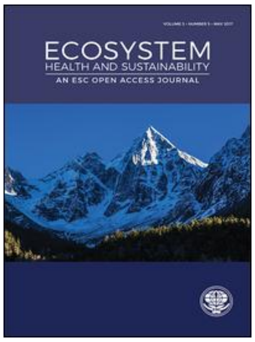

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Conservation and sustainable development in a VUCA world: the need for a systemic and ecosystem-based approach

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Conservation and sustainable development in a VUCA world: the need for a systemic and ecosystem-based approach

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Abstract. Targeting the maintenance of functional ecosystems that provide the significant basis for human well-being is an integral part of an ecosystem-based sustainable development. Underlying causes of ecosystem degradation such as global climate change and ever-growing human demands that rapidly shift socioeconomic and political baselines are often unmanageable at a local scale and require a new approach to planning and action in ecosystem management. The framework conditions that challenge sustainable development are shaped by increasing Volatility, Uncertainty, Complexity, and Ambiguity (VUCA concept). Using the MARISCO method (adaptive management of vulnerability and risks at conservation sites), we analyzed 22 conservation sites, covering 26 protected areas and six administrative areas on four different continents and involving 524 participants. VUCA conditions were present across cultures and biomes, yet the responses in planning and management varied among conservation sites. The findings of both the qualitative and quantitative analyses confirm that participants understand how far human well-being heavily depends on the functionality of ecosystems that were seen to suffer from a wide range of stresses and threats of varying criticality. Worldwide, local stakeholders and experts rated impacts of global climate change as most critical. In attempts to achieve ecosystem-based sustainable development, most management teams strive for more risk-robust and adaptive strategies by advocating for active risk management. A common factor identified among all case studies was the need for cooperative management between smaller conservation sites in order to address large-scale challenges.

Key words: *conservation; development; ecosystem-based approach; MARISCO; VUCA.*

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Introduction

The VUCA concept was first introduced by the U.S. military after the end of the Cold War to describe the conditions of a world ever more difficult to predict and rely on, shaped by Volatility, Uncertainty, Complexity and Ambiguity (Shambach 2004). Since its first appearance in the 1990s, the concept was quickly embraced by other fields such as strategic decision-making, risk management, and situational problem-solving (Tsoukas and Shepherd 2004, MacKay and Costanzo 2009, Tovstiga 2010, Chermack 2011). Business and management science adopted the VUCA concept after the financial crisis in 2008–2009, when societies, companies, and organizations all over the world suddenly found themselves faced with similar conditions in their social and economic environments and models (Doheny et al. 2012, Bennett and Lemoine 2014). Current research related to the VUCA concept focuses on its consequences for leadership and strategic development and the challenges to adapt the mindsets of managers and decision-makers to these new conditions. Even though the principles have been addressed individually, the VUCA concept has not yet found its way into environmental science or conservation practice.

Nonetheless, major ecological crisis, such as the ongoing drought in California (Robeson 2015) and the recent floods worldwide (Gross 2016), as well as the growing intensity and extent of such events in the last decade (Kimberlain et al. 2016), have brought forward the need for many environmental scientists and conservationists to design and plan with uncertainty in mind. Complex systems dynamics are increasingly recognized by a wider scientific community (Young et al.

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2006, Game et al. 2014), with some of the most challenging issues being uncertainty, indeterministic tendencies, emergent properties, and non-linear relationships and feedback processes. However, the response to these challenges is still fragmented and conventional: In order to enhance the predictability of the future, many strive for the increase of knowledge, ignoring that the increasing complexity (stronger interlinkage of socioeconomic and natural systems) inherently limits its knowability. Focusing on narrow objectives and outcomes, conventional management approaches often lack the flexibility and adaptability needed to respond to the fast changes, sometimes leading to the complete failure of conservation efforts (VanderWerf et al. 2006, Martin et al. 2012). Even with cohesive efforts and innovative technologies, the attempts to oppose the complex and interrelated forces driving environmental changes in the future seem to be limited (Orr et al. 2015). In 2000, the Convention on Biological Diversity introduced the comprehensive and holistic ecosystem approach as a theoretical platform from which to launch adaptive management that deals with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. However, its implementation in practice is still very limited and inconsistent (Fee et al. 2009, Fish 2011, Waylen et al. 2014).

The Open Standards for the Practice of Conservation of the Conservation Measures Partnership (CMP 2013) promote the adaptive management based on the more or less comprehensive analysis of complex conservation situations; they represent a framework for the systematic development of strategic solutions using conceptual models that comprise conservation values and targets as well as pressures that cause degradation or loss of biodiversity. An expanded version of the Open Standards, called MARISCO (adaptive management of vulnerability and risks at conservation sites), has been developed that places greater emphasis on ecosystems, system dynamics, change and future risks, with a particular focus on the effects and problems relating to climate change (Ibisch and Hobson 2014).

After applying the MARISCO method in a series of sites and generating corresponding systemic vulnerability assessments in Latin America, Europe, Africa, and Asia, across different cultures and biomes (Ibisch and Hobson 2015) the questions arose if the VUCA concept was applicable to the analyzed socio-ecological systems.

This study aimed to determine if, and so to what degree the stakeholders and conservation actors worldwide actually identify VUCA conditions as challenges to conservation and if they are prepared to come up with corresponding solutions. Additionally, this study intends to provide insights into the consequences of the VUCA concept for nature conservation and ecosystem-based sustainable development.

Methods

The MARISCO method is designed to systematically assess the vulnerability of ecosystems or a landscape subjected to human influence, and to plan for adaptive management strategies aimed at reducing human impacts and restoring optimum functional conditions (Ibisch and Hobson 2014). It encourages participants to think more like "citizen scientists" and to analyze human-induced threats and impacts from an integrated, ecological perspective (Fig. 1; for a detailed overview over the steps of the MARISCO method, please consult Appendix S1). The final product of a systematic analysis is the development of a complex conceptual schematic model based on the perceptions, assumptions, and knowledge of the participants (Appendix S2). The conceptual model depicts the vulnerability of the whole ecosystems as well as the ecosystem-dependent human well-being.

The biodiversity objects build the base of the analyzed conservation site and are located in the center of the conceptual model. Following an ecosystem-based approach, participants are encouraged to identify whole ecosystems, as well as important communities and species. These ecosystems provide vital services for the human well-being and can be found on the right of the biodiversity objects. The human well-being is also influenced by social services, which are provided by social systems, such as governments and institutions, located on the far right of the conceptual model.

Moving to the left of the biodiversity objects, the key ecological attributes can be found. Key ecological attributes are the characteristics of ecosystem components that are essential for their functionality and if being missing or altered would lead to loss or degradation of the component over time (The Nature Conservancy 2007). The stresses on the left indicate such degradations. Stresses are caused directly or indirectly by human activities, the so-called threats. These threats are generated by complexly interacting contributing factors, mostly representing socioeconomic, socio-cultural, and governance-related traits and processes of human societies. The conceptual model is completed by the social systems on the far right, since they are not only the source of important services for the human well-being, but also of many contributing factors.

Based on the findings of the conceptual model, the effectiveness and feasibility of existing management strategies are evaluated and complementary strategies are developed by the participants to address strategic gaps. The conceptual model also serves as a basis for the development of management and monitoring plans.

The outcomes of MARISCO exercises are compatible with the Driver–Pressure–State–Impact-Response framework for integrated environmental reporting and assessment, developed by the European Environmental Agency (Smeets et al. 1999), as well as the Open Standards for the

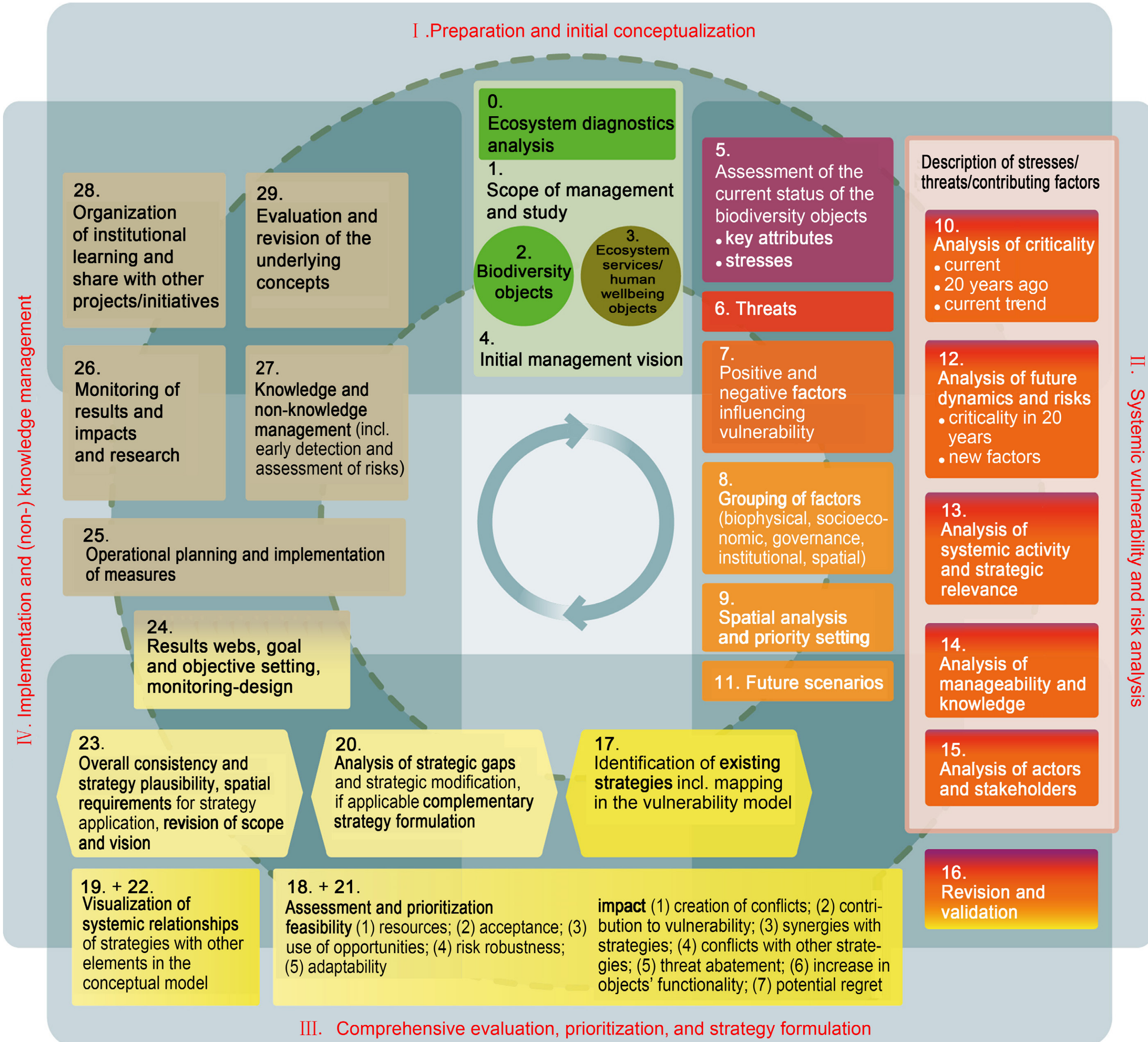

Fig. 1. The steps of the management of vulnerability and risks at conservation (MARISCO) method. For the purpose of this analysis, we focused only on the first three phases of the MARISCO cycle, compromising the steps 0. to 23.

Practice of Conservation of the Conservation Measures Partnership.

Vulnerability analysis

Between 2011 and 2015, 22 ecosystem-based vulnerability assessments were carried out for 26 protected areas in 13 countries spread across four continents (Appendix S3). Overall, 524 participants contributed during the assessments, including local stakeholders, local and national authorities, conservation site managers, national and international NGOs, development aid professionals, and scientists (Appendix S4). The level of analysis varied between short workshops involving a rapid analysis of conditions on a site to more extensive and detailed assessments carried out over a longer period of time. The majority of the assessments were structured as two stakeholder workshops, each lasting 2–3 d, followed by a detailed analysis of the findings undertaken by members of the project team.

During each of the 22 assessments, a so-called conceptual model was produced systemically depicting the conservation situation of the analyzed sites. These conservation sites were not limited to single protected areas and often covered surrounding areas, including areas outside of the buffer zones. The elements of the conceptual models were transcribed into spreadsheets and ranking lists were elaborated for all evaluated elements, namely the stresses, threats, and contributing factors. Stresses and threats were divided into groups according to the unified categories of the International Union for Conservation of Nature and the Conservation Measures Partnership (Salafsky et al. 2008), while the contributing factors were assigned to domains according to the MARISCO method. For a detailed overview of the stresses and threats, see Appendices S5–S8, and for contributing factors, Appendices S9 and S10. The results were then compared using both quantitative and qualitative analyses based on the data embedded in the matrices and ranking lists. The evaluation of existing and complementary strategies was also compared qualitatively.

Qualitative analyses

A conservation site is defined to be subjected to "VUCA" conditions if the system expresses the following symptoms: (1) a change toward increasing dynamics and speed of change forces (Volatility), (2) a high degree of uncertainty within the main drivers of the system (Uncertainty), (3) a high number of interlinkages within the system and with systems of higher orders (Complexity), and (4) multiple interpretations of current and future conditions (Ambiguity). To understand the framework conditions of the conservation sites, study sites were classified according to their status within larger planning units. They either were nested within a larger planned landscape unit at local, national, or international scale. Sites were then ranked on a scale of high, medium, or low according to their perceived degree of complexity based on the total number of elements of the systems and the interlinkages of different sub-systems across scales. Within a workshop setting, stakeholders were also asked to rate the relevance of all factors that contribute to threat generation, including the development of the economy, access to markets, governance, as well as trends of change and future states. Using the rating results of stresses, the probable future status of the various conservation objects identified by the stakeholders was rated as being either positive, stable, or negative. Finally, descriptive indicators and local manifestations of global climate change were classified as high, medium, or low. For a detailed overview, see Appendices S11 and S12.

Quantitative analysis

For each assessment, the percentage of factors that was evaluated as unknowable or unmanageable by the participants was calculated. Similarly, the development and status of the contributing factors were recorded according to the perceived historical level of criticality.

Using a dual coding measure, an assessment was made of the participants' responses to questions about detected potential future risks, identified strategic gaps, views about proactive management, understanding of scales, and landscape management (Appendix S13).

Results

Analysis of the socio-ecological integrity of the conservation sites

The conceptual models that were developed during the 22 assessments comprised in total 464 stresses, 488 threats, and 1,451 contributing factors, with an average of 22.1 stresses, 22.2 threats, and 66.0 contributing factors per model. In order to identify the main drivers of change within the socio-ecological systems, the participants made 17,727 evaluations in total, with an average of 805.77 evaluations per assessment.

Only one out of 22 case studies appeared to be socioeconomically less integrated into the wider regional, national, and international systems (regional: 1 [4.55% of assessed study sites]; national: 2 [9.01%]; international: 19 [86.44%]). In all other cases, there was evidence of more or less intensive integration and socioeconomic exchange with the outside world, even for the more remote project sites such as the community conservancies in the Kalahari sands of north Namibia. In this last example, people from the villages were harvesting and selling medicinal plants such as devil's claw (*Harpagophytum zeyheri*) and wild animals as hunting trophies.

The extent to which local communities integrated with regional or national institutions or appeared connected in some form or other to the wider global community varied among sites, but was generally high. Small rural settlements in more productive landscapes, such as tropical lowland forests, appeared to be better connected to global markets than settlements in harsher environments such as mountain regions, boreal taiga, and semi-arid areas.

In the wider analysis of stakeholder attitudes across the 22 assessments, the expectation among participants was an increase in the near future of better access to markets, and improvements to both economic performance and governance (Table 1).

In relation to the benefits and services derived from the ecosystems, participants identified on average, 17.50 ecosystem services per project site. The multiple interlinkages between conservation objects, ecosystem services, and human well-being indicated the importance of ecosystem health and function to the continued support of human well-being. The majority of participants (80.95%) expected the current pressures on the conservation objects to increase in the future. Among stresses, ecosystem degradations and indirect ecosystem effects were the most common (Fig. 2). In those ecosystems already degraded or heavily disturbed, participants believed conditions could not get any worse than they are, suggesting some measure of levelling off in prevailing conditions.

Across all project sites, local stakeholders and experts rated impacts of global climate change on ecosystems as the most critical problems (Figs. 3, 4). Attitudes reflect the extent and level of influence climate change is having on ecosystems and the living landscape. The descriptions

Table 1. Analysis of the framework conditions of 22 assessed conservation sites in 13 countries on four continents.

Category	Positive/Increase	Stable	Negative/Decrease	Total number of assessments
Access to markets (%)	15 (71.44)	4 (19.04)	2 (9.52)	21
Economy (%)	15 (68.26)	2 (9.01)	5 (22.73)	22
Governance (%)	14 (63.64)	3 (13.64)	5 (22.73)	22
Status of conservation objects (%)	1 (4.76)	3 (14.29)	17 (80.95)	21
Trend in dynamics (%)	17 (77.27)	3 (13.72)	2 (9.01)	22

Notes: Due to differences in the methodological setup, the assessment PE-RCS had to be excluded from the evaluation of the "trend in dynamics." No element relating to "access of markets" was mentioned during the NA-MNY assessment; therefore, the assessment was excluded from the evaluation.

given by participants for climate change effects were generally very detailed and specific to the character and conditions in each of the project areas (degree of detail of climate change descriptions: high: 17 (77.27% of assessed study sites); medium: 1 (4.55%); low: 4 (18.18%). On average, the participants identified 5.55 threats related to climate change per assessment. The most frequently recorded problems were droughts (68.18% of the assessments), followed by increase in mean temperature (55.55%) and changes in the precipitation regime (45.45%). See supplementary materials Appendix S14.

A review of the responses to the section on factors contributing to threats revealed most participants felt there was a good understanding of the environmental problems affecting their area and very little (2% of responses), remained "unknown" (Fig. 5). Nevertheless, participants believed a better knowledge of on average 15.57% of the factors could be obtained by referring to experts. For a detailed overview, see Appendix S15.

In terms of the "manageability" of a threat or contributing factor, the participants were less optimistic. An average of 19% of all factors contributing to every threat were identified as to be unmanageable. Global active factors such as the increasing demand of international markets or the emission of greenhouse gases were singled out as being unmanageable.

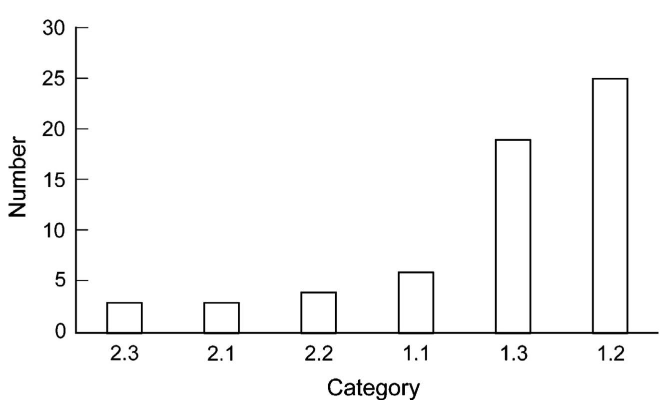

Fig. 2. Distribution of the 60 most critical stresses according to categories of the unified IUCN-Conservation Measures Partnership classification, ranked during 22 assessments in 13 countries: 2.3 indirect species effect, 2.1 species mortality, 2.2 species disturbance, 1.1 ecosystem conversion, 1.3 indirect ecosystem effect, and 1.2 ecosystem degradation.

In the analysis, the percentage of factors that used to be less or more critical in the past was almost the same, yet there existed vast differences between sites. In many cases, we saw that local factors contributing to problems were improving, while new, global factors were emerging, leading to a replacement of local threats by global ones, which in turn is presenting new challenges to managers.

Participants addressed VUCA conditions during all assessments; however, degree and detail varied among sites (Table 2). The majority of the assessments identified volatility, complexity, and ambiguity to a high degree. In contrast, the perception and recognition of uncertainties among participants was generally very low, as indicated by the low percentage of elements rated as unknowable and initially low identification of potential future risks.

Analysis of strategic portfolios

Most of the stakeholder groups identified potential future risks (Table 3), including perceived risks to existing management strategies. The current management strategies for the different project areas addressed a good number of challenges. Many of these strategies were

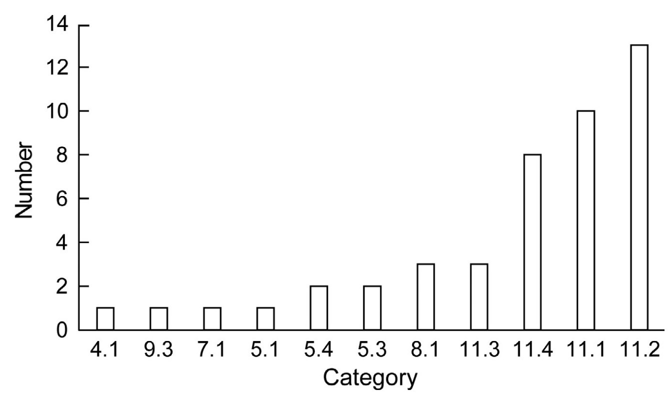

Fig. 3. Distribution of the 45 most critical threats according to categories of the unified IUCN-Conservation Measures Partnership classification, ranked during 22 assessments in 13 countries: 4.1 roads and railroads, 9.3 agricultural and forestry effluents, 7.1 fire and fire suppression, 5.1 hunting and collecting terrestrial animals, 5.4 fishing and harvesting aquatic resources, 5.3 logging and wood harvesting, 8.1 invasive non-native/alien species, 11.3 temperature extremes, 11.4 storms and flooding, 11.1 habitat shifting and alteration, and 11.2 droughts.

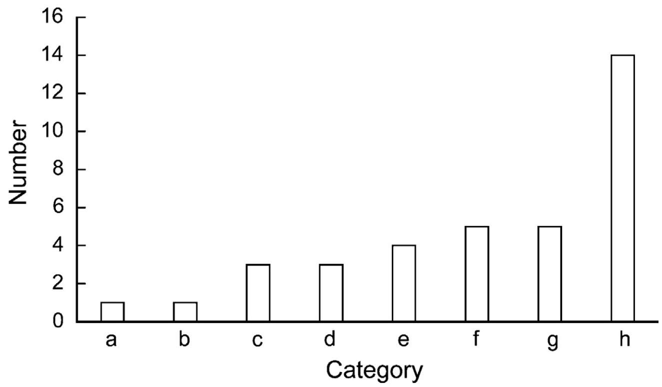

Fig. 4. Distribution of the 36 most critical contributing factors according to their domain, rated during 22 assessments in 13 countries: (a) demographic factors, (b) socio-cultural factors, (c) infrastructure-related factors, (d) institutional factors, (e) governance-related factors, (f) natural resource use-related factors, (g) socioeconomic factors, and (h) natural factors.

aimed at resolving root causes of ecological problems, which are often designed to address issues related to governance, legislation, education, and awareness. Management action to resolve direct on-site threats was evident in all project sites. Among the most common threat-reducing strategies were the control and management of fires and erosion. The mitigation of stresses was also common practice, often including measures such as the rehabilitation of degraded lands or the reconnection of fragmented ecosystem patches.

Nevertheless, all assessed strategic portfolios included strategic gaps identified by the participants themselves (being guided by the MARISCO method). These gaps were often found among elements of the conceptual model that were related to the direct use of natural resources and its distribution or possession. From an institutional

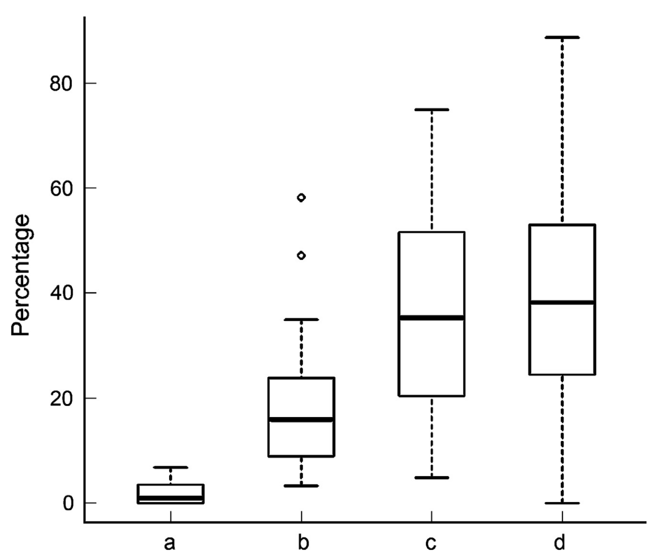

Fig. 5. Contributing factors that were evaluated by the participants as (a) unknowable, (b) unmanageable, (c) its current status less or (d) more critical than in the past.

Table 2. Degree of recognition of VUCA conditions by the participants of 22 assessed conservation sites in 13 countries on four continents.

Category	High	Medium	Low	Total number of assessments
Volatility (%)	18 (81.82)	2 (9.09)	2 (9.09)	22
Uncertainty (%)	0 (0.00)	0 (0.00)	22 (100.00)	22
Complexity (%)	21 (95.45)	1 (4.55)	0 (0.00)	22
Ambiguity (%)	17 (80.95)	3 (14.29)	1 (4.76)	21

Notes: VUCA, Volatility, Uncertainty, Complexity, and Ambiguity. Due to differences in the methodological setup, the assessment PE-RCS had to be excluded from the evaluation of "Ambiguity."

point of view, these were often the most complex issues with the highest potential for conflicts. Yet these elements were usually also the main drivers of degradation of the ecological systems and possessed the biggest potential to generate a considerable impact. For example, the use of fire in agricultural systems arose in most assessments, yet only a few management teams actively addressed this issue. Other typical examples included issues related to land tenure, land use, and social conflicts among different stakeholders. In pursuit of more effective management, all groups developed complementary strategies to fill identified strategic gaps.

The development of conceptual models helped the participants to understand the complexity and dynamics of the conservation sites better, and raised awareness of the resulting challenges of VUCA conditions for their management. The majority of the assessments demonstrated traditional management approaches that focus and act only at local level appeared to be obsolete in times of globalization and interconnected markets, and stressed the need for a more active risk management approach. This included in many cases the desire for a more proactive and integrated set of strategies involving an upscaling of activities through the cooperation among institutions and conservation sites as well as the creation of

Table 3. Evaluation of the capability of current and complementary management strategies to face VUCA conditions.

Category	Yes	No	Total number of assessments
Detection of potential future risks (%)	18 (94.74)	1 (5.26)	19
Identification of strategic gaps (%)	19 (100)	0 (0)	19
Development of complementary strategies (%)	19 (100)	0 (0)	19
Aiming for proactive management (%)	16 (84.21)	3 (15.79)	19
Aiming for larger scale of management (%)	17 (89.47)	2 (10.53)	19

Notes: VUCA, Volatility, Uncertainty, Complexity, and Ambiguity. Due to differences in the methodological setup, the assessments KR-BDA, MY-RSP, and PE-PIN had to be excluded.

larger management units, such as large (transboundary) protected areas.

Discussion

The VUCA concept describes the framework conditions of our global socio-ecological systems as volatile, uncertain, complex, and ambiguous. They were present at all studied sites, across cultures, and biomes, yet the degree of recognition and responses in planning and management varied. The findings of both the qualitative and quantitative analyses confirm that participants understand how far human well-being heavily depends on the functionality of ecosystems that were seen to suffer from a wide range of stresses and threats of varying criticality. The VUCA conditions are highly interrelated, yet we will examine each of them more closely in the context of the findings at the 22 studied conservation sites.

Volatility

Volatility describes the rate of change (usually rapid), and the pattern of dynamics observed in socio-environmental systems. In a modern context, it could describe strong fluctuations in macroeconomic conditions, financial markets, and commodity prices, and to extreme environmental pressures affecting nation states. Until recently, many of scientific and business models have been based on "static state" principles (Svenning and Sandel 2013, Heller and Hobbs 2014, Lawler et al. 2015), despite the evidence for non-linear trends in both natural and cultural systems such as climate change, technological innovation, and rapid fluctuations in world markets (Hall 2003, Lovejoy 2005). Several studies indicate that the speed of interactions and the growth of linkages between elements in biophysical, technical, and human systems at a number of spatial scales are increasing (Held 2000, Young et al. 2006). However, it is still difficult to pinpoint the precise elements within a system where these rapid changes occur. This is especially true if the elements are observed in isolation. A good many conceptual models of the studied sites describe systems that are undergoing a transition from a past situation that has been shaped mainly by local threats to the current situation that is dominated by globally driven threats, or at least its local manifestations.

The speed of these changes is often rapid. To be able to provide a more comprehensive account of the causes of volatility would require a process of monitoring over an extended period of time. Still, a snapshot assessment can provide enough detailed insight, particularly if results are drawn together from a number of different studies. For example, in our assessment of local communities living in the Central Peruvian Amazon, the participants identified the establishment of oil palm plantations as a potential future threat. A follow-up study in the same location three years later revealed the potential future threat had already become a reality (Schick et al. 2015). Actually, volatility at conservation sites mostly does not imply that threats arise and again vanish. Rather, it means that extreme events in relevant driving systems produce a sudden acceleration of problems.

Uncertainty

Uncertainty is characterized by the lack of predictability and the likely prospects for surprise. Uncertainty is the result of the multiple feedback loops and interactions that are inherent to complex systems (Holling 1978, Walters 1986, Gunderson et al. 1995, Gunderson and Holling 2002). There exist various classification schemes of uncertainty in biology (Burgman 2005, Norton 2005).

As the findings of this study indicated, the perception and recognition of uncertainties among participants was generally very low. Participants often assumed that experts would possess the necessary knowledge of most, if not all, of the elements of their conceptual models. This assumption suggests a level of native trust and belief in the skills of experts despite the low level of success in generating accurate predictive models for ecological or socio-political patterns. Climate change modeling is a case in hand. Consequently, the uncertainties of the conceptual models are likely to be much higher than expected by the participants.

Uncertainties also arise due to the rapid interactions of several elements of the complex systems. During such "surprises," the system behavior differs qualitatively from a priori expectations (Gunderson 2000), which can pose risks to the conservation objects, as well as to the effectiveness of management actions.

Perception of risks, as potentially occurring events with a certain probability and impact, as shown by the participants during the assessments was initially very low, even after corresponding input lectures at the workshops. There were some differences between cultures, but generally most groups struggled to see the future critically. Renn (2008) argues that risks are mental "constructions" that are not real phenomena but originate in the human mind. This complicates their perception, because unlike real objects, they cannot be observed and counted in the environment, but have to be created and selected by human actors. Which increases the complexity of risk perception even further is the circumstance that the perception itself depends on what each individual perceives as a risk. What counts as a risk to someone may be an act of God to someone else or even an opportunity for a third party (Tversky and Kahneman 1974).

Despite these challenges, most groups identified potential future risks for the management strategies, as well as the conservation objects, and affirmed that the identification and evaluation of potential risks for their conservation efforts was very beneficial. These outcomes confirm the effectiveness of MARISCO to overcome initial risk aversion and to improve the preparedness of the management teams for future challenges through the development of complementary strategies.

Environmental managers must make decisions in the face of uncertainty and have to choose from an array of possible solutions and strategies (Moore and McCarthy 2010). One approach is to ignore the uncertainties that are inherent in the conceptual models and also in the implementation and outcomes of conservation action but this would leave the conservation plans vulnerable to potential changes under future conditions (McBride et al. 2007). Actually, oversimplification and wishful thinking tend to be common cognitive bias that represents important risks to conservation management. Managers may also seek to make decisions that are robust to uncertainty (Moilanen et al. 2006). A preferable option is to fully embrace the uncertainties as part of the complex systems and instead of trying to predict or eliminate future surprise and uncertainty, to focus on how to design resilient systems that can absorb, survive, and even capitalize on unexpected events.

The benefits of using existing knowledge and evidence are clear (Sutherland et al. 2004), but it is also important to acknowledge that there is a risk linked to any practice that focuses its efforts solely on knowledge-based decisions at the expense of non-knowledge-based action. Therefore, we propose to adopt a more non-knowledge-based approach to nature conservation that operates at a meta-systemic level (Ibisch and Hobson 2012).

Complexity

Complexity refers to the intricate and extensive network structure and dynamic pathways existing between the components of a system. It also infers a state of a system built on principles of chaos and subject to tipping points. The concept of ecological systems as functional, complex systems is well established (Gibson et al. 2000, Gunderson and Holling 2002). Because of the properties inherent in complex systems, cause and effect events are not often closely linked in space and time (Levin 1999). As in any system, complexity increases as the number of system components and connections among components increases.

Independent of cultural or educational backgrounds, participants demonstrated a good understanding of the complex interrelation between the state of the ecosystems and human well-being. At all sites, this understanding was made explicit through the systemic visualization of the elements and their interlinkages.

Complexity poses several challenges for managers. In the first instance, the difficulty with identifying and quantifying causal links between the multitude of potential causal agents and specific observed effects is evident, especially in cases where attempts are made to include positive and negative feedback loops between components in the system. Other confounding situations include long delay periods between cause and effect, widely independent views between participants, and intervening variables (Renn 2008). Secondly, complexity arises due to the wide range of spatial and temporal scales over which ecological systems are structured and operate (Gunderson and Holling 2002, Young 2006). For example, an assessment in Brazil revealed the health of the coral reefs was strongly influenced by the activities of the land users upstream. Therefore, resource managers not only have to consider the different ecosystems that are interacting with each other, but also the economic, social, political, and organizational dimensions of these systems. A more inclusive perspective of a system increases further the level of complexity (Guerbois et al. 2013). In most of the assessments, issues relating to resource management involved government agencies, resources users, and other stakeholder groups, all competing views and expectations of how ecosystems should be valued and managed (Reyes-Garcia et al. 2013). Ideally, resource managers intent to integrate the number and types of competing interests, even though this might add to the complexity of the process, since the interaction of these groups and the way they resolve differences might be complicated.

In times of rapid global change with many complexly related and dynamically acting factors, simple, linear cause–effect solutions too often prove to be ineffective. Across all sites, regardless of cultures and biomes, this was also an insight generated in the course of the MARISCO systemic analyses. Correspondingly, the analyses generally triggered a reflection about the recommendation that rather than focusing on a detailed object-systemic level, management actions should be implemented on a meta-systemic level. In doing so, conservation strategies are better able to focus on the control of inputs and outcomes, processes, functions, and drivers of stress. The use of result webs enables practitioners to comprehend the complex interrelationships of the elements of the conceptual model and helps to improve the understanding of the appropriateness and consistency of strategies.

Ambiguity

Ambiguity is the most abstract factor of VUCA. It relates to the haziness of reality, the potential for misreads, the mixed meanings of conditions, and the mixed outcomes of actions. Ambiguity is a fundamental condition of nature and can be interpreted in more ways than one, thus leading to various conclusions that may suggest a variety of equally attractive solutions, some of which will prove to be good and others to be bad (Yargar 2008). The discussions during the participatory assessments usually revealed a large array of opinions and perceptions, especially when working with a diverse group of actors and stakeholders. Initial disagreement and diversity could catalyze joint learning and normally lead to consensus decisions documented in the conceptual model. Various times participants stated that after running the systemic situation analysis, they would have better understood the position of other actors, and how they were connected.

With a multitude and variety of information broadly available, it is not anymore a question of accessing information, but more of filtering and interpreting it. The challenge for resource managers is to find and select the appropriate source of information for their needs. While the scientific community strives to provide a standardized process for generating and disseminating information, there is a growing trend, driven by cultural shifts and rapid changes in environmental conditions, for non-knowledge frameworks to provide answers and solutions to complex problems (Stanley and Brickhouse 1994, 2001, Roth and Bowen 2001).

Any decision about the effectiveness of conservation action will be determined by the scale chosen to analyze conditions in ecosystems. One of our assessments conducted in the Federal State of Brandenburg in northern Germany demonstrated that from a global point of view, sustainable energy policies, such as the EU renewable energy directive, might have desirable outcomes. Yet on a local scale, its outcomes can be highly negative for local biodiversity, where subsides and incentives to cultivate energy crops have led to the conversion of diverse patchy landscapes to corn monocultures (Reyer et al. 2012).

The outcomes of conservation and development projects are often ambiguous. It is a common dilemma in projects designed to promote development to achieve positive outcomes for a set of objectives can have negative impacts on other goals and targets. This ambiguity was highlighted at one of the studied sites in the Central Peruvian Amazon, where government agencies and international donors are promoting palm oil plantations in order to fight against illegal coca cultivation. Even though this is desirable from a socio-political point of view, its success has had negative consequences for the ecosystems, since in order to be profitable, palm oil plantations need much more land than coca plantations.

Consequences for ecosystem management

During the last 50 yr, humans have greatly altered and degraded the biosphere (Vitousek et al. 1997). The Millennium Ecosystem Assessment (2005) has revealed the vulnerability of human existence, should the loss and degradation of global ecosystems go unchecked and exposed the complexity of both nature and our relationship with it. This has inspired a more sophisticated approach to the way society views and interacts with ecosystems, and to the way we should manage human dependency on them (Ibisch and Hobson 2014). The new direction for conservation is to build and maintain ecological resilience as well as the social flexibility needed to cope, innovate, and adapt to rapid change (Holling 2001).

In recognition of these needs, many more conservation organizations are promoting adaptive management as an alternative approach to resource management (Holling 1978, Walters 1986, Gunderson et al. 1995, Berkes et al. 1998). Despite this extensive interest (Cundill et al. 2012), the effective implementation of adaptive management remains a challenge (Walters 1997, Lee 1999, Moir and Block 2001) and many cases even point to a failure of adaptive management due to institutional rigidity, bureaucratic inertia, and lack of social capital in the form of trust and cooperation (Miller 1999, Jacobson et al. 2006).

Our understanding of the linkages between social and ecological systems has been growing (Clark and Dickson 2003, Turner et al. 2003, McDonald 2008, Rockström et al. 2009). Consequently, both conservation and development narratives have become increasingly unified. Many researchers are now conceptualizing conservation and development as occurring within a single system in which social and ecological components cannot be understood in isolation (Wells and McShane 2004, Chhatre and Agrawal 2009, Waring and Richerson 2011).

In order to achieve true sustainability, a holistic and equitable management approach for socio-ecological systems is needed to mitigate risks without negatively influencing the well-being of human subjects and ecosystems: a more radical ecosystem approach (Ibisch et al. 2010).

Conclusions

Based on the findings of this study, we recommend conservationists to apply VUCA principles during project planning. The involvement of a heterogeneous group of actors and stakeholders during planning can provide a multitude of perspectives and knowledge, which help to highlight ambiguities. Broad participation can also help to identify the complexity of the analyzed social ecological systems and the variety of interlinkages inherent. Methodological approaches such as MARISCO can create opportunities for practitioners to address uncertainties proactively and to assess their knowledge about the analyzed sites, as well as the management solutions they apply. Even though volatility may not be apparent within the first assessment, a continuous evaluation of the complex system later on can enable conservationists to detect the rapid changes and to react in due time.

Holling (2001) stated that attempts to describe complex systems should be "as simple as possible but no simpler" than is required for the purpose of understanding and communicating the situation. Oversimplified descriptions of problems encountered in conservation sites are likely to lead to too simplistic strategies and solutions, which prompts the need to convey to stakeholders the interrelationships existing between all recognized components of an ecosystem. A complete picture understanding of a situation is particularly relevant in the current environment of climate change.

Many sectors of modern society are beginning to work with concepts of vulnerability and uncertainty but not necessarily in the wider conceptual framework of VUCA. The problem with linear or bilinear approaches to problem-solving is the level of misconception about the nature of a system or ecosystem in the first instance, and the loss of resolution in the interpretation of the observed cause–effect patterns. Such narrow perspectives generate blind spots, which can present situations where inappropriate solutions are proposed.

With the increased perception of the urgency to keep decision-makers on board, calls for more inter- and transdisciplinary approaches to conservation are regularly made (Mascia et al. 2003, Sandbrook et al. 2013), yet only little progress can be observed.

Our findings revealed that the majority of participants were initially reluctant, and often unable to address VUCA conditions during the assessments. However, after being guided by the method, most participants embraced the challenges that a VUCA world implies for the management and even were able to appreciate the benefits that such a perspective can provide. We have witnessed that MARISCO represents a tool that is capable to connect different sectors and stakeholders, not only for facilitating multidisciplinary research, but also for translating the corresponding findings into policy and action.

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