MARISCO: Adaptive Management of Vulnerabilities and Risks at Conservation sites

Abbreviated description of the methodology

Based on:

MARISCO. Adaptive Management of vulnerability and RISk at CONservation sites. A guidebook for risk-robust, adaptive and ecosystem-based conservation of biodiversity (Ibisch & Hobson, 2014),
Naturschutz-Handeln im Klimawandel: Risikoabschätzungen und adaptives Management in Brandenburg. 2nd ed. (Luthardt & Ibisch, 2014)
and
Conservation and sustainable development in a Volatility, Uncertainty, Complexity, and Ambiguity world: the need for a systemic and ecosystem-based approach (Schick et al., 2017)

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Axel Schick, Anja Krause & Pierre L. Ibisch

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Introduction

Resource management in the Anthropocene is crisis management. Climate crisis, biodiversity crisis, health crisis and humanitarian crises are mutually dependent and often have a joint impact on humans and nature. In view of this permanent crisis, it becomes clear that "*an extension of the present no longer has a future. Our globalised, ruthless world based on the organisation of inequality no longer works, as it consumes more and more irreplaceable resources and yet does not provide food, water, education, health or peace for most of the world's people* (Ibisch & Sommer 2021)."

To overcome the crisis, new approaches are needed "*that break with the old thinking that caused this crisis".* The proposal is to strive for ecosystem-based sustainable development (Ibisch 2018). Ecohumanism represents an approach to thinking that advocates "*grounding our thinking and actions: Starting from nature and moving towards human beings"* (Ibisch and Sommer 2021). Ecohumanism "*links the acceptance of planetary boundaries with the goal of a just world - and places humans and their strengths at the centre of the debate about ecology and our future. Ultimately, it is based on two simple principles:*

1. the acceptance of the ecological boundaries and our role as a component of this ecosystem.

and

2. the universal human right to a good life for all people today and in future generations. "(Ibisch & Sommer 2021)

The MARISCO method tries to implement these principles within the framework of strategic planning processes: People-focused and ecosystem-based.

The aforementioned "grounding" of our society has also occurred in other scientific disciplines. In the 1990s, UNESCO developed and disseminated the concept of ecohydrology as part of its International Hydrology and Man and Biosphere programmes to place physical science in a socio-ecological context (Bridgewater et al. 2018, Zalewski et al. 1997). This reorientation was necessary because the status of many water bodies and groundwater bodies has deteriorated extremely and groundwater recharge has also been restricted in part due to land use. Overexploitation, increasing demand, pollution, poor management, lack of infrastructure and climate change, which is accompanied by extreme heat and drought events, among other things, are considerably exacerbating the problem situation and endangering the availability of freshwater worldwide.

Ecohydrology uses an understanding of the relationships between hydrological and ecological processes at different scales to improve water security, enhance biodiversity and create further opportunities for sustainable development by reducing ecological threats and achieving greater harmony within watersheds.

The basis for this is a better understanding of the interactions between water and ecosystems, which are inextricably linked to the cycles and flows of nutrients and energy. Precipitation that falls on the land surface in terrestrial ecosystems is converted into either "green water" or "blue water". Green water is the part that is stored in the soil and potentially available for uptake by plants, while blue water either drains into streams and rivers or percolates into an aquifer below the root zone. Green water enters the atmosphere mainly through evaporation from the soil, while blue water flows through the surface or pore space of an aquifer.

Globally, the flow of green water accounts for about two-thirds of the global flow of all water and is equivalent to the flow of all the Earth's rivers into the oceans (Sposito 2017). The green water flow leading to transpiration is a complex process because the soil environment close to the roots, the rhizosphere, is the habitat for the soil microbiome, an extraordinarily diverse collection of microbial organisms that influence water uptake through their symbiotic relationship with plant roots.

Green water is the basis for the functioning of terrestrial ecosystems. It is the most important source of water for the production of food, feed, fibre, wood and bioenergy. To understand how freshwater scarcity limits the production of these vital commodities, it is therefore essential to explain and include the use of green water (and its limits).

In order to implement effective water and ecosystem management, it is therefore important to understand and take into account the complex interactions between the hydrosphere and the biosphere. Complex interactions, feedback effects and non-linear change cause uncertainty and indeterminacy. Decisions with potentially large consequences must be made without sufficient knowledge being available. Goal-oriented, but open-ended and flexible adaptive management is the order of the day.

The **MARISCO method**[1] was initially developed to systematically assess the vulnerability of ecosystems and terrestrial or aquatic landscapes subject to human influence. This is the basis for developing adaptive management strategies aimed at reducing human impacts and securing or restoring the best possible functioning conditions in ecosystems. The methodology enables participants to analyse human-induced threats and impacts from an integrated, ecological perspective. The end product of the holistic analysis is the development of a complex conceptual model based on the participants' perceptions, assumptions and knowledge. The conceptual model represents both whole ecosystem health and vulnerability and ecosystem-dependent human well-being.

MARISCO is a visualised systematic process designed for collecting, organising and documenting both knowledge and non-knowledge related to biodiversity, threats and drivers of change, as well as conservation management (to date) for a given area. It reflects the perceptions, assumptions and knowledge of the people participating in the exercise. The distinctly participatory method uses an orderly, step-by-step approach to strategic planning.

The methodology has been developed for over 10 years at the Centre for Econics and Ecosystem Management at the Eberswalde University of Applied Sciences on the basis of adaptive management methods.

Initially, this was mainly done in the context of and in cooperation with partners in development cooperation - especially for and with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). One focus at the beginning was on protected areas. Eventually, MARISCO was made generally usable for projects and ecosystem-based and participatory diagnostics for the holistic management of landscapes.

[1] Ibisch & Hobson 2014, https://www.marisco.training/resources/manual/

The methodology is also used in other contexts and is adapted for each. It enables the systematic development and implementation of sustainable scenario-based and adaptive-proactive solution strategies.

Notes

It is necessary to introduce some terms. They are an indispensable part of the method and an expression of its systematic. This is done in the knowledge that the reader will already be familiar with some similar facts under other terms. For example, the common "cause of danger" is named "stress driver" here. All experiences from the applications of MARISCO show that this specific conceptual system is quickly accepted and learned. Another peculiarity of MARISCO are the semi-quantitative assessments in four classes (low - moderate - high - very high). To ensure a transparent planning process, each individual decision is visualised. Ratings are made visible by corresponding colours (dark green - light green - yellow - red). The four-level evaluation method represents a compromise between differentiated evaluation on the one hand and intuitive or experiential knowledge on the other. Such knowledge is used where no reliable data is available for decisions.

Glossary

Adaptive management	Adaptive management is best described as a process that allows for micro breakdowns within a system when an external disturbance indicates that the system needs reorganisation. Adaptive management is error-friendly because it encourages systematic learning from errors in order to build more efficient and resilient systems.
Ecological stress	Ecological stresses describe the symptoms and manifestations of the deterioration of key ecological attributes. They manifest themselves as loss of biomass, information and network, among other things. The implication of stress is that under certain conditions, ecological attributes begin to degrade, which then affects the resilience and adaptive capacity of biodiversity elements such as species or ecosystems. Systems take on different states, they degrade or even collapse. Stress describes a specific state, reaction or symptoms of a system or one of its components to anthropogenic pressures - the so-called stress drivers. These unfavourable states in relation to individual components or attributes can in turn trigger further stresses or also interact cumulatively with other stresses. The cumulative effect of several stresses can lead to an escalating degradation of an ecosystem.
Ecological stress driver	Ecological stress drivers are all pressures that can directly or indirectly affect the natural structure and dynamics of an ecosystem. They represent processes of change that negatively affect target systems by causing stress and increasing their vulnerability. Ultimately, they cause a change of state associated with degradation (which means the loss of guiding factors, biomass, information or networks). There are both obvious and subtle examples of stress drivers. Usually the indirect or

imperceptible effects are the most difficult to observe or identify, yet they can cause the greatest disruption to the ecosystem. One example is the complex dynamics of human-induced climate change.

Ecosystem services	Ecosystem services are the benefits that people derive from ecosystems. They include provisioning services such as food and water, regulating services such as flood, drought, soil degradation and disease regulation, and cultural services such as recreation, spiritual, religious and other non-material benefits. Ecosystem services are based on emergent properties of ecosystems. A distinction is made between direct services provided by specific species - e.g. in connection with the production of plant or animal biomass - and indirect services that result from the (inter)interaction of system components (e.g. pollination, climate regulation).
Geographical scope	The geographoical scope defines the planning area and includes all components of biodiversity identified as needing protection. When applying an ecosystem-based approach, it is important to identify whole systems where possible, representing not only the components of an ecosystem, but also the processes, structures and dynamics that constitute and control them.
Human well-being	Human well-being encompasses all the key components that people need for a good life. The components of well-being as experienced and perceived by people are situational and may be strongly influenced by geography, culture and ecological conditions. Nevertheless, it must be assumed that people can universally agree on minimal components of well-being. Hunger, disease or material poverty, the lack of security or esteem, for example, lead to an impairment of human dignity and a fundamentally good life.
Key ecological attribute	Key ecological attributes are best described as the integral elements and properties of ecological systems that maintain their functioning. This includes ensuring that systems have the necessary adaptive and resilient capacity to better cope with disturbance and environmental change. Key ecological attributes include both biological properties of the system itself and corresponding framework conditions that make their existence possible in the first place. These framework conditions mainly include energy supply, water, a certain climatic regime and the availability of nutrients.
Key social attribute	Key social attributes are best described as integral elements and properties of social systems that maintain function and provide the necessary adaptation and resilience to cope with disruption. As with social systems, the organisation and definition of key social attributes is subject to strong cultural differences. They may even vary within members of the same group according to socio-economic status, ethnicity, religion or social function. A basic key social attribute of a social system is often the well-being of individuals. Since human groups

and institutions exist as nested systems, often the functionality of subsystems can be a key social attribute.

(Non)knowledge	Non-knowledge refers to everything that the team could, should or would like to know, but does not or cannot know. It also includes knowledge that the relevant stakeholders do not have or do not want to acquire. In the process of developing the systemic situation model and applying the MARISCO steps (including the assessment of knowledge in relation to the different elements of the model), the team will identify problems caused by knowledge gaps or by (deliberately preserved) ignorance. Ideally, they will be adequately addressed in the strategic portfolio.
Result webs	Result webs illustrate graphically systemic and logically linked assumptions that are formulated for the impacts of strategies. They contain the logical sequence of intermediate outcomes to be achieved that ultimately have a positive impact on biodiversity.
Social service	Social services describe a range of services provided by government, private, for-profit and non-profit organisations, but also by smaller and more informal social institutions such as families or a circle of friends. These services aim to create more effective organisations, build stronger communities and promote equality and opportunity, or simply provide support, affection and care. Basically, provisioning, regulating and cultural social services can be distinguished. Providing refers to supplying people with all the goods and services they need to live (or survive). The regulating services organise the coexistence of people and the functions of institutions. These include all legal and political functions. Cultural services provide people with educational opportunities and all forms of intellectual and spiritual stimulation.
Social stress	Social stress describes the symptoms and manifestations of negative change in key social attributes. As in the ecosystem, they basically present themselves as a loss of a minimum level of mass, information and network and are often related to the deterioration of framework conditions and resources. The effect of stress is that under certain conditions, key social attributes begin to degrade. This in turn ultimately affects the resilience and adaptability of social systems and their components. Over time, this can cause the systems to lose significant functionality or even collapse.
Social stress driver	Social stress drivers are the direct and indirect human activities that have a negative impact on one or more key social attributes, causing social stress.
Social system	Humans are social beings; an important component of our human existence is sharing and caring for each other. Social systems are groups of people interacting with each other. Interaction gives rise to emergent properties of these human groups that would not exist without this

	interaction. Social interaction leads to the emergence of a larger whole that acts and is recognisable as such. This can happen on the basis of a group identity and symbolic effects, but also through the joint management of resources and through structured decisions and the implementation of joint management. Social systems can be very temporary and intuitive. But they can also exist in the long term and function on the basis of constitutional documents or formal statutes.
Strategy	A strategy comprises a set of decisions regarding the use of available resources (management). It also includes the establishment of appropriate socio-institutional conditions (governance) that enable effective action to achieve desirable goals and objectives.
Stress	A stress is the reaction or probable response observed in an object of biological diversity (medical professionals prefer the term "symptoms"), which may be characterised by changes in the physical, chemical or behavioural state of the object.
Stress driver	A stressor is a human-induced driving factor, a direct or indirect effect, that eventually causes a symptom or reaction (a stress) in a protected object.
Systemic situation analysis	A systemic situation analysis enables a detailed understanding of the circumstances and conditions that characterise the character and state of the socio-ecological systems of the processing area. The systemic situation analysis should adequately reflect the complexity of the socio-ecological system. This means that an effort is made to represent the manifold effects and interactions, at least to some extent. In particular, this also involves the human impacts in the ecosystem, which have often led to a very strong change in the system.
Underlying factor and cause	Underlying factors and causes are best described as a human action or activity that directly or indirectly leads to the occurrence of a stress driver. The stress driver then leads to one or more stresses in one or more components of an ecosystem. Often the underlying factors and causes work synergistically, but they can also produce opposing effects. Many of these underlying factors and causes pose risks because they can occur unpredictably in the future or change and contribute to impacts on target systems.
Vulnerability	Vulnerability is the susceptibility of ecosystems to change. Ecosystems that have been damaged to some degree by an impact can become vulnerable to further change and are threatened as a result. Some ecosystems are inherently less vulnerable to threats than others and have developed the capacity to be sensitive. Vulnerability must be understood as a phenomenon of complex interacting processes and analysed systemically. Vulnerability management in nature conservation is related to risk management, but it is a more comprehensive, functional and dynamic process.

1. Methodology

The methodology comprises seven phases with 30 steps:

- Phase I: Motivation and geographical scope,
- Phase II: Human well-being and social systems,
- Phase III: Ecosystem functionality,
- Phase IV: Stresses and risks,
- Phase V: Strategies,
- Phase VI: Plausibility and effectiveness,
- Phase VII: Operational planning and implementation.

Figure 1: MARISCO cycle with seven phases

Diagnostic ecosystem analysis

Most of our ecosystems and the landscapes they form have been used and shaped by humans for a long time. The result is complex overlays of natural conditions with sequences of human-induced changes in changing spatial extents. The diagnostic analysis of ecosystems and their condition creates a common basis for understanding large-scale landscape ecological conditions. For example, it helps to identify the course of important natural boundaries. Furthermore, it gives a first impression of the problems for regional biodiversity. It is important to flexibly vary the section under consideration.

Ecosystem diagnosis can be based on satellite and aerial imagery, maps and existing literature on historical and current land use. If the circumstances require it, looking at Google Earth satellite images can also produce valuable insights. Above all, site visits are indispensable for good ecosystem diagnosis. If possible, both approaches should be combined and carried out before starting the actual work.

1.1 Phase I: Motivation and geographical scope

Phase I addresses the question of what is to be achieved with steps 1 and 2. The motivation and expectation for the exercise, a management vision and the geographical scope of management and study should be established.

Figure 2: Phase I

Steps:

- 1. Motivation, expectation and management vision,
- 2. Identification and dimensioning of the required geographical scope.

It can be helpful to write down what motivated you to start the exercise. This can be used later as an impulse to continue if the exercise does not progress. Similarly, it is advisable to document what outcomes are to be achieved as part of the process. This provides a starting point for discussion and can help avoid frustration at certain points. A shared vision can be a useful tool to motivate and unite a team. The duration of the planning cycle should be kept in mind as it influences how much can be achieved. The final step of this phase is to determine the geographical scope of the processing area, which sets the boundaries for the analysis.

Step 1. Motivation, expectation and management vision

It is rewarding and insightful for a number of reasons to be able to recall later what motivated one to start analysing in the first place. Motivation is what initiates, guides and sustains purposeful behaviour. It causes us to act.

What is to be achieved with this application? What are the expectations of the other people involved? A good understanding of this can help you manage the expectations of the other people involved and avoid any frustration at the end. Expectations are personal beliefs about the effect of an action on achieving a certain outcome.

A management vision helps to guide activities, management goals and objectives. It is important to formulate this vision before moving on to detailed situation analysis because the vision stimulates consensual strategic thinking and provides a basis for goal formulation. The vision should relate to the planning area within the application space. However, it can also relate to the institution that is to be managed. A vision is a general statement of the desired state or end state you want to achieve.

The vision should be general, visionary and brief.

A good vision statement should meet the following criteria:

- Relatively general - Broadly defined to include all activities,
- Visionary - Inspirational in that it outlines the desired change in the state of the goals being worked towards,
- Short - Simple and concise so that everyone involved can remember it.

Step 2. Identification and dimensioning of the required geographical scope

The observation and management area of a planning area (e.g. a protected area) first and foremost encompasses the entire biodiversity that is to be conserved. Its boundaries should be based on natural boundaries (e.g. watersheds) as the ecological basis for the existence of biodiversity. A planning area should be as large as possible in order to accommodate viable populations and functioning ecosystems, including their fluctuations over time. Another criterion is that the planning area should include the places of origin of significant stress drivers for the biodiversity to be protected. For the above reasons, a 'generous' landscape scale should be considered. The landscape scale in the case of an existing protected area may extend more or less far beyond its current administrative boundaries.

1.2 Phase II: Human well-being and social systems

In phase II, steps 3 to 7 examine what the social framework conditions look like. This involves compiling what people need for a good life and what services contribute to their well-being. In addition, it is determined which systems produce these services and which conditions they need in order to provide them.

Figure 3: Phase II

Steps:

- 3. Human well-being,
- 4. Social services,
- 5. Social systems,
- 6. Key social attributes,
- 7. Ecosystem services.

Ecosystems are the basis for sustainable development in the processing area, including adaptation to environmental changes. Their ability to function must also be ensured so that the local population can live in an environment of adequate quality. Humans are an integral part of the global ecosystem. In reality, complex situations of different social and ecological systems occur in areas of application and consideration, which influence each other - they are called social-ecological systems. Therefore, any specific strategies proposed to bring about change and transformation in the complex social-ecological systems of the planning area must also adequately take into account people's needs and attitudes. Otherwise, they are very likely to be ineffective. It is particularly important to reflect social conflicts and (presumed) reasons for certain habits and actions. In this context, it must always be remembered that people are part of the complex ecosystems on which they live and which they change. As a key element of these systems, the human subsystem therefore deserves particularly careful analysis.

Step 3. Human wellbeing

All your actions ultimately affect the people within the planning area and even beyond. A good understanding of the elements that make up the well-being of people in the planning area is important. It will also make it easier - if necessary - to raise awareness among local people about how they benefit from functioning ecosystems in the form of ecosystem services. It will also help to understand potential conflicts of interest and risks that may arise from different interests in the use of natural resources.

Human well-being includes immediately understandable elements such as access to clean water, nutritious and healthy food and good physical health. However, other important elements also relate to mental and emotional well-being and social relationships.

Step 4. Social services

Humans are social beings. Therefore, it is not surprising that our well-being is strongly influenced by our social environment. Many social systems have been created by humans to achieve a better life. Social systems contribute to human well-being through social benefits. They describe a range of public services provided by government, private, for-profit and non-profit organisations. These services aim to create more effective organisations, build stronger communities and promote equality and opportunity.

Social services include e.g. education, food subsidies, health care, police, fire brigade, vocational training and subsidised housing, adoption, municipal administration, political research, lobbying and many more.

(For evaluation criteria, see section 3).

Step 5. Social systems

Humans are social beings; important components of our human existence are sharing and caring for each other. Social systems are groups of people interacting with each other. Interaction gives rise to emergent properties of these human groups that would not exist without this interaction. Social interaction leads to the emergence of a larger whole that acts and is recognisable as such. This can happen on the basis of a group identity and symbolic effects, but also through the joint management of resources and through structured decisions and the implementation of joint management. Social systems can be very temporary and intuitive. But they can also exist in the long term and function on the basis of constitutional documents or formal statutes.

(For evaluation criteria, see section 3).

Step 6. Key social attributes

The ultimate goal of any sustainability management is to ensure the functioning of relevant systems. To be functional, social systems need certain components and conditions. These are the key social attributes.

They include both tangible factors, such as access to resources, information and energy, and intangible factors, which relate to the interactions of various social components, such as cooperation, coordination and trust.

A detailed description of the key social attributes increases the understanding of the current state of the social systems and enables better management decisions to be made.

Key social attributes are best described as integral elements and properties of social systems that maintain function and provide the necessary adaptation and resilience to cope with disruption. As with social systems, the organisation and definition of key social attributes is subject to strong cultural differences. They may even vary within members of the same group according to socio-economic status, ethnicity, religion or social function. A basic key social attribute of a social system is often the well-being of individuals. Since human groups and institutions exist as nested systems, often the functionality of subsystems can be a key social attribute.

(For evaluation criteria, see section 3).

Step 7. Ecosystem services

Identifying ecosystem services is essential for working with stakeholders and understanding their needs and perspectives. It is also important for communicating the benefits of protecting functional ecosystems to the public. The representation of ecosystem services reflects the potential of a given area for ecosystem-based sustainable development. When this step is completed, the ways in which people use or depend on the ecosystems of the planning area can be understood and visualised.

Ecosystem services are the benefits that people derive from ecosystems or their functions. These include provisioning services such as food and water, regulating services such as flood, drought, soil degradation and disease regulation, and cultural services such as recreation, spiritual, religious and other non-material benefits. Ecosystem services are based on emergent properties of ecosystems. A distinction is made between direct services provided by specific species - e.g. in connection with the production of plant or animal biomass - and indirect services that result from the (inter)interaction of system components (e.g. pollination, climate regulation).

(For evaluation criteria, see section 3).

1.3 Phase III: Ecosystem functionality

Phase III focuses on the ecological framework with steps 8 and 9. It is compiled which types of ecosystems are present. It is also examined which key ecological properties they need in order to be functional.

Figure 4: Phase III

Steps:

- 8. Ecosystems and components,
- 9. Key ecological attributes.

Functioning ecosystems are the basis for sustainability. Therefore, a good understanding of ecosystems is fundamental to the development of any planning. When applying an ecosystem-based approach, it is important to identify, where possible, whole systems that represent not only the compositional elements of an ecosystem, but also the processes, structures and dynamics that govern them.

In most cases, this refers to ecosystems at the landscape level, which may also include smaller aquatic and terrestrial subsystems. A large spatial system may represent a particular landscape type - e.g. a forest landscape, a lake landscape (around a large lake including the surrounding mountains and [lower] catchments), a seascape, a coastal landscape, a groundwater landscape, and so on. This may well be the highest order ecosystem object to be conserved, and it is likely to extend beyond the boundaries of the established protected areas within the processing area.

Step 8. Ecosystems and components

A sufficiently large spatial unit must be identified that encompasses the most important ecological processes in the region and is encompassed by boundaries that are as natural as possible. Smaller ecosystems should be listed that are included and assumed to contribute significantly to the functionality of the larger system - e.g. rivers, lakes, forests, peatlands. Important components such as species, populations, functional groups or habitats can be added to one or more ecosystems.

Groups of species (guilds) or individual species should be identified that are of particular importance for ecosystem functionality. These can be: structure builders, such as dominant tree species; engineering species, such as beavers; or important keystone species known to play a relatively large role in the system. Typical species that should be listed include apex predators.

(For evaluation criteria, see section 3).

Step 9. Key ecological attributes

The ultimate goal of ecosystem-based management is to ensure ecosystem functioning. To be functional, ecosystems need certain components and conditions. These are the key ecological attributes. They include abiotic factors, such as temperature regimes, precipitation patterns and soil conditions, and biotic factors, which refer to the presence and interaction of different biological components.

Specific key ecological attributes can be identified for each ecosystem. Alternatively, generic key ecological attributes are inserted and then linked to one or more ecosystems. The identification of specific key ecological attributes for each ecosystem provides a much more accurate understanding of the current state of the ecosystem. This allows for better diagnosis and, if necessary, better management decisions can be made.

(For evaluation criteria, see section 3).

1.4 Phase IV: Stresses and risks

Phase IV is dedicated to the question of which problems (drivers of stress) occur with steps 10 to 19. For this purpose, the current state of the protected objects is assessed.

Furthermore, the criticality of stress, stress drivers and underlying factors and causes are described and analysed.

Figure 5: Phase IV

Steps:

- 10. Ecological stress analysis,
- 11. Drivers of ecological stresses,
- 12. Underlying factors and causes,
- 13. Social stress analysis,
- 14. Drivers of social stresses,
- 15 Underlying factors and causes (Part II),
- 16. Revision and completion of the systemic relationships,
- 17. Element rating,
- 18. Identification of systemic drivers, revision and validation.

Once the target objects are defined and before further action is taken to formulate the strategy, it is important to create as good as possible a detailed understanding of the circumstances and conditions that characterise the character and state of the socio-ecological systems of the processing area. The systemic situation analysis should adequately reflect the complexity of the socio-ecological system. This means that an effort is made to represent the manifold effects and interactions, at least to some extent. In particular, this also involves the human impacts in the ecosystem, which have often led to a very strong change in the system.

The end result of the MARISCO situation analysis is a visual representation of a systemic situation model. This model aims to include as many of the elements involved in the cause-effect dynamics of the complex socio-ecological system as possible. On another level, the model also tries to capture what is known about the system. It also tries to uncover the existing knowledge gaps and other forms of "non-knowledge" associated with the indeterminacy of the complex system to be managed. Knowledge management and consciously working with the various forms of non-knowledge, which include unresolvable uncertainty, is an essential component of the adaptive management approach. Working with knowledge and evidence is very important, but even more significant is the recognition of how provisional and incomplete knowledge about complex systems usually is.

Step 10. Ecological stress analysis

A detailed stress analysis of ecosystems is important for understanding how ecosystems and their components are affected by the negative impacts of direct and indirect human activities. It is the starting point for identifying and understanding stress drivers and for formulating hypotheses about cause-effect chains' that will eventually be triggered by policy implementation. The number of stresses provides further insight into the vulnerability of an ecosystem, as highly stressed ecosystems are generally expected to have higher vulnerability.

There are two ways to conduct an ecological stress analysis. Either the stress level of each key ecological attribute can be assessed, created specifically for the ecosystems and their components, or generic stresses can be formulated, which can then be linked to the key ecological attributes. The first option provides a detailed understanding of the state of each ecosystem and its components, but takes a little more time. Of course, in water bodies or forests, for example, there are clearly differentiated key attributes in each case. In human-dominated agro-ecosystems or settlement ecosystems, there are again completely different attributes and thus also stresses. The second option of formulating generic attributes will be faster, but remains much more superficial.

One can always return to this step and revise and deepen it if necessary. Ultimately, spending more time at this point means a deeper understanding and, especially in interdisciplinary and transdisciplinary planning groups, definitely important gains in knowledge.

(For evaluation criteria, see section 3).

Step 11. Drivers of ecological stresses

Ecological stress is caused by corresponding drivers. In the case of the MARISCO analysis, the focus is on direct and indirect human activities that have a negative impact on one or more key ecological attributes.

Guiding questions for the identification of ecological stress drivers are:

- Which human activities have a negative impact on the viability of the various ecosystems or their components?
- What other processes degrade the functionality of key ecological properties by causing stress?

(For evaluation criteria, see section 3).

Step 12. Underlying factors and causes

Underlying factors and causes are human actions or activities that directly or indirectly lead to the emergence of a stressor.

Guiding questions for this process are:

- What are the reasons for the occurrence of a stress driver or an underlying factor?
- Which relevant actors and stakeholders are involved in the creation of a stressor? What are their reasons for doing so?
- Are there factors from the list that positively influence another underlying factor and causer or stress driver?

(For evaluation criteria, see section 3).

Step 13. Social stress analysis

Once the team has identified key social attributes for the social systems, they may decide to conduct a social stress analysis, similar to the ecological stress analysis described in step 10.

First, the key social attributes need to be gone through. Those that are degraded or could be degraded within the time frame of the planning horizon can be classified as stresses. When a full functional analysis has been carried out, it should be somewhat clearer from the status given to the attributes which are in such poor condition that stress is present. Once this step has been completed, one should reflect on the status of the social systems and their components. This may lead to the identification of other stresses that may have been neglected in determining the most important social attributes.

In general, the following guiding questions help to identify stress:

- What kind of negative changes in key social attributes can be observed?
- What are the signs of "disorder" and "disease" of the social system?
- Is there a loss of quantity of components, information or networks within the system?
- Is there a loss of connectedness within the system or with other systems?

(For evaluation criteria, see section 3).

Step 14. Drivers of social stresses

Social stress is caused by the direct and indirect human activities that negatively affect one or more important key social attributes. These are the social stress drivers.

Guiding questions for the identification of social stress drivers are:

- Which human activities have a negative impact on the viability of the various social systems?
- What other processes degrade the functionality of key social attributes by causing social stress?

(For evaluation criteria, see section 3).

Step 15. Underlying factors and causes (Part II)

Underlying factors and causes are best described as a human action or activity that directly or indirectly leads to the occurrence of a stress driver. The stress driver then leads to stress or stresses in one or more components of an ecosystem. Often the underlying factors and causes work synergistically, but they can also produce opposing effects. Many of these underlying factors and causes pose risks because they can occur unpredictably in the future or change and contribute to impacts on target systems.

(For evaluation criteria, see section 3).

Step 16. Revision and completion of the systemic relationships

Now it is time to identify the links between the elements. The connections can be between elements of the same category or between neighbouring categories. Sometimes these connections form feedback loops.

The connections are important for your understanding of the dynamics of the systemic situation model. They are used to calculate the systemic activity of the elements.

Step 17. Element rating

The strategic relevance of a stress, stress driver, underlying factor or cause refers to the perceived importance of these elements to the vulnerability of the target system. Any element with a high strategic relevance rating should be examined in more detail in the final prioritisation process.

There are two ways to assess the current criticality of the elements. Either a detailed assessment can be made by evaluating the scope, severity and irreversibility of the elements, or the current criticality can be assessed using summary or simplified criteria. The first option provides a detailed understanding of the current criticality of each element but takes a little more time. The second option is quicker but less specific. However, one can always come back and revise this step if needed (see section 3 for assessment criteria).

Step 18. Identification of systemic drivers, revision and validation

The complexity of ecosystems does not result from a random combination of a large number of interacting factors, but from a certain number of controlling processes and components that are particularly significant for their functionality. Similarly, the behaviour of complex socio-ecological systems is usually determined by a number of highly influential elements. These are the systemic drivers.

The rankings can help identify the drivers within the complex system. In general, all elements with high strategic relevance are potential drivers, as they have a strong influence on a large number of elements. These drivers should be taken into account in the next step, the formulation of strategies.

Any decision made during any part of the MARISCO process is considered preliminary and may be changed at a later stage when more information is available. In this step, it is recommended to revise the systemic situation model and check its coherence.

Some guiding questions are:

- Are some elements missing or is some of the information available more than once?
- Are all the connections made plausible?

- Do the scope and vision still fit the systemic situation model?
- Has the motivation or expectation changed?

Every change made leads to changes within the systemic situation model.

1.5 Phase V: Strategies

In phase V, steps 20 to 25 examine which problem-solving strategies are necessary. For this, existing strategies are evaluated and prioritised. An impact analysis and a strategic gap analysis are carried out. Based on this, complementary strategies are developed.

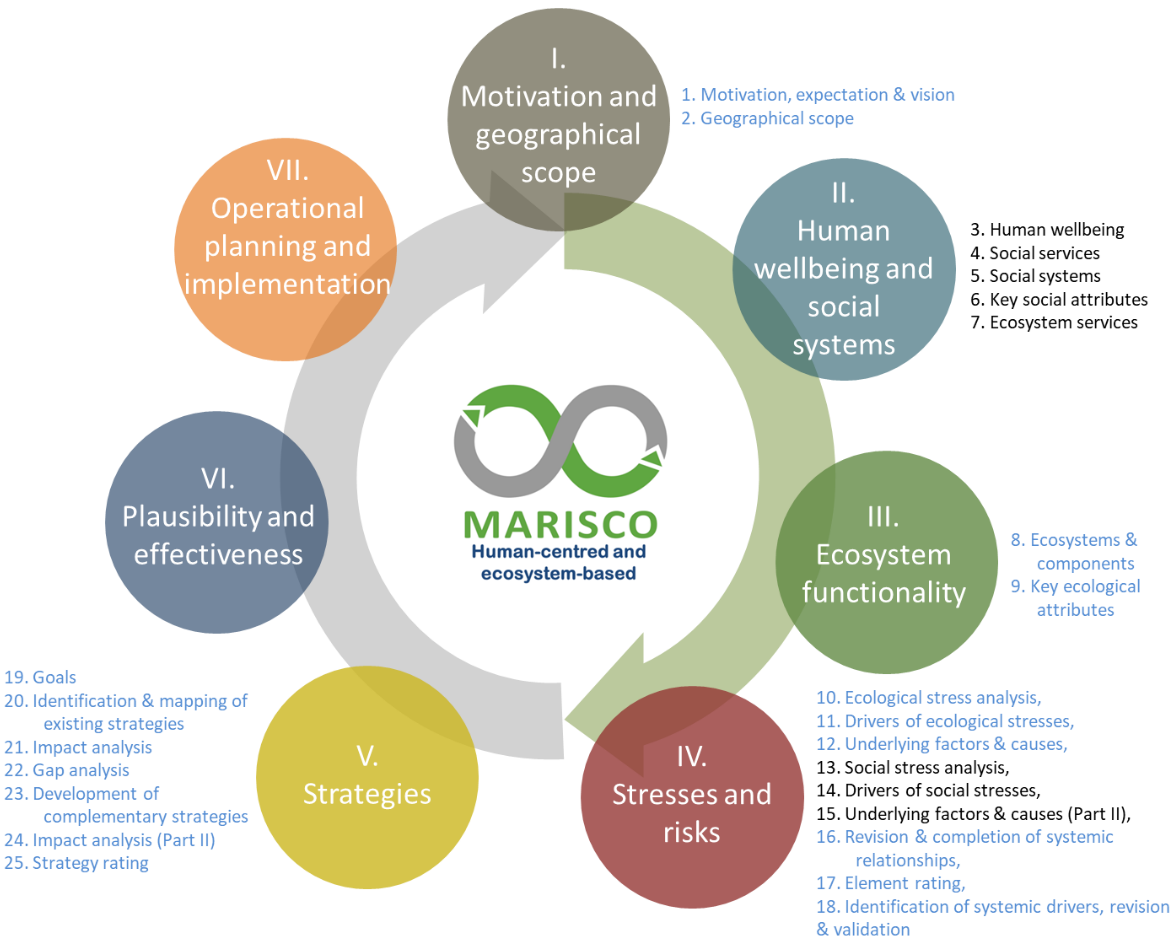

Figure 6: Phase V

Steps:

- 19. Goals
- 20. Identify and map existing strategies,
- 21. Impact analysis,
- 22. Gap analysis,

- 23. Development of complementary strategies,
- 24. Impact analysis (part II),
- 25. Strategy rating.

Once the full situational analysis of the planning area has been completed and the various stresses, stress drivers and underlying factors and causes have been identified, the next step is to develop a comprehensive strategic plan. An effective strategic plan includes well thought-out objectives. These should be designed to be consistent, complementary, risk resistant and effective in bringing about positive change for the target systems. There is no perfect plan, but it is possible to formulate robust, assessable and meaningfully feedback strategies (the strategy influences the system, and the system influences the strategy) that also promote institutional learning and adaptive improvement.

Not only are ecological or social systems vulnerable to unexpected change, strategies are also sensitive to disruptions and threats. The same stress drivers, underlying factors and causes, and risks that affect target systems can also affect the effectiveness of strategies, not to mention posing other unforeseen risks in the future. It is therefore recommended that strategies are developed from the outset with integrated adaptability and incorporating the principles of risk management.

Management of the planning area becomes more effective when it takes a "meta-systemic approach". This approach focuses more on understanding and responding to processes driven by non-linear and interconnected dynamics, as well as the framework conditions that enable such processes. Such a more holistic approach promotes self-organising change and adaptation in the managed system. This type of management should also target the synergistic interactions of as many strategies as possible to achieve critical mass for the transformation of the managed area.

Step 19. Goals

Before action planning can begin, it is important to be clear about what you want to achieve. The next stage of the process is to formulate objectives for all target systems, especially for the ecosystems. Each target system can be assigned a target. However, it is more beneficial to create more detailed targets for groups of objects (e.g. forest ecosystems) or subsystems that contain target system groups (e.g. forest peatlands). It is important to remember that all objectives must be impact-oriented, measurable, time-bound and specific. For a target to be effective, all related targets should correspond to the stress drivers and their underlying factors and causes.

Step 20. Identification and mapping of existing strategies

Now, all existing strategies of the planning area are listed, including the strategies that are currently being implemented as well as the strategies that are planned for the future (e.g. as part of a management plan). Once all strategies are identified, they are inserted into the systemic situation model together with the corresponding elements they affect. They are then linked with arrows to the stress drivers and underlying factors and causes.

Step 21. Impact analysis

The visualisation process of the actual or potential relationships of the strategies with other elements in the systemic situation model provides a better understanding of the complex environments in which the strategies are to be implemented. It can even lead to the identification of previously overlooked risks. New risks could be those that reduce the feasibility and effectiveness of strategies.

To begin the impact analysis, one selects a strategy and systematically draws arrows connecting the strategy to other elements in the systemic situation model, in particular: underlying factors and causes, stress drivers, stresses and other strategies. The connecting arrows can be adjusted to distinguish between different types of connection, e.g. *strong* versus *weak* or *positive* versus *negative*.

Step 22. Gap analysis

It should now be checked whether all elements in the systemic situation model with high strategic relevance are adequately addressed by the strategies. If not, what kind of strategies could be applied to address the critical elements? If there are obvious gaps, one tries to close them by adapting existing strategies or creating new strategies in the next step.

Step 23. Development of complementary strategies

If underlying factors and causes, stress drivers and stresses of high strategic relevance have been identified that are not addressed by existing strategies, it needs to be discussed whether and what kind of strategies could be applied to address the relevant elements.

Where appropriate, strategies need to be formulated that would reduce and mitigate the problems or adapt to the risks. In formulating strategies, their manageability and knowledge assessment need to be considered. In this regard, less manageable elements require adaptation strategies rather than change strategies. Strategies that address elements that are not sufficiently understood could include research components or precautionary measures.

Step 24. Impact analysis (part II)

To complete the visual assessment, one performs an impact analysis for the complementary strategies. This visualisation process applies the same objectives and procedure as described for the gap analysis two steps earlier. The analysis should also take into account the existing strategies.

To begin the impact analysis, one selects a strategy and systematically draws arrows connecting the strategy to other elements in the systemic situation model, in particular: underlying factors and causes, stress drivers, stresses and other strategies. The connecting arrows can be adjusted to move between different types of connection.

Step 25. Strategy rating

Often strategies are set and implemented without a subsequent assessment of their feasibility and potential impact. This can lead to unreflective management where those executing the strategies have little understanding of their effectiveness. An assessment of strategies helps to adjust the strategy design and prioritise from the portfolio of strategies. This process improves the effectiveness and robustness of the strategies and helps to avoid negative impacts of the implemented strategies that remain unforeseen without proper reflection.

During this step, each strategy is assessed for both feasibility and potential impact (see section 3 for assessment criteria).

1.6 Phase VI: Plausibility and effectiveness

In phase VI, the question of whether the theory of change is plausible is investigated with step 26. For this purpose, **outcome networks** are developed to analyse the effects of the strategies.

Figure 7: Phase VI

Steps:

- 26. Development of result webs.

All too often, planning teams propose strategies before they have fully reflected on the assumptions made. As a result, scenarios are presented before the cause-and-effect endpoints of strategies have been carefully considered. This can lead to inconsistencies in the effectiveness of proposed strategies. In the case of natural resource management, it is not possible to predict the impacts of a strategy with absolute accuracy because ecosystems - and also the social systems involved - are very complex. Many elements may react in unexpected ways, or new factors and feedbacks may emerge.

The planning tool of result webs can help us to better visualise complexities of managing socio-ecological systems, while also taking into account unavoidable uncertainties. They represent webs of hypotheses and provide initial conceptual models for predicting potential changes that management strategies will bring about in a system. As such, they enable managers to identify potential blind spots and reduce avoidable risks. In some cases, the results of an outcome-impact network analysis may lead to the conclusion that existing or complementary strategies are unlikely to change the situation. In this case, the strategic portfolio would need to be reconsidered.

As result webs are a tool for recording the team's perceptions of the effectiveness of their strategies, this step also paves the way for designing an effective monitoring system and operational plans. Some strategies may represent key or 'milestone' strategies that need to be implemented before further steps are taken.

Step 26. Development of outcome-impact networks

The process begins with the selection of a strategy from the systemic situation model and the creation of an outcome-impact network. Now the underlying factors and causes or stress drivers that are likely to be influenced by the strategy have to be translated into assumed outcomes and reformulated as positive outcomes. To do this, the respective element must be selected and the text changed. For the assumed chains of effects given by the systemic relationships in the systemic situation model, the corresponding outcomes have to be presented as "if-then" relationships.

All underlying factors and causes as well as stress drivers in assumed outcomes should be systematically transformed. In the course of the activity, it is possible that other elements not previously thought of will be identified. These then need to be included in the outcome-impact network. During the construction of the 'if-then' result webs, it may be decided to include other strategies in the network before the final strategy portfolio is considered complete. However, it is best to start the analysis with simple result chains before constructing more complex networks.

1.7 Phase VII: Operational planning and implementation

Phase VII is about how to implement the strategies in steps 27 to 30. Monitoring and operational planning is carried out. In addition to this, the measures are implemented and knowledge management is applied.

Figure 8: Phase VII

Steps:

- 27. Monitoring design,
- 28. Implementation planning,
- 29. Implementation and monitoring of results and impacts,
- 30 (Non-)knowledge management.

The steps taken so far represent an important part of an initial knowledge management exercise carried out in the processing area. These steps have succeeded in structuring the existing knowledge from various sources and improving the understanding within the team of the complex systems to be managed. The acquired knowledge was translated into a consistent and risk-resistant strategy portfolio. In the final MARISCO phase, the strategy portfolio will be implemented.

In adaptive management, it is important to track the implementation of activities by collecting relevant information and knowledge. The information gathered needs to be assessed and tested for its suitability to adapt the underlying concept in a targeted manner. The unpredictable nature of management within complex systems requires vigilance and there is a need for continued evaluation and adaptation throughout the management period.

The evaluation process ensures that the knowledge management system is fit for purpose and provides the relevant information and knowledge for further (management) tasks.

The aspect of systematic learning and exchange of experience is also important. Sharing knowledge and experience with peers is crucial to ensure continuous improvement and progress towards best practice.

Step 27. Monitoring design

The monitoring plan is the plan for the long-term control of the strategic results. It clearly defines indicators, methods, persons responsible, time frame and place of implementation.

To complete the monitoring plan, answers to the following guiding questions can be added:

- Monitoring method: How is the indicator measured/what method is used?
- Responsible person: Who will carry out the measurement?
- Time: When is the data collected and at what intervals?
- Location: Where is the data collected or the measurement carried out?

The analysis of monitoring data should not be limited to a single event in the work cycle. In order to understand what is happening in the planning area and to change things in time, it is important to integrate the analysis of your monitoring data into routine work. The data management system that you set up in this step can be used for this. This way, what is learned can be used and the effectiveness of the work can be improved by reviewing the parameters and core assumptions, the monitoring plan, the operational plan, the work plan and the budget and adjusting them if necessary.

Step 28. Implementation planning

Implementation plans give people in the responsible organisation a clear picture of their tasks and responsibilities over a period of time. At the beginning, the strategies and activities are translated into practical and concrete tasks. This requires defining the resources needed, such as time, money, labour and others, and the specific responsibilities within the managing unit.

Step 29. Implementation and monitoring of results and impacts

This is a very important step in the MARISCO cycle, as it is where all the planning efforts of the exercise are put into action. The tasks of the work and monitoring plan must be carried out according to the schedules and budgets set in the previous steps. To monitor implementation, one should regularly and systematically assess whether one is on track to achieve the set goals. It may be useful to prepare regular progress reports. This allows for more nuanced reflections as you go along, to fill in gaps in knowledge, to determine whether the expected intermediate results have been achieved and to assess whether you are on track for long-term success. Progress should be reviewed at least annually (preferably more frequently) and progress should be considered in the context of the theory of change detailed in the outcome-impact networks.

Step 30. (Non)knowledge management

The management of knowledge and non-knowledge is a crucial task, as it forms the basis for the development of an institution that is capable of learning and adapting. MARISCO software provides an appropriate infrastructure to store, use, adapt and develop existing knowledge at any time and by all relevant persons.

Knowledge management must also include non-knowledge. This includes, among other things, knowledge gaps and new research questions, assessing the relevance of the unknown or reflecting on blind spots. Proactive knowledge management also integrates the method of *horizon scanning*, i.e. the systematic and active search for and classification of future risks appearing on the 'horizon'.

The starting point for such (non-)knowledge management is the systemic situation model itself and the team's defined assessments of knowledge about the different elements.

Figure 9: MARISCO cycle with specific questions for each phase

2. Knowledge mapping

Within the framework of a series of workshops that build on each other, complex and scattered knowledge from a wide range of actors is transparently collected, structured, evaluated and processed for the development of holistic approaches to solutions[2]. To this end, various questions and topics are systematically dealt with in the workshops.

Step by step, systemic knowledge mapping (knowledge 'maps') is developed together with the participants. These knowledge maps systematically depict existing knowledge and non-knowledge of all participants about ecosystems in the study area, their threats and drivers of the respective changes as well as existing management strategies. The ecosystem is understood as a complex dynamic system, but humans and their well-being as part of the ecosystem are at the centre of the consideration.

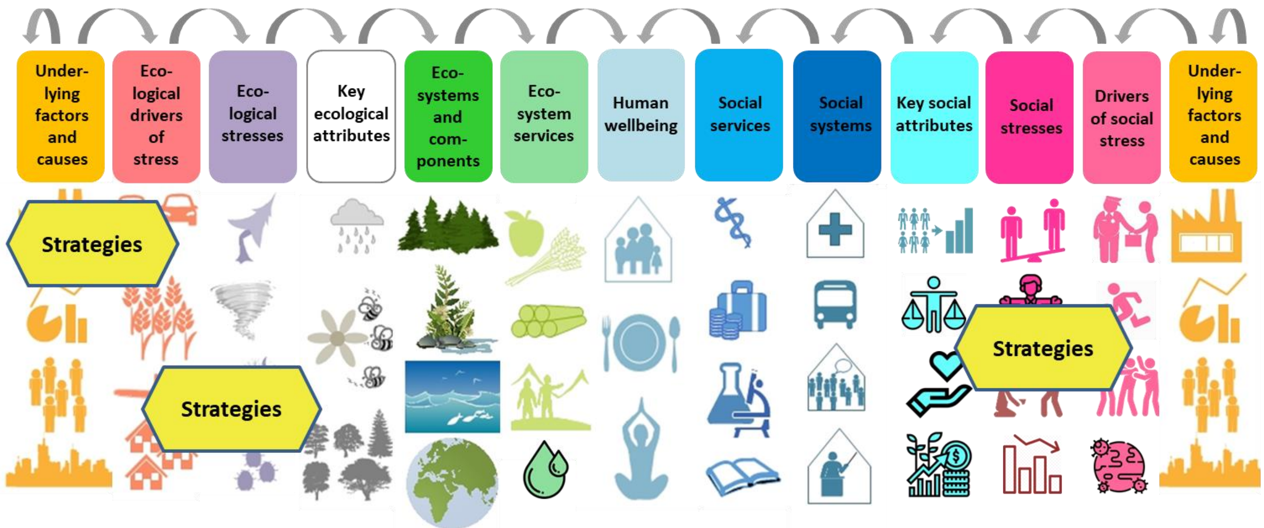

Figure 10: Structure of the knowledge mapping

When creating a knowledge map, the respective occurring ecosystem(s) forms the basis. In the next step, the key ecological attributes of the ecosystems are identified (e.g. rainfall) and the ecosystem services (e.g. drinking water) that are provided for humans are worked out. These ecosystem services contribute directly to human well-being. However, social systems (e.g. schools) also contribute to human well-being through their services (e.g. education) and can then be analysed together. Now the challenges are examined, first recording the stresses occurring in the ecosystems (e.g. drought stress of trees). Then the stress drivers (e.g. prolonged droughts) and causes (e.g. increasing CO_2 emissions) are analysed.

The resulting knowledge maps reflect the knowledge or lack of knowledge and the views and assumptions of the participants and form the basis for developing sustainable solution strategies.

The systematic and systemic way of working using such knowledge maps enables the development of holistic and sustainable approaches to solutions that can leverage at the root causes of the problems that

[2] Schick et al. 2017, 2018, Ibisch & Hobson 2015, Luthardt & Ibisch 2013

arise. This makes a networked mode of action visible which, in contrast to the linear view, does more justice to the complexity of our times.

3. Rating criteria of the elements and strategies

3.1 Rating criteria of social and ecosystem services (steps 4 and 7)

The quantity and quality of all social and ecosystem services that contribute to human well-being should be valued equally.

Table 1: Assessment categories for the current status of social and ecosystem services

Current state of the services			
very good	**good**	**mediocre**	**bad**
The service is available in very good quantity and quality and fully covers the needs of the population in the area of application.	The quantity and quality of the service are within acceptable limits and cover the needs of the population in the area of application for the most part.	The quantity and quality of the service are outside the acceptable range and only partially meet the needs of the population in the area of application.	The quantity and quality of the service are far below the acceptable range and do not meet the needs of the population in the area of application.

3.2 Rating criteria of the key social and environmental attributes (steps 6, 9 and 17)

The stress level of key social and environmental attributes is assessed against several criteria to enable thoughtful and rational prioritisation of system elements for structuring effective management strategies. Three main criteria were used for assessment:

- Strategic Relevance (SR)
- Manageability (M) and
- Knowledge (W)

In this context, criticality is understood as the importance of degraded key attributes/constraints to the state of vulnerability of a target (environmental or social) system. Degraded key attributes/stresses with high criticality values would ideally receive higher attention in the strategy development process.

Assessment of the functionality of the most important social and ecological key attributes

The first step is to determine the acceptable range of variation and a rating scale.

According to the principles of non-equilibrium ecology, all properties vary in a naturally functioning ecosystem. Such natural variations are recognised as part of the fluctuations and dynamics of an ecosystem and are considered to be within an "acceptable range of variation" if their condition is defined as very good or good. Scientists and managers are alerted to a potential threat if the condition does not fall into one of these two categories.

Guiding questions for determining the range of variation are:

- How much change in an indicator is acceptable for a system? How much change is too much?
- How much restoration is sufficient?

In order to determine the rating and thus the status of a key social or environmental attribute, an initial distinction can be made between very good/good and moderate/poor using best-fit data and information. Once a rough distinction has been made, it is somewhat easier to divide the categories into four levels: very good, good, moderate and poor. Although informed decision-making is important at this stage of the process, this should not preclude attempting to categorise when there is very little information on which to base decisions. MARISCO's focus is on continuing adaptive management planning and knowledge mapping even when circumstances are far from perfect - in this case, when there are noticeable gaps in knowledge availability.

With this approach, the process can move forward without stalling or getting lost in the goal of achieving a knowledge-perfect situation analysis.

Once the assessment status for each indicator of a key social or environmental attribute is determined, the next step is to determine the current and projected future status for each of the key attributes. The desired future status of the key social or environmental attribute is the status that is aimed for in the future - i.e. by the end of the planning horizon, when the management vision is expected to have been achieved.

Table 2: Rating criteria for indicators of key social and environmental attributes

Rating criteria for indicators			
Very good = 4	**Good = 3**	**Mediocre = 2**	**Bad = 1**
The indicator is in a desirable state. Only minimal intervention - or no intervention at all - is required to maintain the functionality of the target system.	The indicator is within an acceptable range of variation. Some intervention may be required to maintain the functionality of the target system.	The indicator is outside the acceptable range of variation. The functionality of the target system could be at risk if the situation is not changed. Interventions are required.	The indicator is far outside the acceptable range of variation. The functionality of the target system is seriously endangered. Recovery could be difficult.

Table 3: Example of key ecological attributes, indicators and indicator scores

Target system	Key attribute	Indicator	Indicator				Current state	Desired state
			Very good	Good	Medium	Bad		
Forest eco-system	Wood biomass	Standing and lying deadwood	Significant density of standing and lying, large, dead trunks throughou t the forest	Standing and lying dead logs found in most parts of the forest	Only a few standing and lying dead trunks here and there;	Hardly any or no dead trunks or branches in the forest	Deficient	Good

					hardly any dead branches on the forest floor.			
River ecosystem	Water quality	pH	7.8-7.9	7.0-7.7	5.5--6.9	< 5.5	Good	Very good

3.3 Social or environmental stress analysis (steps 10, 13 and 17)

The use of key attributes to assess the status of target systems is strongly recommended. However, if it is not possible to assess them thoroughly due to time constraints, a higher-level assessment of the system should be made. For this purpose, the assessment criteria of the key attributes should be used directly for the target system.

Table 4: Rating categories for current criticality

Rating categories for current criticality			
Current criticality: Spatial extent (extent of spatial distribution)			
Local occurrence = 1	**Middle area = 2**	**A large part of the area = 3**	**(Almost) omnipresent = 4**
The degraded key attribute / stress is unlikely to be widespread in its spatial extent or is only widespread in a small area (1-10 %).	The degraded key attribute/stress is likely to be widespread in its spatial extent in a fairly limited area (11-30 %).	The degraded key attribute / stress is likely to be widespread in its spatial extent over a large part of the area (31-70%).	The degraded key attribute/stress is likely to be widespread in its spatial extent across all or most of its area (71-100%).
Current criticality: severity (extent of impact)			
Light = 1	**Moderate = 2**	**Heavy = 3**	**Extreme = 4**
Within the spatial extent, the degraded key attribute / stress does not cause a reduction in the overall functionality of the system.	Within the spatial extent, the degraded key attribute / stress could lead to a small reduction in the overall functionality of the system over the next 10 years.	Within the spatial extent, the degraded key attribute / stress is likely to lead to a reduction in the overall functionality of the system within the next 10 years.	Within the spatial extent, the degraded key attribute / stress will most likely lead to a serious reduction in the overall functionality of the system or even its loss within the next 10 years.
Current criticality: irreversibility (probability of permanence)			
Short-term disappearance probable = 1	**Probable medium-term and reversible = 2**	**Probably long-term and difficult to reverse = 3**	**Probably more permanent and irreversible = 4**
It is likely that the degraded key attribute/stress will disappear spontaneously	It is likely that the degraded key attribute / stress will not disappear in the medium term (6	It is likely that the degraded key attribute / stress will persist in the long term (21 to 100	It is very likely that the degraded key attribute/stress will persist in the long term (probably

Rating categories for current criticality			
(without management) in the short term (1 to 5 years), with possibly only slightly reversible consequences for the system.	to 20 years) (without management), but this does not mean long-term and irreversible consequences for the system.	years) (without management), which will also have long-term consequences for the system that are difficult to reverse.	even longer than a century), which also entails long-term consequences for the system that may be irreversible for decades.

To calculate the **total current criticality,** the three sub-criteria *spatial extent, severity* and *irreversibility* must be combined. First, the combination of *spatial extent* and *severity is* calculated as *extent.* Then the combination of *extent* and *irreversibility/permanence is* calculated, resulting in the total current criticality.

Table 5: Matrix for calculating the extent (combination of extent and severity)

Extent				
Spatial expansion (to the right)	**Local occurrence = 1**	**Middle area = 2**	**A large part of the area = 3**	**(Almost) omnipresent = 4**
Severity (bottom)				
Light = 1	1	2	2	3
Moderate = 2	2	2	3	3
Heavy = 3	2	3	3	4
Extreme = 4	3	3	4	4

Table 6: Matrix for calculating the total current criticality (combination of extent and irreversibility)

Total current criticality				
Extent (to the right)	**Low = 1**	**Medium = 2**	**High = 3**	**Very high = 4**
Irreversibility (below)				
Short-term disappearance probable = 1	1	2	2	3
Probable medium-term and reversible = 2	2	2	3	3
Probably long-term and difficult to reverse = 3	2	3	3	4
Probably more permanent and irreversible = 4	3	3	4	4

Table 7: Explanation of the total current criticality

Total current criticality			
Slightly critical = 1	**Moderately critical = 2**	**Critical = 3**	**Very critical = 4**
The degraded key attribute / stress does not play a very important role in determining the overall vulnerability of the target system within the geographical area of analysis.	The degraded key attribute / stress plays a moderately important role in determining the overall vulnerability of the target system within the geographical area of analysis.	The degraded key attribute/stress plays an important role in determining the overall vulnerability of the target system within the geographical area of analysis. It/it is an important driver of negative change in the analysed system.	The degraded key attribute/stress plays an extremely important role in determining the overall vulnerability of the target system within the geographical area of analysis. It/it is an important and persistent driver of negative change in the analysed system.

Table 8: Rating categories for past criticality, trend of change and future criticality

Criticality assessment			
Past criticality (about 20 years ago)			
Lower than current = 1	**Corresponds to the current = 2**	**Higher than current = 3**	**Much higher than current = 4**
The past criticality (20 years ago) of the degraded key attribute / stress is lower than the current one.	The past criticality (20 years ago) of the degraded key attribute / stress is more or less the same as the current one.	The past criticality (20 years ago) of the degraded key attribute / stress is higher than the current one.	The past criticality (20 years ago) of the degraded key attribute / stress was much higher than the current one.
Current trend of change in criticality (change in criticality)			
Decreasing = 1	**Stable = 2**	**Gradually increasing = 3**	**Rapidly increasing = 4**
Currently, the criticality of the degraded key attribute / stress tends to decrease.	Currently, the criticality of the degraded key attribute / stress seems to be quite stable. No change can be seen.	Currently, the criticality of the degraded key attribute / stress tends to increase, but rather gradually and apparently quite predictably.	Currently, the criticality of the degraded key attribute s/ stress tends to increase rapidly and at an accelerated rate (exponentially).
Future criticality (in about 20 years)			
Lower than current = 1	**Corresponds to the current = 2**	**Higher than current = 3**	**Much higher than current = 4**
Future criticality (20 years from now) is expected to be lower than current criticality.	It is assumed that the future criticality (in 20 years) is the same as the current one.	Future criticality (20 years from now) is expected to be higher than current criticality.	The future criticality (20 years from now) is expected to be much higher than the current one.

Table 9: Rating categories for manageability and knowledge

Rating categories for manageability and knowledge			
Manageability			
Very manageable = 1	**Somewhat manageable = 2**	**Insufficiently manageable = 3**	**Not manageable = 4**
The degraded key attribute / stress can be easily and directly managed through strategies and project activities; usually these mainly relate to local elements.	The degraded key attribute / stress can probably be directly managed to some extent through strategies and project activities, especially if more resources are made available than before.	The degraded key attribute/stress is most likely not directly manageable. Instead, it can be influenced in a meta-systemic and indirect way.	The degraded key attribute/stress is not manageable at all; it is highly unlikely that local management would change it directly or indirectly.
Knowledge			
Well known = 1	**Somewhat known = 2**	**Not known, but theoretically possible to find out = 3**	**Not known = 4**
Knowledge of the degraded key attribute/stress is very high; the planning team has a precise idea of the characteristics, importance and dynamics of the element.	Knowledge of the degraded key attribute/stress is adequate; the planning team has a fairly good idea of the characteristics, importance and dynamics of the element. Some knowledge gaps might have been identified.	Knowledge about the degraded key attribute/stress is low; the planning team does not have a good idea of the characteristics, importance and dynamics of the element. Better knowledge may be available, but the team does not currently have it.	It is impossible to gain good knowledge about the degraded key attribute/stress; the planning team can only formulate assumptions about the characteristics, significance and dynamics of the element. Further research would not provide better knowledge. This lack of knowledge is related to the fact that the element is influenced in complex ways by other uncertain elements or that it represents future risks.

Strategic relevance summarises the result of the assessments of *overall current criticality*, *current trend of criticality change* and *future criticality:*

Strategic relevance for stress analysis of key attributes: $SR = K_A + K_T + K_Z$ (Strategic relevance = total current criticality + current trend of criticality change + future criticality)

3.4 Environmental and social stress drivers and their underlying factors and causes (steps 11, 12, 14, 15 and 17)

Ecological and social stress drivers and their underlying factors and causes are assessed against several criteria to enable considered and rational prioritisation of system elements for structuring effective conservation strategies. Four main criteria are used to assess ecological and social stress drivers and their underlying factors and causes:

- Criticality (K)
- Systemic activity (S_A)
- Manageability (M) and
- Knowledge (W)

The strategic relevance (R) is calculated from the criticality and the systemic activity. Strategic relevance can be used as a gauge to measure the importance of the stress driver, underlying factor or cause to the state of vulnerability of a system. Stress drivers, underlying factors or causes with high strategic relevance would ideally receive more attention in the strategy development process.

Table 10: Rating categories for current criticality

Current criticality			
Spatial extent (extent of spatial distribution)			
Local appearance = 1	**Middle area = 2**	**A large part of the area = 3**	**(Almost) omnipresent = 4**
The stress driver is probably very limited in its spatial extent and only affects the system in a small part of the planning area (1-10 %). The underlying factor or cause is likely to be very narrow in its spatial extent, affecting other elements in a small part of the planning area (1-10%).	The stress driver is likely to be fairly limited in its spatial extent, affecting the system in a medium sized part of the planning area (11-30 %). The underlying factor or cause is likely to be fairly limited in its spatial extent, affecting other elements in a medium sized part of the planning area (11-30%).	The stress driver is probably widespread in its spatial extent and affects the system in a large part of the planning area (31-70 %). The underlying factor or cause is likely to be widespread in its spatial extent and to affect other elements in a large part of the planning area (31-70%).	The stress driver is likely to be ubiquitous in its spatial extent, affecting the system in all or most of the planning area (71-100 %). The underlying factor or cause is likely to be widespread in its spatial extent and to affect other elements in all or most of the planning area (71-100 %).
Severity (extent of impact)			
Light = 1	**Moderate = 2**	**Heavy = 3**	**Extreme = 4**
Within the defined scope of application, the stress driver is unlikely to affect or damage the system. The underlying factor or cause is unlikely to have a	Within the defined scope, the stress driver could lead to some impairment and damage to the system over the next 10 years.	Within the defined scope, the stress factor is likely to affect and damage the system within the next 10 years. The underlying factor or cause is likely to have a	Within the defined scope, the stress driver will most likely affect and damage the system and even cause its loss within the next 10 years.

Current criticality			
significant impact on the affected elements.	The underlying factor or cause could have some effect on the influenced elements.	significant impact on the affected elements.	The underlying factor or cause will most likely have a significant impact on the influenced elements and become a driving force that ultimately harms one or more systems (at least within the identified scope).
Irreversibility (probability of permanence)			
Short-term disappearance probable = 1	**Probable medium-term and reversible = 2**	**Probably long-term and difficult to reverse = 3**	**Probably more permanent and irreversible = 4**
It is likely that the stress driver, underlying factor or cause will spontaneously disappear (without management) in the short term (1 to 5 years), which may mean only slightly reversible consequences for the systems.	It is likely that the stress driver, underlying factor or cause will not disappear in the medium term (6 to 20 years) (without management), but this does not mean that the consequences for the systems are long-term and irreversible.	It is likely that the stress driver, underlying factor or cause will persist over the long term (21 to 100 years) (without management), which will also have long-term consequences for the systems that are difficult to reverse.	It is very likely that the stress driver, underlying factor or cause will persist (without management) over the long term (probably even longer than a century), which also entails long-term consequences for the systems that may be irreversible for decades.

To calculate the **total current criticality,** the three sub-criteria *spatial extent, severity* and *irreversibility* must be combined. First, the combination of *spatial extent* and *severity* calculates the *extent.* Then the combination of *extent* and *irreversibility/permanence is* calculated, resulting in the total current criticality.

Table 11: Matrix for calculating the extent (combination of spatial extent and severity)

Extent				
Spatial expansion (to the right)	**Local occurrence = 1**	**Middle area = 2**	**A large part of the area = 3**	**(Almost) omnipresent = 4**
Severity (bottom)				
Light = 1	1	2	2	3
Moderate = 2	2	2	3	3
Heavy = 3	2	3	3	4
Extreme = 4	3	3	4	4

Table 12: Matrix for calculating the total current criticality (combination of extent and irreversibility)

Total current criticality				
Extent (to the right)	**Low = 1**	**Medium = 2**	**High = 3**	**Very high = 4**
Irreversibility (below)				
Short-term disappearance probable = 1	1	2	2	3
Probable medium-term and reversible = 2	2	2	3	3
Probably long-term and difficult to reverse = 3	2	3	3	4
Probably more permanent and irreversible = 4	3	3	4	4

Table 13: Simplified assessment of the overall current criticality

Total current criticality			
Slightly critical = 1	**Moderately critical = 2**	**Critical = 3**	**Very critical = 4**
The stress driver, underlying factor or cause does not play a very important role in generating the vulnerability of the system within the application space of the analysis.	The stress driver, underlying factor or cause plays a moderately important role in generating the vulnerability of the system within the application space of the analysis.	The stress driver, underlying factor or cause plays an important role in generating the vulnerability of the system within the application space of the analysis. It is an important driver of negative changes in the analysed system.	The stress driver, underlying factor or cause plays an extremely important role in generating the vulnerability of the system within the application space of the analysis. It is an important and persistent driver of negative change in the analysed system.

Table 14: Rating categories for the trend of change and future criticality

Rating of the trend of change and future criticality			
Past criticality (about 20 years ago)			
Lower than current = 1	**Corresponds to the current = 2**	**Higher than current = 3**	**Much higher than current = 4**
The past criticality (20 years ago) of the stressor, underlying factor or cause was lower than the current criticality.	The past criticality (20 years ago) of the stressor, underlying factor or cause is more or less the same as the current one.	The past criticality (20 years ago) of the stressor, underlying factor or cause was higher than the current criticality.	The past criticality (20 years ago) of the stress driver, underlying factor or cause was much higher than the current one.

Rating of the trend of change and future criticality			
Current trend of change in criticality (change in criticality)			
Decreasing = 1	**Stable = 2**	**Gradually increasing = 3**	**Rapidly increasing = 4**
Currently, the criticality of the stress driver or underlying factor or cause tends to decrease.	Currently, the criticality of the stress driver or underlying factor or cause seems to be quite stable. No change can be seen.	Currently, the criticality of the stress driver or underlying factor or cause tends to increase, but rather gradually and seemingly quite predictably.	Currently, the criticality of the stress driver or underlying factor or cause tends to increase rapidly and at an accelerated rate (exponentially).
Future criticality (in about 20 years)			
Lower than current = 1	**Corresponds to the current = 2**	**Higher than current = 3**	**Much higher than current= 4**
Future criticality (20 years from now) is expected to be lower than current criticality.	It is assumed that the future criticality (in 20 years) is the same as the current one.	Future criticality (20 years from now) is expected to be higher than current criticality.	Future criticality (20 years from now) is expected to be much higher than current criticality.

Systemic activity

Estimates the degree of influence of a stressor, underlying factor or cause. It is described by the *level of activity* and the *number of elements influenced.*

Table 15: Rating categories for systemic activities

Rating categories for systemic activities			
Level of activity			
Passive = 1	**Inactive = 2**	**Active = 3**	**Very active = 4**
The element is influenced by more elements than it influences itself. (Difference [influencing - influenced] = < 0).	The element is influenced by as many elements as it influences itself. (Difference [influencing - influenced] = 0).	The element is influenced by fewer elements than it influences itself. (Difference [influencing - influenced] = 1-3).	The element influences other elements much more than it is influenced itself. (Difference [influencing - influenced] = >3).
Number of influenced elements			
Low influence = 1	**Moderately influential = 2**	**Very influential = 3**	**Extremely influential = 4**
The element has influence on 1 element.	The element has influence on 2-3 elements.	The element has an influence on 4-5 elements.	The element has influence on >5 elements.

Table 16: Matrix for calculating the total systemic activity

Total systemic activity				
Level of activity (to the right)	**Passive = 1**	**Inactive = 2**	**Active = 3**	**Very active = 4**
Number of influenced elements				
Slightly influential = 1	1	2	2	3
Moderately influential = 2	2	2	3	3
Very influential = 3	2	3	3	4
Extremely influential = 4	3	3	4	4

Strategic relevance summarises the result of the assessments of *overall current criticality*, *future criticality*, *current trend of criticality change*, *future criticality* and *overall systemic activity:*

Strategic relevance for stressors and contributing factors: $R = K_A + K_T + K_Z + S_A$ (Strategic relevance = total current criticality + current trend to change criticality + future criticality + total systemic activity).

Table 17: Rating categories for manageability and knowledge

Rating categories for manageability and knowledge			
Manageability			
Very manageable = 1	**Somewhat manageable = 2**	**Insufficiently manageable = 3**	**Not manageable = 4**
The stress driver, underlying factor or cause is easily and directly manageable through strategies and project activities; usually these relate mainly to local elements.	The stress driver, underlying factor or cause is likely to be directly manageable to some extent through strategies and project activities, especially if more resources are made available than before.	The stress driver, the underlying factor or cause is most likely not directly manageable. Instead, it can be influenced in a meta-systemic and indirect way.	The stress driver, underlying factor or cause is not manageable at all; it is highly unlikely that local management can directly or indirectly effect change.
Knowledge			
Well known = 1	**Somewhat known = 2**	**Not known, but theoretically possible to find out = 3**	**Not known = 4**
Knowledge of the stress driver, underlying factor or cause is very high; the planning team has a precise idea of the characteristics, relevance and	Knowledge of the stress driver, underlying factor or cause is adequate; the planning team has a fairly good idea of the characteristics, relevance and	Knowledge of the stress driver, underlying factor or cause is poor; the planning team does not have a good idea of the characteristics, significance and dynamics of the element. Better knowledge may be	It is not possible to gain good knowledge about the stress driver, underlying factor or cause; the planning team can only make assumptions about the characteristics, relevance and dynamics of the element. Further

dynamics of the element.	dynamics of the element. Some knowledge gaps may have been identified.	available, but the team does not currently have it.	investigation would not yield better insights. This lack of knowledge is related to the fact that the element is influenced in complex ways by other uncertain elements or that it represents future risks.

3.5 Evaluation of the strategies (step 25)

Table 18: Rating categories for feasibility

Feasibility			
Relevant stakeholders			
Very positive = 4	**Positive = 3**	**Neutral = 2**	**Negative = 1**
The relevant stakeholders in this category are very positive about the strategy and strongly support its implementation.	The relevant stakeholders in this category are positive about the strategy and support its implementation.	The relevant stakeholders in this category have a neutral attitude towards the strategy, they do not support its implementation but do not oppose it either.	The relevant stakeholders in this category have a negative attitude towards the strategy and reject its implementation.
Degree of acceptance by the relevant stakeholders			
Very good acceptance = 4	**Good acceptance = 3**	**Rather low acceptance = 2**	**Extremely low acceptance = 1**
The strategy is accepted by (almost) all relevant stakeholders.	The strategy is accepted by a large part of the relevant stakeholders.	The strategy is only supported by a small part of the relevant stakeholders, but not rejected.	The strategy is supported by only a few of the relevant stakeholders and rejected by most.
Supportive legal framework			
Strong binding legal framework = 4	**Non-binding legal framework = 3**	**Weak or missing legal framework = 2**	**Contradictory legal framework = 1**
There are clear, strong and binding legal frameworks that support implementation.	There are non-binding legal framework conditions that support implementation.	Weak or diffuse legal frameworks exist or legal frameworks are lacking.	There tend to be contradictory legal frameworks that could hinder implementation.
Resources needed			
No resource problems = 4	**Some resources available = 3**	**Only limited resources available = 2**	**Not enough resources = 1**
Sufficient financial, human, time and professional resources are available within the managing institution to implement the strategy.	Some resources are available to implement the strategy, at least in part, and it is likely that additional resources can be obtained.	Few limited resources are available for the implementation of the strategy and only very small and rather isolated activities can be carried	The resources of the managing institution are not sufficient to implement the strategy and it is unlikely that

Feasibility			
		out. It will be difficult to obtain additional resources.	additional resources can be obtained.
Plausibility of ownership			
Strong personal responsibility = 4	**Some personal responsibility = 3**	**Only limited personal responsibility = 2**	**No personal responsibility = 1**
The managing institution has developed strong ownership of the strategy and will make significant efforts to maintain it in the long term.	The managing institution has developed some ownership of the strategy and will make some effort to maintain the strategy, at least in part, in the long term.	The managing institution has developed only limited ownership of the strategy and is unlikely to make efforts to sustain the strategy in the long term.	The managing institution has not developed ownership of the strategy and will not make any effort to maintain it in the long term.
Likelihood of benefiting from external factors (especially opportunities)			
Very high = 4	**High = 3**	**Low = 2**	**Very low = 1**
It is very likely that the strategy will be able to take advantage of existing or emerging opportunities such as additional resources or external support.	It is quite likely that the strategy can take advantage of existing or emerging opportunities such as additional resources or external support.	It is not very likely that the strategy will be able to take advantage of existing or emerging opportunities such as additional resources or external support.	It is very unlikely that the strategy will be able to take advantage of existing or emerging opportunities such as additional resources or external support.
Likelihood of damaging risks to the implementation of the strategy			
Unlikely to be affected by risks = 4	**Probably not threatened by risks = 3**	**Probably threatened by risks = 2**	**Extremely threatened by risks = 1**
There is (almost) no likelihood of risks that (could) complicate the implementation of the strategy.	There is a low probability of risks that (could) make the implementation of the strategy somewhat more difficult.	There is a high probability of risks that (could) complicate or even hinder the implementation of the strategy.	There is a high probability of risks that (could) significantly hinder the implementation of the strategy or even render it completely ineffective.
Adaptability to change			
Very adaptable = 4	**Rather adaptable = 3**	**Not adaptable without significant additional resources = 2**	**Poorly adaptable or not adaptable at all = 1**
Adapting the strategy to changing circumstances or unexpected events can be done easily and without additional resources.	Adapting the strategy to changing circumstances or unexpected events can probably be achieved with some additional resources.	Adapting the strategy to changing circumstances or unexpected events could possibly be achieved, but requires significant additional resources.	The strategy is (possibly) not adaptable to changing circumstances or unexpected events.

Table 19: Rating categories for impact

Impact			
Emergence of social, political and institutional conflicts			
Very low risk of conflict arising = 4	**Medium risk of conflict arising = 3**	**High risk of conflict arising = 2**	**Very high risk of conflict arising = 1**
There is no or almost no likelihood that the strategy will lead to conflicts between different stakeholders.	It is possible that some degree of conflict may arise between different interest groups and that these may affect the processing area.	It is likely that there will be relevant conflicts between different stakeholders and that these have the potential to influence the processing area.	It is (almost) certain that there will be relevant conflicts between different interest groups and that these will influence the processing area.
Emergence of negative impacts on the target systems			
No risk of a negative impact on the target systems = 4	**Low risk of causing negative impacts on target systems = 3**	**High risk of causing negative impacts on target systems = 2**	**Very high risk of causing negative impacts on target systems = 1**
There is no risk that the implementation of the strategy will have a negative impact on the target systems in the processing area.	It is not very likely that the implementation of the strategy will have a negative impact on the target systems in the processing area.	There is a high risk that the implementation of the strategy will have a negative impact on at least one target system in the processing area.	There is a very high risk that the implementation of the strategy will have negative impacts on several target systems in the processing area.
Synergy effects with other strategies			
Very high probability of synergy effects with other strategies = 4	**High probability of synergy effects with other strategies = 3**	**Mean probability of synergy effects with some strategies = 2**	**Low probability of synergy effects with other strategies, if any = 1**
The strategy is very likely to develop important synergies with several other strategies.	The strategy will most likely develop important synergies with some other strategies.	The strategy is moderately likely to develop synergies with some other strategies.	The strategy is quite isolated and is unlikely to develop synergies with other strategies.
Conflicts with other strategies			
Low probability of conflict with other strategies, if any = 4	**Mean probability of conflict with other strategies = 3**	**High probability of conflict with other strategies = 2**	**Very high probability of conflicts with many strategies = 1**
The strategy has (almost) no conflicts with other strategies implemented in the processing area.	The strategy conflicts to some extent - but not problematically - with other strategies being implemented in the processing area.	The strategy conflicts with a number of strategies being implemented in the processing area.	The strategy is in strong conflict with a significant number of strategies being implemented in the processing area.
Effectiveness in reducing stress drivers			
Very high effectiveness in reducing stress drivers = 4	**High effectiveness in reducing stress drivers = 3**	**Low effectiveness in reducing stress drivers = 2**	**Very low effectiveness in reducing stress drivers = 1**

The strategy is very effective: it will lead to a significant and sustainable reduction or even elimination of several stress drivers.	The strategy is quite effective: it will lead to a far-reaching reduction of at least one stress driver.	The strategy is not very effective: it will only lead to a minor reduction in a stressor, and possibly only temporarily.	The strategy is (almost) ineffective: it will not even indirectly lead to a reduction in stress drivers.
Direct increase in the functionality of the target system			
Very positive for the functionality of the target system = 4	**Positive for the functionality of the target system = 3**	**A small and rather indirect contribution to the functionality of the target system = 2**	**No measurable improvement in the functionality of the target system = 1**
The strategy will ensure or fully restore the long-term functionality of one or more systems.	The strategy will go a long way towards maintaining or restoring the functionality of one or more systems.	The strategy will make a small contribution to maintaining or restoring the functionality of one or more systems.	The strategy is unlikely to contribute to maintaining or restoring the functionality of any of the systems.
Degree of possible regret			
Strategy without regret = 4	**Strategy with low regret = 3**	**High regret strategy = 2**	**Strategy with very high regret = 1**
The strategy will produce clear positive side effects, even if the originally intended effect is not achieved.	The strategy is likely to produce some positive side effects, even if the originally intended effect is not achieved.	The potential level of regret is high. If the originally intended effect is not achieved, the strategy will not generate (significant) positive side effects. The strategy will also be difficult to reverse and could lead to a waste of resources.	The potential level of regret is very high. If the originally intended effect is not achieved, the strategy will not produce positive side effects. The strategy cannot be reversed in time and would clearly lead to a waste of resources.

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