Conservation Biology

Using cognitive mapping to understand conservation planning

Kelly Biedenweg ,[1] * David Trimbach,[1] Jackie Delie,[1] and Bessie Schwarz[2]

[1]Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR, 97331, U.S.A.
[2]Yale University

Abstract: We considered a common research tool for understanding the mental models behind conservation decisions: cognitive mapping. Developed by cognitive psychologists, the elicitation of mental models with cognitive mapping has been used to understand soil management in Spain, invasive grass management in Australia, community forest management in the Bolivian Amazon, and small-scale fisheries access in Belize, among others. A generalized cognitive mapping process considers specific factors associated with the design, data-collection, data-analyses, and interpretation phases of research. We applied this tool in a study about the integration of social data in shoreline master plans of Washington State. Fourteen policy makers and managers (approximately 85% of the region's potential sample) were asked to identify the factors they considered when making their plans. Researchers coded these factors into mental-model objects and summarized mental-object frequency and co-occurrence trends. Although managers prioritized the perceived needs of social groups in their mental model of shoreline master plans, they focused specifically on tribal and private property rights, even though existing social data identified a diversity of interests around timber harvesting, tourism, and agriculture. Understanding their mental models allowed us to more effectively present this social data so that it could fit within their existing thoughts around planning. Although our case study provides a description of the cognition of a particular policy process, cognitive mapping can be used to understand cognitive processes that influence any conservation planning context.

Keywords: mental models, natural resource decisions, restoration, social science

Uso de Mapeo Cognitivo para Entender la Planeación de la Conservación

Resumen: Consideramos una herramienta común de investigación para entender los modelos mentales detrás de las decisiones de conservación: el mapeo cognitivo. Desarrollado por los psicólogos cognitivos, la obtención de los modelos mentales mediante el mapeo cognitivo se ha usado para entender el manejo del suelo en España, el manejo del pasto invasivo en Australia, el manejo de la comunidad del bosque en la Amazonía de Bolivia y el acceso a las pesquerías a pequeña escala en Belice, entre otros ejemplos. Un proceso de mapeo cognitivo generalizado considera los factores específicos asociados con las etapas del diseño, recolección de datos, análisis de datos e interpretación de la investigación. Aplicamos esta herramienta en un estudio sobre la integración de datos sociales en los planes de ordenación de la costa del Estado de Washington. Se les pidió a catorce formuladores de políticas y administradores (aproximadamente el 85% de la muestra potencial de la región) identificar los factores que consideran cuando formulan sus planes. Los investigadores codificaron estos factores en objetos de modelos mentales y resumieron las tendencias de frecuencia y coocurrencia mente-objeto. Aunque los administradores priorizaron las necesidades percibidas por los grupos sociales en su modelo mental de los planes de ordenación para la costa, se enfocaron específicamente en los derechos tribales y privados de propiedad, aunque los datos sociales en existencia identificaron una diversidad de intereses entorno a la extracción de madera, el turismo y la agricultura. El entendimiento de sus modelos mentales nos permitió presentar estos datos sociales de manera más efectiva de tal manera que pudiera tener cabida dentro de sus ideas actuales en torno a la planeación. Aunque

*Address correspondence to K. Biedenweg, email kelly.biedenweg@oregonstate.edu
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nuestro estudio de caso proporciona una descripción de la cognición de un proceso particular de políticas, el mapeo cognitivo puede usarse para entender los procesos cognitivos que influyen sobre cualquier contexto de planeación de la conservación.

Palabras Clave: ciencias sociales, decisiones sobre recursos naturales, modelos mentales, restauración

摘要: 本研究聚焦于一种用于理解保护决策背后的心理模型的常用研究工具: 认知映射。利用认知映射的心理模型是由认知心理学家提出的, 目前已被用于研究西班牙的土壤管理、澳大利亚的草地入侵生物管理、玻利维亚亚马逊社区森林管理以及伯利兹的小规模渔业等具体问题。广义的认知映射过程需考虑与研究设计、数据收集、数据分析和结果解释各个阶段相关的具体因素。我们将这一工具应用于华盛顿州海岸线总体规划的社会数据整合研究之中。我们采访了十四名决策者和管理者 (约占该地区潜在样本的 85%), 以确定他们在制定计划时考虑的因素, 并将这些因素编码为心理模型对象, 以总结其出现频率和共现趋势。虽然管理者在海岸线总体规划的心理模型中优先考虑了社会群体感知到的需求, 但他们特别关注的是部落和私有财产权, 尽管现有的社会数据表明, 在木材采伐、旅游业和农业方面也存在着复杂的利益问题。理解他们的心理模型有助于更有效地展示这些社会数据, 从而使其更符合管理者对计划的已有想法。我们的案例研究提供了对特定政策过程认知的描述, 此外, 认知映射还可以用来理解任何影响保护规划的认知过程。

关键词: 心理模型, 自然资源决策, 恢复, 社会科学

Introduction

Conservation decisions are made regularly about where to create marine protected areas, whether to fund an elephant conservation program, where to hunt for animals for household consumption, and whether a timber harvesting enterprise will follow sustainable practices. The actors in conservation decision-making thus span the breadth of society, from conservation scientist, to nonprofit funder, to local farmer reliant on and affected by surrounding natural resources. Because conservation is explicitly about protecting natural resources from the impacts of human actions, the field is entirely shaped by how and why people make the decisions they do.

Cognitive psychology is the specific branch of psychology focused on mental processes, such as perception, problem solving, and thinking. A key concept in cognitive psychology is the mental model, a thought-based representation of the external world (Craik 1943; Johnson-Laird, 1983, 2010). A mental model allows people to conceptually simulate reality, a process that contributes to how people understand, learn, reason, predict, and eventually make decisions (Gentner 2001). Mental models contain a variety of information ranging from physical descriptors of a concept (such as green trees), to beliefs about a concept (trees produce oxygen), to attitudes about a concept (trees should be harvested for economic production). Each of these pieces of information we refer to here as a *mental object*. Mental objects interact in a mental model based on how the person perceives relationships between these objects. Through the holistic understanding of the content and structure of one's mental model about a conservation concept, researchers can get a clearer view of how the person rationalizes the issue and the potential factors influencing the person's behaviors and attitudes toward it. The variety of ways that people perceive and mentally model a conservation issue can inform diverse opportunities for framing, understanding, and designing conservation strategies (Moon et al. 2019).

Mental-model research has been used to explore thought processes around a range of conservation issues, including stakeholder group understandings of soil management in Spain (Prager & Curfs, 2016), community member perceptions of flash floods and landslides in the Bavarian alps (Wagner 2007), natural resource managers' perceptions of invasive grass management in Australia (Moon & Adam, 2016), villager and extension agent perceptions of community forest management in the Bolivian Amazon (Biedenweg & Monroe 2013), and fisher and policy-maker perceptions of managed access in Belizean small-scale fisheries (Wade & Biedenweg 2019). These studies represent a variety of situations in which identifying different ways of perceiving an issue could benefit conservation, including policy design, strategic program development, outreach and communication, conflict resolution, and policy analysis. In Bolivia and Belize, for example, the analyses of mental models in policy makers, extension agents, and community-based natural resource users showed that extension agents and policy makers do not perceive the same critical factors as influencing conservation success as resource users do.

The theoretical foundations of cognitive psychology are often attributed to the behaviorist Edward Tolman, whose experiments in the early twentieth century showed that as rats learn, they generate an organized body of information about their environment called a *cognitive map* (summary of E. Tolman's work in Ormrod [2004]). The cognitive map in this context is a mental representation of spatial reality; and although the map affects behaviors based on simulated expected outcomes, it does not necessitate a behavioral response: just because rats hold a cognitive map that guides them toward a behavior does not always mean they did the behavior.

This behaviorist research occurred at the same time that Gestalt psychologists in Germany were finding that as people learn, their resulting perceptions of reality are often organized in predictable ways, including that people group mental objects based on the perceived similarity of physical appearance, proximity, or other factors (Ormrod 2004).

From early stages of development of cognitive science, multiple terms have been used to describe the process of acquiring and organizing information that guide human understanding of and interactions within the world. More recently, psychologists have been using the terms *mental model* and *cognitive map* synonymously (e.g., Kaplan & Kaplan 1982:5–7). Others use the term *cognitive map* to refer to representations of reality not unlike a geographic map within one's brain (Tversky 1993). A key point of distinction seems to come from the cognitive map being inherently spatial in a way that mental models are not necessarily. Overall, the term *mental model* is generally associated with the abstract representation of reality as defined by Johnson-Laird (1983), whereas *cognitive map* is often associated with the work of rat wayfinding, as led by Tolman (1948). For a more complete description of the theoretical foundations and distinctions between these terms and their relationships to other similar concepts, see Jones et al. (2011).

For the purposes here, we used the term *mental model* to refer to an internal cognitive structure that represents how people simulate a component of the real world, based on the definition provided by Johnson-Laird (1983). We diverge from some of the earlier psychological foundations with the term *cognitive map*, however, to better align with growing colloquial references to cognitive mapping as a research tool that represents internal mental structures across several fields, including environmental management, geography, and soft computing (e.g., Kearney and Kaplan 1997; Kitchen & Blades 2002; Marney et al. 2009). In most cognitive-mapping activities, respondents are asked to describe everything they understand about a particular concept and then physically organize those thoughts to demonstrate their perceptions of interactions. The conceptual content cognitive map (3CM) is a specific cognitive mapping process in which cards are sorted to allow a respondent to identify mental objects and interactions of those objects to elicit a mental model (Kearney & Kaplan 1997). Other methods that similarly elicit mental models include concept maps (Novak & Cañas 2006), mind maps (Buzan 1974), and conceptual diagrams (Eppler 2006). A mental model could also be created by coding information from an open-ended interview (e.g., Elsawah et al. Jakeman 2015).

We focused on the use of a modified 3CM process that allows respondents to select and engage with the sorting of cards to represent their mental models. In offering this opportunity for respondents to depict their mental models, researchers can address some of the negative effects on reliability associated with open-ended interviews or overly structured surveys (Bernard 2006), including providing the participant greater agency in how they share their knowledge, broadening the type of information shared by allowing the respondent to use both spatial and linguistic modes of communication, and removing one of the threats to researcher interpretation by allowing respondents to define their own words for mental objects and structures.

We sought to construct a cognitive mapping process as a tool for collecting mental-model data that influences conservation decisions. We applied the tool in a study that identified whether conservation planners considered social data in their strategic planning.

Detailed Cognitive Mapping Procedure

Cognitive mapping activities that use card sorting, including 3CM, tend to follow specific steps in research design, data collection, data analysis, and interpretation (Fig. 1). Once researchers have identified the specific concept to be understood, they begin the design phase by identifying the research population (i.e., from whom understanding is to come) (step 1) and an appropriate prompt to elicit the mental model of interest (step 2). For example, the questions what is biodiversity and what is fisheries management would be effective at eliciting how different types of people perceive these concepts. A more opinion-based question, however, such as how do you feel about marine protected areas would not be effective at eliciting a mental model about protected areas because this type of question limits the response to one piece of the cognitive puzzle (an attitude).

Once the research population and prompt are chosen, researchers decide whether they will use an open or closed elicitation method (step 3) (Kearney & Kaplan 1997). In an open method (Fig. 1, top row, collect phase), mental model objects that respondents associate with the conservation concept are solicited from each participant as the first step in the card-sorting activity. This means that each respondent will use different words to represent their mental objects, requiring a qualitative-based analysis to synthesize and compare data once collected. In the open method, then, the researcher has less preparation prior to card sorting, but postprocessing requires more effort.

In contrast, in a closed method (Fig. 1, bottom row, collect phase), mental objects are solicited prior to card sorting through an extensive literature review, findings from preliminary fieldwork, a free listing exercise with a representative sample of the target population, or some combination of all. This closed structure means that all respondents will select from the same options to identify the content of their mental model, resulting in less

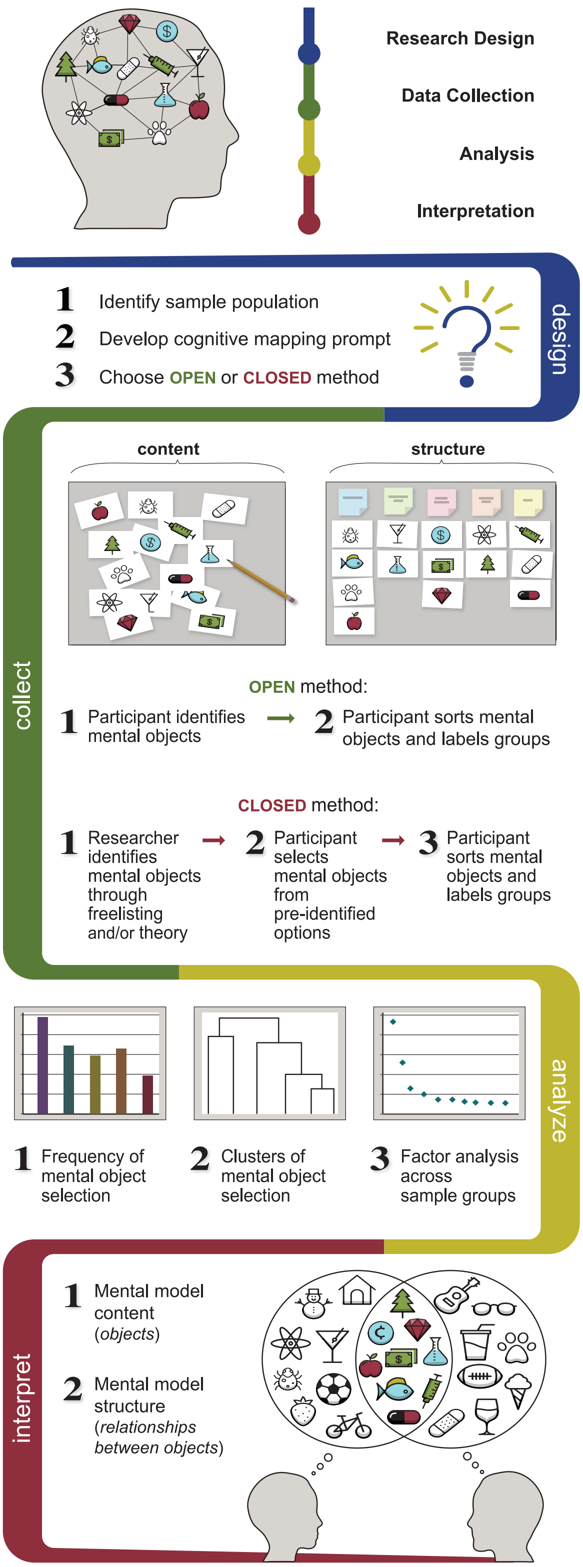

Figure 1. Step-by-step process for conducting a cognitive map research project to elicit mental models.

variation in response types, thus minimizing potential misinterpretation in the coding process by the researcher. If the researcher chooses to define mental objects from free lists, a subsample of respondents would be given the prompt and asked to list all the ideas that come to mind. This generally takes <5 minutes for each respondent, and the researcher can stop once no new mental objects are shared, usually within 10–15 interviews. Free listing will often result in dozens of items and from our experience respondents can be quickly overwhelmed with too many choices that may be conceptually similar. Thus, to minimize cognitive overload in the card-sorting step, we recommend selecting 20–30 potential mental objects to write (or draw) on cards, sticky notes, or some other object that can be easily moved around. Narrowing the number of objects requires employing a prioritization scheme, such as the most frequently mentioned items from the free lists or the most relevant objects to test a theoretically based hypothesis.

With these potential objects in hand (developed from free lists, literature review, or other sources), the researcher then chooses a separate sample from the population to engage in the full card-sorting activity (Fig. 1, steps 2 and 3, data collection, closed method). The researcher states the prompt and asks participants to select the cards that would be important for them to describe their thoughts to someone who is unfamiliar with the topic. Often, participants are also provided blank cards to add mental objects that are critical to representing their mental model but are missing from the existing set.

Open versus closed object identification is similar to that for open versus closed interview or survey questions in that processing and analyzing data from the open method differs from processing and analysis of data collected using the closed method (e.g., inductive vs. deductive, coding, or descriptive statistics). Regardless of method (open or closed), when the respondent is asked to describe everything they understand about a concept, they first identify mental objects.

The selection (data collection step 2, closed method) or writing (data collection step 1, open method) of mental objects represents the content of the respondents' mental models. To understand the structure of their mental models, researchers can ask them to complete a variety of tasks depending on the research question. If researchers want to understand the relative importance of mental objects in a mental model, they can ask the respondent to rank each card in order of importance by having respondents physically arrange the cards in a specific order. If researchers also (or alternatively) want to understand how different mental objects are related to each other in the respondents' minds, they can ask participants to group objects into piles of similarity (step 2 open method, step 3 closed method). Requesting that the respondent describe these piles (through naming or some other oral process) adds qualitative depth to understanding the thinking informing these structures.

Once data are compiled, there are several ways to analyze for interpretation. First, the content of mental models is measured by conducting frequency statistics for each mental model object (e.g., each concept card used) (Fig. 1, first option, analysis phase). If the research question included some sort of comparison across time (e.g., before and after an intervention) or across social groups (e.g., fisher and policy makers), statistical tests of variance can be conducted to determine significant differences in the frequency of identifying certain cards. Any differences in frequency would signify that each sample group perceived the fundamental components of the conservation issue differently. For example, in Bolivian community forest management, Biedenweg & Monroe (2013) found that community forest managers identify the ideas of home and cattle within their conceptualization of sustainable forest management, whereas extension agents and policy makers have neither items as components of their mental models. This fundamental understanding, and its priority for community forest managers, would be critical in the design of community-forest policy that would otherwise explicitly prohibit cattle activity, or, at best, fail to acknowledge its importance for forest-based communities. Understanding the differences and similarities in mental model content can thus enable effective conversations and policies that build from existing knowledge and values.

With the mental objects that have been grouped in piles, researchers commonly employ both exploratory and confirmatory analyses to summarize and compare the relationships between mental objects to describe the structure of mental models. Hierarchical cluster analysis depicts how frequently objects are grouped together and is often visualized via a dendrogram (Fig. 1, second option, analysis phase). This structural level of analysis is important because people may hold the same mental objects associated with a conservation topic, but the way they group these objects together can show considerably different understandings of the topic. Even after participating in a pilot rights-based fisheries program for small-scale fisheries in Belize, for example, both pilot-program and nonpilot-program fishers held the same mental objects associated with the policy, but organized these objects differently than policy makers. Fishers linked the mental objects of more money, increased fish stocks, and either alternative livelihoods (nonpilot fishers) or traditional use (pilot fishers), whereas policy makers linked money and stocks only to the regulations associated with the policy such as control fishers, meetings, and rights based (Wade & Biedenweg 2019). This demonstrates a disconnect in how people perceive the goals of the policy will be achieved and highlights potential areas for miscommunication, development of mistrust, and barriers to creative problem-solving.

Finally, confirmatory statistical analyses, such as factor analysis and consensus analysis, can verify significant differences in the structure of mental models across time or populations (Bernard 2006) (Fig. 1, third option, analysis phase). For example, through a consensus analysis of mental models about water use in South Africa, Stone-Jovicivich et al. (2011) statistically confirmed that irrigators and conservationists do not hold shared understandings of the major causes for water-flow problems because the relationships between mental objects does not load into unique factors. Yet, they found that that there is consensus about the consequences to rivers not flowing. The authors note that this latter result helped identify a starting point for negotiations around priorities, whereas the former helped identify the diversity of opinions across all stakeholders, further solidifying the need for plurality in the planning process. Importantly, this confirmatory analysis works only with the closed version of the method because it requires data for all mental object pairings that are not present when people create their own mental objects.

Methods

Context

We analyzed cognitive mapping data to understand mental models associated with shoreline restoration planning and the inclusion of relevant social data. We sought to determine to what extent planners' mental models around shoreline master plans included social factors and how to best share relevant social data about their constituents' landscape values and activities in a way that would easily integrate with their existing mental models.

Shoreline master plans (SMPs) are required of coastal counties and cities by the State of Washington Shoreline Management Act to identify how they will protect water quality, human lives, private property, wildlife habitat, and recreation opportunities (Washington State Department of Ecology 2019). These plans are created in partnership with the local communities and the Department of Ecology over approximately 12–18 months in three stages: information gathering led by policy makers and their experts, public hearings attended by the policy makers and citizen volunteers, and drafts and final decisions crafted by the mayor and county commissioners. The Shoreline Management Act requires each SMP be reviewed and revised every 8 years.

Sampling and Data Collection

Thirteen policy makers and 1 forest planner who participated in the process of revising their SMP for renewal submission to Washington State were recruited to participate in a study to better understand whether planners considered social data in their SMPs (Schwartz

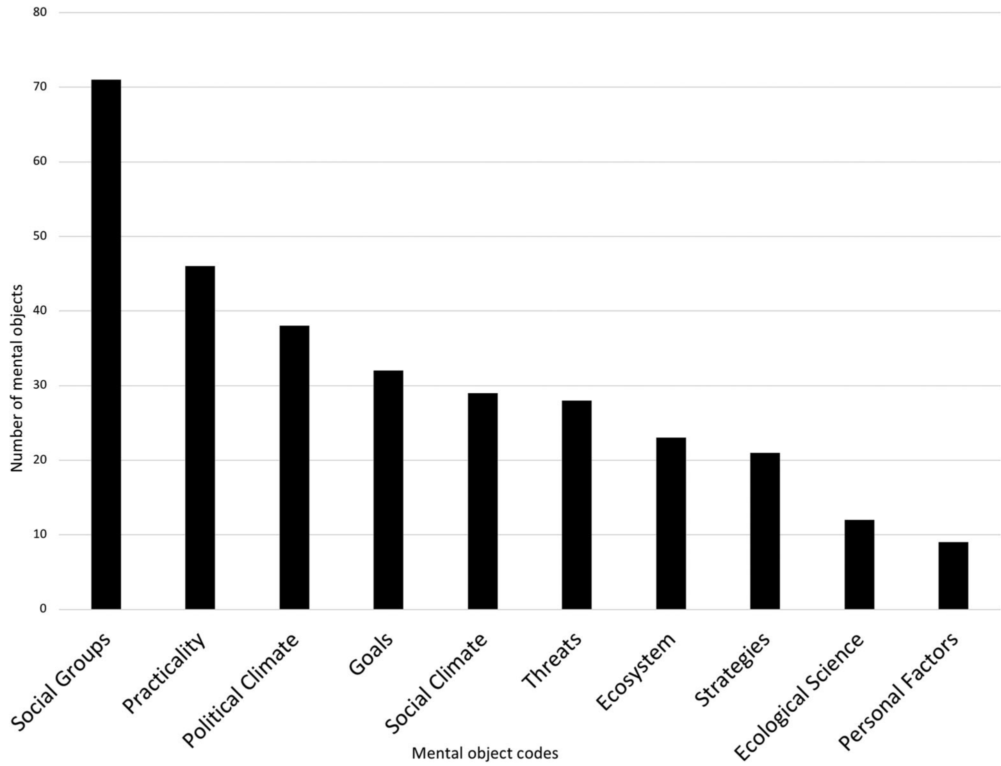

Figure 2. Frequency of mental objects associated with shoreline master plan decisions.

2014). This sample represented approximately 85% of the SMP decision makers for the western Puget Sound region. Each participant engaged in a 2 to 3-hour semistructured interview that included a modified open 3CM activity. By *open* we mean that the researcher did not bring preselected objects to the interview. Rather, each participant wrote their own mental objects associated with their SMP on cards as part of the activity (Fig. 1, open path process). The researcher chose the open structure to give full agency to the respondents in expressing their thoughts. All maps were photographed for later analysis.

First, participants were asked to write down their intentions for their SMP, such as overarching goals for the plans and steps that would help achieve those goals. Second, they were prompted to share factors that influenced their shoreline master plans. They were asked to write as many factors (mental objects) that came to mind that influenced their intentions on separate cards. The notes included ideas, specific types of people, places, etc. Third, the participants grouped their cards into as many piles of cards as they wanted based on their internal perceptions of interrelationships and were asked to provide a description of each pile.

Analyses

Because of the open process, the first step in analysis was to develop a codebook and apply it to all responses (Bernard et al. 2017). An initial coder used a grounded coding process to develop first- and second-order codes. These codes were reviewed by a second coder for face validity. Both coders then deductively applied the codebook to mental-model objects, identifying potential new codes when necessary. The coders agreed on 74% of the first-order codes. All disagreements were discussed, and the final codes were modified according to mutual agreement.

Frequency was calculated for each mental-model object code with SPSS 25. We also conducted a hierarchical cluster analysis with nearest-neighbor linkage and squared-Euclidean distances to explore common relationships between mental objects across our sample.

Results

The most common mental objects associated with SMP decisions were specific social groups, particularly tribal members and private property owners (Fig. 2). Practicality (which included perceived ability to enforce policy, costs, staff capacity, and perceived feasibility), political climate, goals (which included balancing interests, economic sustainability, and clean water), and social climate were the next most frequent mental objects associated with managers' SMPs. These basic trends demonstrated that specific social groups were most salient when considering the factors affecting SMP content.

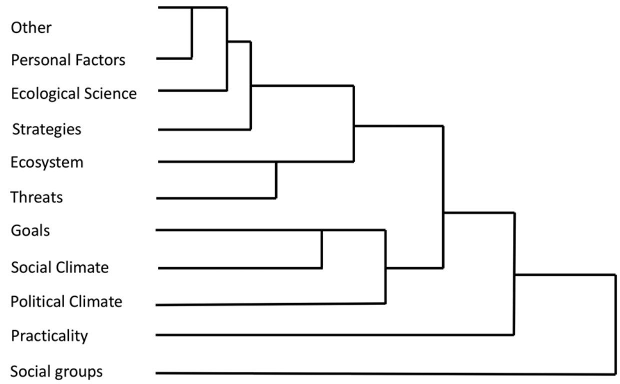

Figure 3. Hierarchical cluster analysis representing mental model structure for shoreline master planning.

In regards to the structure of the SMP mental models, we noticed qualitatively interesting differences at the fourth linkage in the HCA dendrogram (Fig. 3). The mental object social groups was perceived as the most unique from all other objects, followed by practicality, reflecting that these were key components of SMPs, but not inherently linked to other aspects of their mental model. At the fourth linkage, however, goals for SMPs were more linked to political climate and social climate than to ecosystems and threats. And, at the fifth linkage, the strategies they were considering for implementation were more related to both ecological science and personal factors than other components of their mental model.

Discussion

There are many lessons from this case study that could be applied to improve the transparency and consistency of conservation decision-making. We know, for example, that humans learn best when new information is easily added to existing categories of thought and when it does not contradict existing beliefs (Ormrod 2004). The relevant social data we wanted to offer these managers was public participatory GIS (PPGIS) data that summarized spatially explicit landscape values obtained from diverse constituents within the managers' jurisdictions (McLain et al. 2013). Each pixel in these digital maps included qualitative responses and quantitative demographics associated with valued places. Because all managers' mental models identified social groups, these data were relevant to their understanding but also novel. Their mental models focused on meeting the specific needs of tribal members and private property owners, yet the PPGIS data showed specific, widely expressed interests by other constituents for recreation, forestry, and agriculture. Thus, presentation of social data could be concentrated in a way that would parallel managers' existing focus on constituents, yet show information that was not contradictory or threatening to their current mental models. The researcher did so using an interactive activity with the PPGIS data and found that almost all managers were willing to consider this new information to modify their SMPs.

Cognitive mapping can elucidate the mental models associated conservation issues, either in preparation for collaboration, to find new ideas for conservation strategies, to evaluate the social impacts of strategies, or to prepare for outreach and communication campaigns. Eliciting mental models goes beyond common methods that measure more specific cognitive variables, such as stakeholder preferences, goals, or values through structured survey questions (Jones et al. 2011). Rather, cognitive mapping provides a more holistic understanding of people's thought processes around a conservation topic, information that would be difficult to abstract from constrained questions and unstructured interviews. By understanding people's mental simulations in conservation issues of interest, one can more effectively identify the pathways to misconceptions, opportunities for learning, or critical barriers to affecting the attitudinal and behavioral changes sought (Ormrod 2004). Equally important, as the conversation around implicit biases grows across all fields that use decision-making (e.g., Kahneman 2011), including conservation planning (e.g., Iftekar & Pannell 2015), mental-model research provides an opportunity to identify consistent biases across demographic groups. Our experience showed that natural resource managers often assume that if anyone needs to change the way they think, it is the people who are using the natural resource at risk. Although this may be true, it is equally true that managers and policy makers may need to consider how their own thinking hinders or promotes real conservation solutions.

Reliability

The ability of a tool to capture the data one intends to capture is a form of reliability. Common social science tools, like surveys, interviews, or focus groups, each solicit specific types of data, all of which have their issues with response effects. For example, when conducting an open-ended interview it can be common to encounter a deference effect (interviewees telling interviewers what they think interviewers want to hear) or an expectancy effect (interviewers hearing what they expect to hear) (Bernard 2006). Yet, the common alternative of self-administered surveys can also result in questions that are easily misinterpreted, leading to the researcher not knowing what the respondent thought they were answering. Cognitive mapping overcomes some of these problems. The interactive component of writing (or drawing) on cards and organizing them in a way that represents the respondent's mental simulations requires a level of cognitive processing that appears to limit deference effects while capitalizing on the fact that people communicate through oral and graphic media (Jones et al. 2011). This combination of activities results in a reliable tool to capture mental models from diverse stakeholder groups. For example, in the Bolivian Amazon, illiterate individuals were able to engage in the research the same as literate populations because of the use of images to represent objects (Biedenweg & Monroe 2013).

Most importantly, the reliability of the cognitive mapping we described here lies in its ability to motivate respondents to describe direct and indirect connections about the objects of their mental models, creating the space for a rich, relevant, and comprehensive description of the concept under analysis. We do not mean to imply that card-sorting activities result in perfect representations of people's mental models. As with all data-collection tools, there are limitations. One can never ensure that interviewers interpret information as the respondent intends or that respondents are able to access subconscious parts of their mental models that are equally important for understanding their cognitions. Rather, we highlight that what is often needed for learning, communication, and decision-making in conservation is a broad understanding of the thought processes people engage in and that cognitive mapping is a tested tool for eliciting various components of those mental models.

External Validity

The ability of results to inform other contexts is a demonstration of their external validity. For example, many studies that explore he mental models of community-based resource users have identified the importance that users place on stakeholder involvement and considerations of place (and home) in resource management (e.g., Biedenweg and Monroe 2013; Wade and Biedenweg 2019). These same mental objects have not been regularly found in policy maker mental models, however. Although we found this general similarity across contexts, we do not expect data from a cognitive mapping activity in Kenyan fisheries to represent the mental models of lobster fishers in Maine. The validity of cognitive mapping data is inherently context dependent and based on relatively small sample sizes. As such, the use of cognitive mapping for conservation is most appropriate in specific situations where conservation scientists or practitioners want to compare the way people think about an issue across time or relevant populations.

Applicability to Conservation

In addition to scientific rigor, conservation practitioners are also concerned with practicality. To what extent can cognitive mapping be easily implemented and result in useful data? We argue that although collecting individual response data is always time and resource intensive, the benefit of understanding how people think merits the investment. First, we found that both the process and product of cognitive mapping is intriguing to participants and researchers, resulting in greater satisfaction with the research process. Given that responses are solicited in concise, discrete chunks of data, results can be easily analyzed, interpreted, and visualized for diverse, nonsocial science audiences. For example, practitioners can show a photograph of a card sort response (e.g., Fig. 1) or a hierarchical cluster dendrogram (e.g., Fig. 3), and target audiences can engage in a conversation about the data with minimal guidance.

Cognitive mapping can help stakeholders, scientists, and practitioners become aware of their own and others' internal assumptions and thought processes about a conservation issue. In our SMP example, although stakeholders were the most identified factor influencing SMP decisions, the stakeholders that were initially most considered by planners were Tribes and private property owners. Upon viewing data that highlighted their constituents' extensive value for recreation and timber management, they were able to expand their category of stakeholders to include these interests, expressing the intention to modify their SMPs accordingly. The study exemplifies how conservation planners can use cognitive mapping to assess thought processes at one point in time, across relevant social groups to facilitate cross-group collaborations (e.g., Moon & Adams 2016) or even to evaluate shifts in thinking as a result of new information or programmatic activities, such as for program evaluation.

What conservationists should not expect as a result of mental-model data is a lighted pathway to behavior change. Returning to the psychological theory from the introduction, Tolman's early work on cognitive processes demonstrated that new information can, but does not necessarily, associate with behavioral decisions (Ormrod 2004). Rather, the elicitation of mental models yields a rich understanding of information processing from the many actors in the conservation sector, highlighting opportunities for communication, cooperation, and maybe even creative problem-solving.

Caveats

A few caveats are worth sharing regarding the use of cognitive mapping and mental-model research for conservation. First, it is important to remember that cognitive mapping results in snapshots in time of continually evolving mental models. Not only should researchers and practitioners provide space for people's models to evolve, it should also be assumed that they will. Conservation practitioners must consider the timing of data collection in terms of its ability to inform a conservation action.

Second, although the method appears simple, the reliability and validity of cognitive mapping can only be ensured by one who is trained to identify the potential threats to scientific rigor with these types of data-collection tools. For example, cognitive scientists recognize the potential impact of cognitive overload on the reliability of respondent data. As a result, they carefully design cognitive mapping experiments to minimize the amount of effort and time the respondent must dedicate to the research task. Last, interpreting mental-model data should only be done by researchers and data users who are committed to nonjudgmental introspection on how and why different stakeholders perceive conservation-related information. Mental-model data can help conservation if there is a genuine attempt to allow differences in perception to inform the design of strategies and engagement in conversation. It will be less helpful if one's singular goal is to change an individual or group's mental model to be more like another's.

Acknowledgments

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