
Uncertain Inclusion: Unsure, but final conclusion is that humans are, or probably are part of an ecosystem.	May use terms that convey uncertainty, or they may start out with one conclusion and talk their way to a final conclusion in the inclusion category. May also describe humans as part of an ecosystem, but include exclusionary caveats, such as human artifacts (roads, etc.)	*'I don't want to not include humans as being part of the ecosystem because we are natural, but I wouldn't say a big building like this is necessarily part of an ecosystem.'* – Charlie
Inclusion: Humans are definitely part of an ecosystem.	Describes ecosystems as inclusive of humans and human influence. May include terms such as 'altered ecosystem,' or caveats of a bounded system, such as, if something is not physically present it is excluded.	*'First, humans live within, not apart from, ecosystems, and we depend on them for our continued existence … . One example of a system that crossed a threshold is the Tallgrass Prairie. Today only 4% of the original prairie exists, and the rest has been cultivated into cropland in such a way that even if all cultivation ceased, the prairie may not regenerate to its previous condition due to changes in the soil profile and fire regime. The slow variable in this case was likely the persistent use of cultivation tools over time that altered the natural landscape.'* – Debbie

*All names used are pseudonyms.

social systems or non-human environmental systems. Only participants whose essays fell into the Inclusion category articulated enough explicit information to code their essays on the continuum scale. These participants often provided examples that included human-environment interactions. For example, Dale demonstrated his integrated conception of ecosystems when he wrote: '*Ecosystem management attempts to manage in a holistic way, viewing the system as one interactive system (which it is).*' Similarly, Debbie wrote, '*First, humans live within, not apart from, ecosystems, and we depend on them for our continued existence.*' In the same essay, Dale's example of thresholds (which can occur in any type of system) included human-environment interactions: '*We talked about the effects of dams on rivers, and how they make the water temperature rise to a point in which some fish* *species cannot survive and die off. This changes the behavior of the entire river system …* ' His example clearly described the interrelationship of human-environment interactions.

Not all participants were consistent; their interviews did not always reflect their classwork. Drew, an international student and English Language Learner, wrote about his personal experiences with social-ecological system feedbacks, but he did not use any of the disciplinary vocabulary. As a transfer student from an international institution in his country of origin, Drew revealed the deeper cultural differences he grappled with when conceptualizing the entire field of NRM, ' *… resource science includes the natural resources, but we also have the study of people and other things … there is not a barrier between them. [It is just seen as] all of them together.'* Thus, Drew's interpretation of the vocabulary used in class occurred through his own socio-cultural lens, as we believe it does for all students.

Participants whose interviews fell into the Uncertain-Inclusion category provided fewer supportive examples about human-ecosystem relationships, compared to those in the Inclusion category. One of the Uncertain-Inclusion participants, Sam, implicitly placed humans as external to ecosystems in his interview but specifically situated humans in relationship to ecosystems or the environment in his writing:

> *Thresholds are a very important component of natural resource management because we must recognize when human manipulation of a certain variable may alter an ecosystem into something that can no longer supply us with the product that we were dependent upon.*

In this excerpt from his writing, Sam described interdependence of humans and ecosystems, without stating if humans are part of or external to ecosystems.

Jade, who was classified as Uncertain-Inclusion in her initial interview, mostly focused on social examples in her essay written early in the semester, such as the minimum population of a town required to support necessary services: 'w*ith the decline in population, services such as the school and/or the post office would close. This would lower the draw to the area and would unravel the community structure.'* Jade's examples that did include human-environment interactions, such as over-fishing, focused on the extractive problems, rather than the specific human-ecosystem interactions. Although Jade described humans as important components of the environment, she limited her discussion to unidirectional interactions; for example, human behaviors affected fish populations. She never integrated examples of how the environment affected the lives of humans, nor the larger ramifications of the fish population decline.

Some participants, who were classified as Uncertain-Inclusion in their interviews, described integrated conceptions in their writing, even though they did not describe an integrated conception in their initial interviews. Shortly after his interview, Kevin wrote: '*… Forests are encroaching on naturally occurring pockets of pine-free grasslands … Due to human fire suppression, these forests are allowed to grow unchecked, forcing treeless areas to become less common.'* He described how human management practices are influencing forest processes. However, in his interview Kevin's formative ideas illustrated his uncertainty position: '*I mean aside from humans, I can't think of anything [that is not part of an ecosystem].*' Upon further questioning about ecosystems, though, he said,

> I feel like [humans are] detrimental to most ecosystems. I can't think of any ecosystem where human activity has actually improved it … I feel like we are definitely a part of [ecosystems], just because we interact with it, and we affect it.

In the span of a few minutes, Kevin shifted the way he described his conception of ecosystems, illustrating the tentativeness of his ideas.

Unlike Kevin, Noah started out including humans within ecosystems, but specifically excluded built environments, such as buildings, because they '*don't contribute to anything [regarding the ecosystem].*' Like Kevin, Noah did not describe human impact on ecosystems as positive, and therefore the students either initially (Kevin) or continually (Noah) excluded this impact from their concept of an ecosystem during their respective interviews.

It is possible that the diagram used in class to depict integrated human-ecosystem relationships contributed to some of the difficulties that Uncertain-Inclusion participants had. Despite describing an integrated relationship, the diagram, derived from Verstraete, Scholes, and Smith (2009) and Stafford-Smith et al. (2007), showed humans and ecosystems as two interacting boxes. We cannot conclusively link participant confusion to this diagram; however, they worked with variations of the diagram throughout the semester and frequently cited instances when it influenced their learning.

Discussion

This study has two important outcomes. First, we developed and tested a tool that likely can be adapted and implemented across a broad range of contexts to gauge individuals' conceptions about ecosystems, including whether humans are situated within ecosystems. Second, we describe the variables that probably influenced these conceptions. The testing of our tool highlights the types of nuanced conceptions that people may have about human-environment interactions. We recognize, though, that in each setting participants' conceptions will likely reflect the diversity of ideas that exist within that cultural context. Therefore, conceptions that do not fit well within our continuum may be found in other settings.

We found that participants' conceptions about ecosystems differed, indicating that students did not all develop the same conception based on their similar undergraduate experience. These differing conceptions were probably influenced by their prior conceptions and vocabulary. In some cases their difficulty with vocabulary may have been based on word-finding, while for others, it may be rooted in deeper cultural worldviews (Nisbett 2003; Luykx et al. 2007). Some participants, such as Drew, struggled with one or both categories, possibly due to challenges with language and differing discipline-specific conceptions of ecosystems and larger differences in cultural backgrounds (Nisbett 2003; Luykx et al. 2007; Druschke and McGreavy 2016; Balgopal et al. 2017).

We argue that our described continuum of human-ecosystem interaction conceptions is a useful tool that NR professionals and educators can use to measure and track conceptions that their audience or stakeholders might have about the level of human-environment coupling within ecosystems (e.g. Casper and Balgopal 2018). Since the tool was developed to be used as a rubric for either open-response writing or oral communication, it provides flexibility that concept inventories and other environmental behavior measures do not. Analyzing writing and transcribed interviews allowed us to uncover our participants' nuanced conceptions that a multiple pre- and post-test may not have (Smith and Tanner 2010). The value of a continuum is that it potentially can be used across a variety of educational and collaborative contexts and can be used without specialized knowledge of statistical analyses. For example, this continuum is currently being used by another researcher to analyze the conceptions of secondary science teachers, as conveyed through their writing and teaching practices (Wright and Balgopal 2020). We recognize that NRM professionals work with diverse populations in many different contexts. Therefore, a tool to better understand stakeholders' views is useful, and may be vital in revealing prevailing conceptions of community members, which can help scientists, managers, extension specialists, and educators develop relevant local frameworks for connecting to specific communities (Hunter and Brehm 2003). Additionally, by measuring change over time within a given set of stakeholders, managers can evaluate the effectiveness of education strategies. Although someone using the tool may choose to simplify the scale from five categories to three, we posit that more categories decrease ambiguity in classifying conceptions and allow for the measurement of less dramatic shifts in conceptions (Casper and Balgopal 2018).

Our work points to the importance of co- constructing shared meanings of terms (Druschke and McGreavy 2016). Similar to our findings, Glaser (2006) and Balgopal et al. (2012) both found that individuals vary in how they describe human-environment relationships and human-environment interactions. These varying conceptions provide different foundations for decision-making, possibly leading to unintended differences in outcomes. For example, historical management of the Florida Everglades that did not take into account the complex hydrological function of the system, nor the way human influence altered the system, has led to problems with far-reaching social and ecological ramifications (Walker and Salt 2006). Therefore, through an explicit examination of how individuals situate humans in relationship to the concept ecosystem, our ecological literacy tool can help managers and their collaborators develop shared meanings as they communicate, and help prevent potential management problems that could arise from excluding humans from ecological conceptions. Moreover, the tool can generate discourse and themes from participants' worldviews that can inform theoretical papers about shared meanings. Although this paper was not designed to inform theory of ecological or environmental meaning making per se (see Casper and Balgopal 2018; Balgopal et al. 2017 for examples of such), we do posit that our tool can inform and support such studies.

Implications

NRM professionals should be aware of how they describe ecosystems and make sure to explicitly delineate the systems they are working with. They also need to work to reveal the underlying conceptions of ecosystems of those they work with, including professional peers, stakeholders, students and extension clientele. People draw on diverse funds of knowledge (cultural, economic, scientific, etc.) throughout their lives, and, in turn, develop their own conceptions (Balgopal et al. 2017). The term 'ecosystem' represents differing conceptual constructs, and one cannot be confident that others have the same conceptions without directly asking people to share their perspectives (Posner et al. 1982; Risser 1986; Lemke 2001; Alberti et al. 2003; Kitcher 2004; Glaser 2006; Kueffer and Larson 2014; Druschke and McGreavy 2016).

The fields of NRM and agriculture have a history of being anthropocentric and focused on harvesting resources for human use; however, this view is shifting (Cecil 2004; Chapin, Kofinas, and Folke 2009; Chapin et al. 2011). Part of this shift in agricultural education is exemplified by the growing field of agroecology, which approaches agricultural systems from an ecological systems perspective (Østergaard et al. 2010). Therefore, our ecological literacy tool is particularly timely, in that it can be used by instructors and others in these fields to help directly reveal and address how students and collaborators are conceptualizing the human-ecosystem relationship, which is important in both integrated ecosystem management and agroecology, as well as other integrated agricultural models (Gunderson and Holling 2002; Walker and Salt 2006; Lovell et al. 2010). The discussions in the field of agricultural education point to a potential expansion of our tool – one that addresses if and how individuals conceptualize agricultural systems as ecosystems (Lovell et al. 2010; Østergaard et al. 2010).

If participants' existing conceptions are not directly discussed, NRM professionals and educators may unintentionally reinforce outdated conceptions or create confusion due to incongruent meaning of terms across disciplines. Although our results may be applicable across a broad range of situations in ecology and NRM, our data are drawn only from undergraduate participants majoring in NRM and Rangeland Ecology. Therefore, further research that includes data from a broader range of stakeholders is important to further develop this ecological literacy tool.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available because they contain information that could compromise the privacy of research participants.

Notes on contributor

Anne Marie A. Casper was a graduate student in the Graduate Degree Program in Ecology and in the Department of Biology at Colorado State University at the time this research was performed. She is currently a research scientist in the Department of Civil and Environmental Engineering at Colorado State University and the Mountain Studies Institute. Her research spans natural and social sciences and works to address pressing social and ecological problems from a socially justice rooted social ecological systems thinking perspective.

M.E. Fernández-Giménez is a Professor of Rangeland Social-ecological Systems in the Department of Forest & Rangeland Stewardship. She teaches ecosystem management, monitoring and community-based natural resource management, and studies individual and collective decision-making in ranching and pastoral systems around the world.

Meena M. Balgopal is an Associate Professor of Science Education in the Department of Biology. Her research centers on ecological literacy and how people make meaning of and decisions about environmental issues.

ORCID

Anne Marie A. Casper http://orcid.org/0000-0001-6557-4425
María E. Fernández-Giménez http://orcid.org/0000-0001-9641-1434
Meena M. Balgopal http://orcid.org/0000-0002-3846-9256

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Appendix A: Interview questions.

As part of a longer interview, all participants were asked the following questions regarding their conceptions surrounding ecosystems.

(1) a. How would you define a ‘system’?
  b. How were your thoughts challenged, reinforced, and/or extended throughout the semester?
  c. How do you think this will influence your approach a career in NRM?
(2) a. How would you define a ‘resilient system’?
  b. How were your thoughts challenged, reinforced, and/or extended throughout the semester?
  c. How do you think this will influence your approach a career in NRM?
(3) a. How would you define an ‘ecosystem’?
  b. How were your thoughts challenged, reinforced, and/or extended throughout the semester?
  c. How do you think this will influence your approach a career in NRM?
(4) a. How would you define a ‘social-ecological system’?
  b. Describe what you remember about your thoughts were about a social- ecological system at the beginning of the semester.
   How were your thoughts challenged, reinforced, and/or extended throughout the semester?
  c. How do you think this will influence your approach a career in NRM?

Appendix B. Example reading reflection questions

Reading reflection prompts gave participants direction to interact with the in-class readings. While these questions were not written to directly gather data about participants’ conceptions of the human-ecosystem relationship, the way participants wrote about ecosystems provided data about these conceptions.

Week 2:

(1) List 3 sources of uncertainty and complexity that are environmentally driven, and 3 that are human-driven. Based on your past experiences, describe one example of complexity in natural resources that you have experienced or observed. How did it affect you? How did you respond? How are humans a component of this complexity? What did you learn from this that would influence how you would plan for or respond to future events?
(2) What are 4 approaches to dealing with uncertainty and complexity in natural resource management? Would any of these approaches apply to the example you provided in the last question? Why or why not?

Week 3:

(1) Can you think of an example from your personal experience, other courses, etc. of another system that crossed a threshold? What was the slow variable in that case? Why are thresholds important to natural resource management?
(2) Describe the 4 phases of the adaptive cycle. Apply the cycle to describe a system you are familiar with.
(3) Why is it important to consider potential linkages across scales or cross-scale effects in managing for resilience? Describe one example of a cross-scale effect from your personal experience, reading, etc.
(4) Explain the difference between specific resilience and generalized resilience. In the [local river] watershed, what would be an example of each type of resilience?