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Illuminating divergence in perceptions in natural resource management: A case for the investigation of the heterogeneity in mental models

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Much research has been dedicated to map mental models of natural resources to aid effective management of the natural resource. The variety of approaches result in a variety of outputs, but most research in this domain reports mental models that have been aggregated across participants. This results in a misrepresentation of mental models as it overlooks valuable variance in understanding between individuals that could be key in effective decision-making. This paper illustrates such variance in mental models through a case study that explored mental models of the Nile perch fisheries at Lake Victoria. This case study suggests that divergence in mental model present a barrier to effective management of the fisheries. Hence, this paper proposes avenues to further investigate and report the heterogeneity of mental models between and within individuals. Such research uncovers divergence in understanding, which can be addressed to aid decision-making in natural resource management.

Keywords: cognitive maps, decision-making, divergent perceptions, fisheries, Lake Victoria, method, mental models, natural resource management, stakeholders, system understanding

Investigating mental models of natural resources

Mental models are internal constructs that structure an external environment, facilitate interpretation and function as an important factor in individual decision making (Denzau & North, 1994). These cognitive representations can reflect complex dynamic systems and its functioning, the components of the system (the driving forces) and dynamics. Mental models allow a person to describe, explain and predict system states and allow decision-makers to adopt strategies for interaction with that system (Rouse & Morris, 1986; Veldhuyzen & Stassen, 1977). A comprehensive literature is available on mental models in relation to natural resources. These include people's mental models of climate change and vulnerability to natural hazards (Amelung, Fischer, Kruse, & Sauerborn, 2016; Bostrom, 2016; Dutt & Gonzalez, 2012; Gigerenzer & Gaissmaier, 2011; Halbrendt et al., 2014; Henly-Shepard, Gray, & Cox, 2015; Kumar & Dutt, 2018; Leiserowitz, Smith, & Marlon, 2010; Otto-Banaszak, Matczak, Wesseler, & Wechsung, 2011; Sterman, 2008; Tschakert & Sagoe, 2009; Weber, 2006), agricultural dynamics (Gray et al., 2015; Halbrendt et al., 2014; Hoffman, Lubell, & Hillis, 2014; Vanwindekens, Baret, & Stilmant, 2014), water management (Jones, Ross, Lynam, & Perez, 2014; Kolkman, Kok, & van der Veen, 2005; Lynam et al., 2012), forest management (Kearney, Bradley, Kaplan, R., & Kaplan, S., 1999; Tikkanen, Isokääntä, Pykäläinen, & Leskinen, 2006), eutrophication (Cloern, 2001; Janssen, 2001), lake ecosystems (Downing et al., 2014; Hobbs et al., 2016), and fisheries (Garavito-Bermúdez, Lundholm, & Crona, 2016; Gray, Chan, Clark, & Jordan, 2012; Gray, Hilsberg, McFall, & Arlinghaus, 2015; Henly-Shepard et al., 2015; Li, Gray, & Sutton, 2016; Radomski & Goeman, 1996).

Mental models are assessed through a range of methods including (semi-structured) interviews with open-ended questions (Abel, Ross, & Walker, 1998; Findlater, Donner, Satterfield, & Kandlikar, 2018; Garavito-Bermudez, 2018; Jones, Ross, Lynam, & Perez, 2014; Otto-Banaszak, Matczak, Wesseler, & Wechsung, 2011); the Fuzzy Cognitive Mapping approach in which participants draw a cognitive map reflecting the dynamic processes of the subject at hand (Gray et al., 2015; Henly-Shepard et al., 2015; Özesmi & Özesmi, 2003; Tschakert & Sagoe, 2009); the Conceptual Content Cognitive Map, in which concepts are identified and organised among certain dimensions (Kearney, & Kaplan, 1999) and the ARDI method in which participants identify the actors, resources, dynamics and their interactions (Etienne, du Toit, & Pollard, 2011; Mathevet, Etienne, Lynam, & Calvet, 2011). Most of these approaches are employed with groups of participants co-constructing the representation of the dynamic system of the natural resource, while few researchers have applied these methods on an individual level (Findlater et al., 2018; Gray et al., 2015; Jones et al., 2014; Otto-Banaszak et al., 2011).

The outcomes of such methods are also presented in different ways. While only few studies measure mental models on an individual level, even fewer report mental models at this level. The latter type of research presents selected individual cognitive maps (Findlater et al., 2018) or describes the interviews and concepts generated per person (Otto-Banaszak et al., 2011). However, the majority of research on mental models, including most of the research that measured mental models on an individual level, aggregate the mental models across their participants. Research that presents mental models for different groups (e.g. different stakeholders) present separate cognitive maps (Abel, Ross, & Walker, 1998), statistics of the mental models

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(Findlater et al., 2018; Gray et al., 2015; Mathevet et al., 2011) or a textual description of the patterns in the mental models (Garavito-Bermudez, 2018). In such studies, qualitative interview data is coded (through word-search or consensus analysis) into existing categories (Findlater, Donner, Satterfield, & Kandlikar, 2018) or into a coding system derived from the data (Mathevet et al., 2011), which in turn allows for a statistical description of the models.

Another popular approach is to combine the responses from all participants (and thus all groups) into one all-compassing model. Such an aggregated model includes all the variables that were initiated by each participant (Gray et al., 2015; Gray et al., 2012; Mathevet et al., 2011; Tschakert & Sagoe, 2009). Individual cognitive maps of environmental issues have been found to include 23 variables on average and combining just 20 individual mental models may result in a collective mental model that includes 120 variables (Özesmi & Özesmi, 2004). Such complex models are hardly helpful for decision-makers that want to identify opportunities to better manage the natural resource. Therefore, in this paper we propose that mental model data can be better exploited by considering the variance in mental models across individuals.

Exploring mental models of Nile perch fish stock at Lake Victoria

This paper presents a case study of an exploration of the heterogeneity of mental models of the Nile perch fish stock among different stakeholders at Lake Victoria. A thorough stakeholder analysis resulted in a sample consisting of 76 participants from 33 different institutions, in Uganda, Kenya and Tanzania. These included 9 governmental organisations, 9 NGO's, 5 business organisations, 3 research institutions and 7 community groups. To ensure a wide variety of approaches, matching the exploratory approach, mental models were assessed though a combination of interviews and cognitive mapping, as well as on an individual as group level.

The interactions with the stakeholders during field trips at Lake Victoria showed great heterogeneity in their mental models in terms of 1) the state of the Nile perch stock, and 2) the causes of changes to the stock. The issue in relation to the Nile perch fishery was characterised differently and at different degrees of specificity among stakeholders. While most participants reported that the Nile perch stock had *decreased*, others thought that the Nile perch stock had *increased*. Some stakeholders reported that the Nile perch fish *stock* had declined whilst others mentioned a reduction in fish *catch*. Still others reported that the reduction in catch was specific to *mature* Nile perch fit for export.

Not only did stakeholders provide different accounts of this problem, heterogeneity was also apparent in perceptions of the *drivers* of changes in fish catch. Examples of the drivers discussed include: fishing pressure, illegal fishing, climate change, fishing in breeding grounds, presence of water hyacinth, floods, growing populations, local demand for immature Nile perch, corruption, the open access nature of the lake, commercialization of the fishing industry in the region, a lack of enforcement, and a lack of ownership or responsibility to conserve. See Figure 1 for an example of a cognitive map drawn by a group of fishers.

Similarly, discussions with stakeholders about the future of the Nile perch stock demonstrated diverse views. Some stakeholders were convinced the Nile perch stock was steadily increasing, some perceived the stock to be highly volatile while others assumed a stable stock flow, and some experienced the stock to be decreasing rapidly. Stakeholders who believed that the Nile perch would decrease rapidly also strongly differed in the envisioned period until a tipping point. Whilst some expected this to happen as soon as in the next five years, others expected a 50-year period.

These differences in mental models may be highly problematic in terms of collaboration between stakeholders toward the management of the lake's resources. Indeed, in the discussions with the stakeholders, different types of stakeholders (including fishing communities, businesses, and governments) emphasized that there was insufficient collaboration between the stakeholders to manage the lake's resources.

Misrepresentations of mental models

From this exploratory work, it is clear that mental models of dynamic natural resource systems may differ widely across stakeholders. Conservation issues may be interpreted differently, including the driving forces and processes that lead to the issue. Since it is likely that these differences in perceptions prohibit effective decision-making between stakeholders to manage the natural resource, it is this difference between individuals that is of interest. That is, differences in mental models may underpin challenges in natural resource management.

Nevertheless, it is this variance in mental models between individuals that is often overlooked in mental model research. Many approaches in the mental model literature report aggregated models, including the elicitation of mental models in group settings and the aggregation of individual models. However, it is unlikely that such an aggregated model can be found in a single participant. This assumption of homogenous models therefore results in a misrepresentation of mental models in the natural resource literature.

Mental models are often elicited to demonstrate how a certain dynamic system works and to directly infer management solutions from the mental models. For example, the fuzzy cognitive mapping approach is often used to conduct a scenario analysis, which is to inform decision-making to address the conservation issue (Gray, Gray, et al., 2015; Gray, Hilsberg, et al., 2015). Such approaches assume that the participants will (jointly) produce a mental model that reflects the processes accurately. However, the divergence in mental models suggests that it is unlikely that all participants participants (individually or jointly) will have an accurate understanding of the system. The mental model approach could, alternatively, provide an opportunity to map out differences in understanding between individuals, thereby illuminating the divergence of the perception of the environmental problem.

Investigating heterogeneity of mental models to address dynamic natural resource issues

Many of the current approaches in mental model research disregard valuable information by not inspecting the variance in mental models that can underpin challenges in decision-making and addressing the conservation issues effectively. Investigating this heterogeneity in mental models may therefore be key to improve decision-making processes. That is, divergence in mental models has been found to

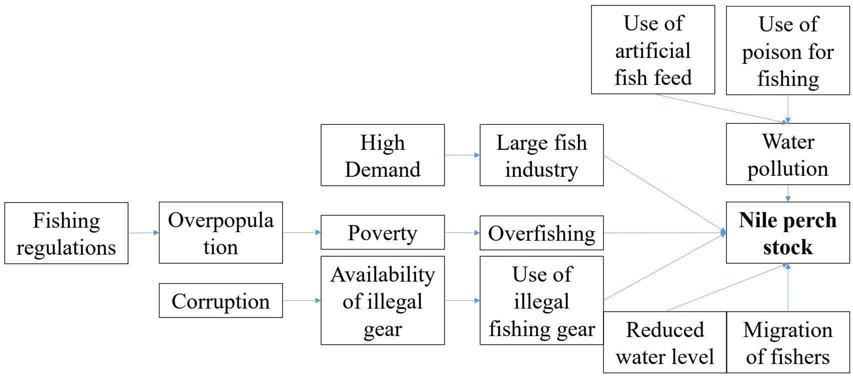

Figure 1. Cognitive map created by a group 6 Ugandan fishers.

affect communication processes between decision-makers (Blickensderfer, Cannon-Bowers, & Salas, 1997; Marks, Zaccaro, & Mathieu, 2000; Waller, Gupta, & Giambatista, 2004), coordination among decision-makers (Marks, Sabella, Burke, & Zaccaro, 2002), collective efficacy (the belief among group members that the required action can be organised and executed; Mathieu, Rapp, Maynard, & Mangos, 2010) and strategy implementation (Gurtner, Tschan, Semmer, & Nägele, 2007).

Convergence between mental models of individuals within a group can be even more important than the accuracy of their mental models for group performance. For example, in a study where basketball players rated the effectiveness of strategic actions for basketball scenario's (which had been rated by subject matter experts), the accuracy of the team members (their agreement with the subject matter experts) could not predict the team's last season's performance while the agreement between participants on the actions did (Webber, Chen, Payne, Marsh, & Zaccaro, 2000). Mapping out the heterogeneity in understanding can therefore provide a first step to enhance convergence in mental models between individuals to aid decision-making. Furthermore, the identification of the divergence of mental models facilitates tailoring conservation campaigns to the stakeholder's mental model, since messages tailored to recipient's characteristics are most effective (van den Broek, Bolderdijk & Steg, 2017). The field of natural resource management would particularly benefit from this, as conservation of natural resources requires the collaboration of diverse stakeholders.

Heterogeneity in mental models can be measured by examining the *variance* (standard deviations, ranges etc.) in the complexity of the mental models (number of variables included, number of links included, the ratio of these two, the density) and concepts in the mental models (variance in central, forcing and receiving variables across participants; Gray, Gray, et al., 2015). For example, variables from all mental models can be listed, and it can be indicated how frequently they were included in an individual mental model. Furthermore, individual mental models that together represent the heterogeneity of the mental models can be reported. Reporting such findings in addition to communalities across mental models (e.g. mean number of variables, most common links) will ensure the presentation of a complete picture of the heterogeneity of the mental models.

An aggregated mental model of the perceptions of the Nile perch stock at Lake Victoria would have disregarded key nuances. Such an aggregated model would only include 4.4 concepts, with 4.5 links. The typical mental model would show that the stakeholders think the Nile perch stock has declined, and that this is due to corruption, which is linked to the use of illegal fishing gear, climate change and water pollution. However, when we consider the full range of mental models, we see that stakeholders have diverse perceptions of the causes for the decline of the Nile perch. The number of concepts included ranges from 1 to 16, with a standard deviation of 3.4, and the number of links ranges from 1 to 19, with a standard deviation of 4.0. Inspecting the variety of the concepts and links, we now see that some stakeholders focus on the responsibility of the fisher (attributing the use of illegal gear to a lack of awareness, or a lack of ownership of the lake's resources), or the consumer (high demand for Nile perch leading to overfishing), or the government (lack of monitoring, effective policy), still others focus on demographic factors (overpopulation leading to overfishing, poverty causing fishers to use illegal fishing gear).

Such divergence in perceptions may be explained by a number of individual differences between stakeholders. Research has shown that differences in the number of target species of fishers, and their dependency on the species, influences fishers' perception of the ecosystem structure, and the complexity of mental model of the ecosystem (Garavito-Bermúdez, 2018; Garavito-Bermúdez et al., 2016; Gray, Hilsberg, McFall, & Arlinghaus, 2015). Moreover, many stakeholders expressed that they expect significant differences in mental models between migratory fishers and indigenous fishers because of differences in perceived ownership of the natural resources between the two groups. Furthermore, research has demonstrated that eliciting a mental model near the natural resource results in more specific mental models with lower density compared to elicitation practices that are conducted at people's homes, which were more generic and more dense (Jones et al., 2014). Similarly, the interaction with the lake (type of interaction, frequency), is likely to affect mental models and may cause systematic difference between stakeholder groups. Knowing which factors underpin such variance may provide an indication on how to harmonize mental models to aid decision making.

Mental models of complex systems inevitably leave room for disagreement, but few studies report the variance in mental models of their sample, and the heterogeneity of mental models has therefore not yet received sufficient research attention. Such research would demonstrate the divergence in understanding, which can then be addressed to aid decision-making among individuals. Besides this heterogeneity in mental models *between* individuals, it is also important to investigate the variance in mental models *within* individuals. That is, future research should also consider the development of the mental models. Little research on natural resource mental models has investigated if these mental models are static, or change over time. Since the latter is more likely due to changing environments and the updating of mental models with new information, it is important to understand how these mental models change and how this affects decision-making. Through repeated measures of mental models, the stable components of mental models can be distinguished from the dynamic components. Such research would further our understanding of the heterogeneity of mental models that inform decision-making processes.

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References

Abel, N., Ross, H., & Walker, P. (1998). Mental models in rangeland research, communication and management. *The Rangeland Journal*, *20*(1), 77–91. doi:10.1071/rj9980077

Amelung, D., Fischer, H., Kruse, L., & Sauerborn, R. (2016). Defogging climate change communication: How cognitive research can promote effective climate communication. *Frontiers in Psychology*, *7*(1340), 1–4. doi:10.3389/fpsyg.2016.01340

Blickensderfer, E., Cannon-Bowers, J. A., & Salas, E. (1997). Training teams to self-correct: An empirical investigation. *In 12th Annual Meeting of the Society of Industrial and Organizational Psychology*. St. Louis, MO.

Bostrom, A. (2016). Mental models and risk perceptions related to climate change. *Oxford Research Encyclopedia of Climate Science*, 1–31. doi:10.1093/acrefore/9780190228620.013.303

Cloern, J. E. (2001). Our evolving conceptual model of the coastal eutrophication problem. *Marine ecology progress series*, *210*, 223–253. doi:10.3354/meps210223

Denzau, A. T., & North, D. C. (1994). Shared mental models: Ideologies and institutions. *Kyklos*, *47*(1), 3–31. doi:10.1111/j.1467-6435.1994.tb02246.x

Downing, A. S., Van Nes, E. H., Balirwa, J. S., Beuving, J., Bwathondi, P., Chapman, L. J., . . . Mooij, W. M. (2014). Coupled human and natural system dynamics as key to the sustainability of Lake Victoria's Ecosystem services. *Ecology and Society*, *19*(4): 31. doi:10.5751/ES-06965-190431

Dutt, V., & Gonzalez, C. (2012). Decisions from experience reduce misconceptions about climate change. *Journal of Environmental Psychology*, *32*(1), 19–29. doi:10.1016/j.jenvp.2011.10.003

Etienne, M., du Toit, D. R., & Pollard, S. (2011). ARDI: A co-construction method for participatory modeling in natural resources management. *Ecology and Society*, *16*(1): 44. doi:10.5751/es-03748-160144

Findlater, K. M., Donner, S. D., Satterfield, T., & Kandlikar, M. (2018). Integration anxiety: The cognitive isolation of climate change. *Global Environmental Change*, *50*(September 2017), 178–189. doi:10.1016/j.gloenvcha.2018.02.010

Garavito-Bermúdez, D. (2018). Learning ecosystem complexity: a study on small-scale fishers' ecological knowledge generation. *Environmental Education Research*, *24*(4), 625–626. doi:10.1080/13504622.2016.1269877

Garavito-Bermúdez, D., Lundholm, C., & Crona, B. (2016). Linking a conceptual framework on systems thinking with experiential knowledge. *Environmental Education Research*, *22*(1), 89–110. doi:10.1080/13504622.2014.936307

Gigerenzer, G., & Gaissmaier, W. (2011). Heuristic decision making. *Annual Review of Psychology*, *62*(1), 451–482. doi:10.1146/annurev-psych-120709-145346

Gray, S. A., Gray, S., de Kok, J. L., Helfgott, A. E. R., O'Dwyer, B., Jordan, R., & Nyaki, A. (2015). Using fuzzy cognitive mapping as a participatory approach to analyze change, preferred states, and perceived resilience of social-ecological systems. *Ecology and Society*, *20*(2): 11. doi:10.5751/ES-07396-200211

Gray, S., Chan, A., Clark, D., & Jordan, R. (2012). Modeling the integration of stakeholder knowledge in social – ecological decision-making: Benefits and limitations to knowledge diversity. *Ecological Modelling*, *229*, 88–96. doi:10.1016/j.ecolmodel.2011.09.011

Gray, S., Hilsberg, J., McFall, A., & Arlinghaus, R. (2015). The structure and function of angler mental models about fish population ecology: The influence of specialization and target species. *Journal of Outdoor Recreation and Tourism*, *12*, 1–13. doi:10.1016/j.jort.2015.09.001

Gurtner, A., Tschan, F., Semmer, N. K., & Nägele, C. (2007). Getting groups to develop good strategies: Effects of reflexivity interventions on team process, team performance, and shared mental models. *Organizational Behavior and Human Decision Processes*, *102*(2), 127–142. doi:10.1016/j.obhdp.2006.05.002

Halbrendt, J., Gray, S. A., Crow, S., Radovich, T., Kimura, A. H., & Tamang, B. B. (2014). Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture. *Global Environmental Change*, *28*(1), 50–62. doi:10.1016/j.gloenvcha.2014.05.001

Henly-Shepard, S., Gray, S. A., & Cox, L. J. (2015). The use of participatory modeling to promote social learning and facilitate community disaster planning. *Environmental Science and Policy*, *45*, 109–122. doi:10.1016/j.envsci.2014.10.004

Hobbs, B. F., Ludsin, S. A., Knight, R. L., Ryan, P. A., Ciborowski, J. J. H., & Ciborowski, J. A. N. J. H. (2016). Fuzzy cognitive mapping as a tool to define management objectives for complex ecosystems. *Ecological Applications*, *12*(5), 1548–1565. doi:10.2307/3099990

Hoffman, M., Lubell, M., & Hillis, V. (2014). Linking knowledge and action through mental models of sustainable agriculture. *Proceedings of the National Academy of Sciences*, *111*(36), 13016–13021. doi:10.1073/pnas.1400435111

Janssen, M. A. (2001). An exploratory integrated model to assess management of lake eutrophication. *Ecological Modelling*, *140*(1–2), 111–124. doi:10.1016/S0304-3800(01)00260-5

Jones, N. A., Ross, H., Lynam, T., & Perez, P. (2014). Eliciting mental models: A comparison of interview procedures in the context of natural resource management. *Ecology and Society*, *19*(1): 13. doi:10.5751/ES-06248-190113

Kearney, A. R., Bradley, G., Kaplan, R., & Kaplan, S. (1999). Stakeholder perspectives on appropriate forest management in the Pacific Northwest. *Forest Science*, *45*(1), 62–73.

Kolkman, M. J., Kok, M., & van der Veen, A. (2005). Mental model mapping as a new tool to analyse the use of information in decision-making in integrated water management. *Physics and Chemistry of the Earth*, *30*(4–5 SPEC. ISS.), 317–332. doi:10.1016/j.pce.2005.01.002

Kumar, M., & Dutt, V. (2018). Experience in a climate microworld: Influence of surface and structure learning, problem difficulty, and decision aids in reducing stock-flow misconceptions. *Frontiers in Psychology*, *9*(MAR), 1–19. doi:10.3389/fpsyg.2018.00299

Leiserowitz, A., Smith, N., & Marlon, J. R. (2010). *Americans' knowledge of climate change. yale project on climate change communication*. Retrieved from http://environment.yale.edu/climate/files/ClimateChangeKnowledge2010.pdf%5Cnpapers3://publication/uuid/230CA706-26C2-4156-8133-1AC9E7701E6A

Li, O., Gray, S. A., & Sutton, S. G. (2016). Mapping recreational fishers' informal learning of scientific information using a fuzzy cognitive mapping approach to mental modelling. *Fisheries Management and Ecology*, *23*(3–4), 315–329. doi:10.1111/fme.12174

Lynam, T., Mathevet, R., Etienne, M., Stone-Jovicich, S., Leitch, A., Jones, N., ... Perez, P. (2012). Waypoints on a journey of discovery: Mental models in human- environment interactions. *Ecology and Society*, *17*(3): 23. doi:10.5751/ES-05118-170323

Marks, M. A., Zaccaro, S. J., & Mathieu, J. E. (2000). Performance implications of leader briefings and team-interaction training for team adaptation to novel environments. *Journal of Applied Psychology*, *85*(6), 971. doi:10.1037//0021-9010.85.6.971

Marks, M. A., Sabella, M. J., Burke, C. S., & Zaccaro, S. J. (2002). The impact of cross-training on team effectiveness. *Journal of Applied Psychology*, *87*(1), 3–13. doi:10.1037/0021-9010.87.1.3

Mathevet, R., Etienne, M., Lynam, T., & Calvet, C. (2011). Water management in the Camargue biosphere reserve: Insights from comparative mental models analysis. *Ecology and Society*, *16*(1): 43. doi:10.5751/es-04007-160143

Mathieu, J. E., Rapp, T. L., Maynard, M. T., & Mangos, P. M. (2010). Interactive effects of team and task shared mental models as related to air traffic controllers' collective efficacy and effectiveness. *Human Performance*, *23*(1), 22–40. doi:10.1080/08959280903400150

Otto-Banaszak, I., Matczak, P., Wesseler, J., & Wechsung, F. (2011). Different perceptions of adaptation to climate change: A mental model approach applied to the evidence from expert interviews. *Regional Environmental Change*, *11*(2), 217–228. doi:10.1007/s10113-010-0144-2

Özesmi, U., & Özesmi, S. (2003). A participatory approach to ecosystem conservation: Fuzzy cognitive maps and stakeholder group analysis in Uluabat Lake, Turkey. *Environmental Management*, *31*(4), 518–531. doi:10.1007/s00267-002-2841-1

Özesmi, U., & Özesmi, S. L. (2004). Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. *Ecological modelling*, *176*(1–2), 43–64. doi:10.1016/j.ecolmodel.2003.10.027

Radomski, P. J., & Goeman, T. J. (1996). Decision making and modeling in freshwater sport-fisheries management. *Fisheries*, *21*(12), 14–21. doi:10.1577/1548-8446(1996)021<0014:DMAMIF>2.0.CO;2

Rouse, W., & Morris, N. (1986). On Looking into the Black Box: Prospects and Limits in the Search for Mental Models. *Psychological Bulletin*, *100*(3), 349–363. doi:10.1037//0033-2909.100.3.349

Sterman, J. D. (2008). Risk communication on climate: mental models and mass balance. *Science*, *322*(5901), 532–533. doi:10.1126/science.1162574

Tikkanen, J., Isokääntä, T., Pykäläinen, J., & Leskinen, P. (2006). Applying cognitive mapping approach to explore the objective-structure of forest owners in a Northern Finnish case area. *Forest Policy and Economics*, *9*(2), 139–152. doi:10.1016/j.forpol.2005.04.001

Tschakert, P., & Sagoe, R. (2009). Mental Models: understanding the causes and consequences of climate change. In *Community-based adaptation to climate change* (pp. 154–159). Retrieved from http://www.iadb.org/intal/intalcdi/PE/2010/04833.pdf#page=156

van den Broek, K., Bolderdijk, J. W., & Steg, L. (2017). Individual differences in values determine the relative persuasiveness of biospheric, economic and combined appeals. *Journal of Environmental Psychology*, *53*, 145–156. 145–156. doi:10.1016/j.jenvp.2017.07.009

Vanwindekens, F. M., Baret, P. V., & Stilmant, D. (2014). A new approach for comparing and categorizing farmers' systems of practice based on cognitive mapping and graph theory indicators. *Ecological Modelling*, *274*, 1–11. doi:10.1016/j.ecolmodel.2013.11.026

Veldhuyzen, W., & Stassen, H. G. (1977). The internal model concept: An application to modeling human control of large ships. *Human Factors*, *19*(4), 367–380. doi:10.1177/001872087701900405

Waller, M. J., Gupta, N., & Giambatista, R. C. (2004). Effects of adaptive behaviors and shared mental models on control crew performance. *Management Science*, *50*(11), 1534–1544. doi:10.1287/mnsc.1040.0210

Webber, S. S., Chen, G., Payne, S. C., Marsh, S. M., & Zaccaro, S. J. (2000). Enhancing team mental model measurement with performance appraisal practices. *Organizational Research Methods*, *3*(4), 307–322. doi:10.1177/109442810034001

Weber, E. U. (2006). Experience-based and description-based perceptions of long-term risk: Why global warming does not scare us (yet). *Climatic Change*, *77*(1–2), 103–120. doi:10.1007/s10584-006-9060-3