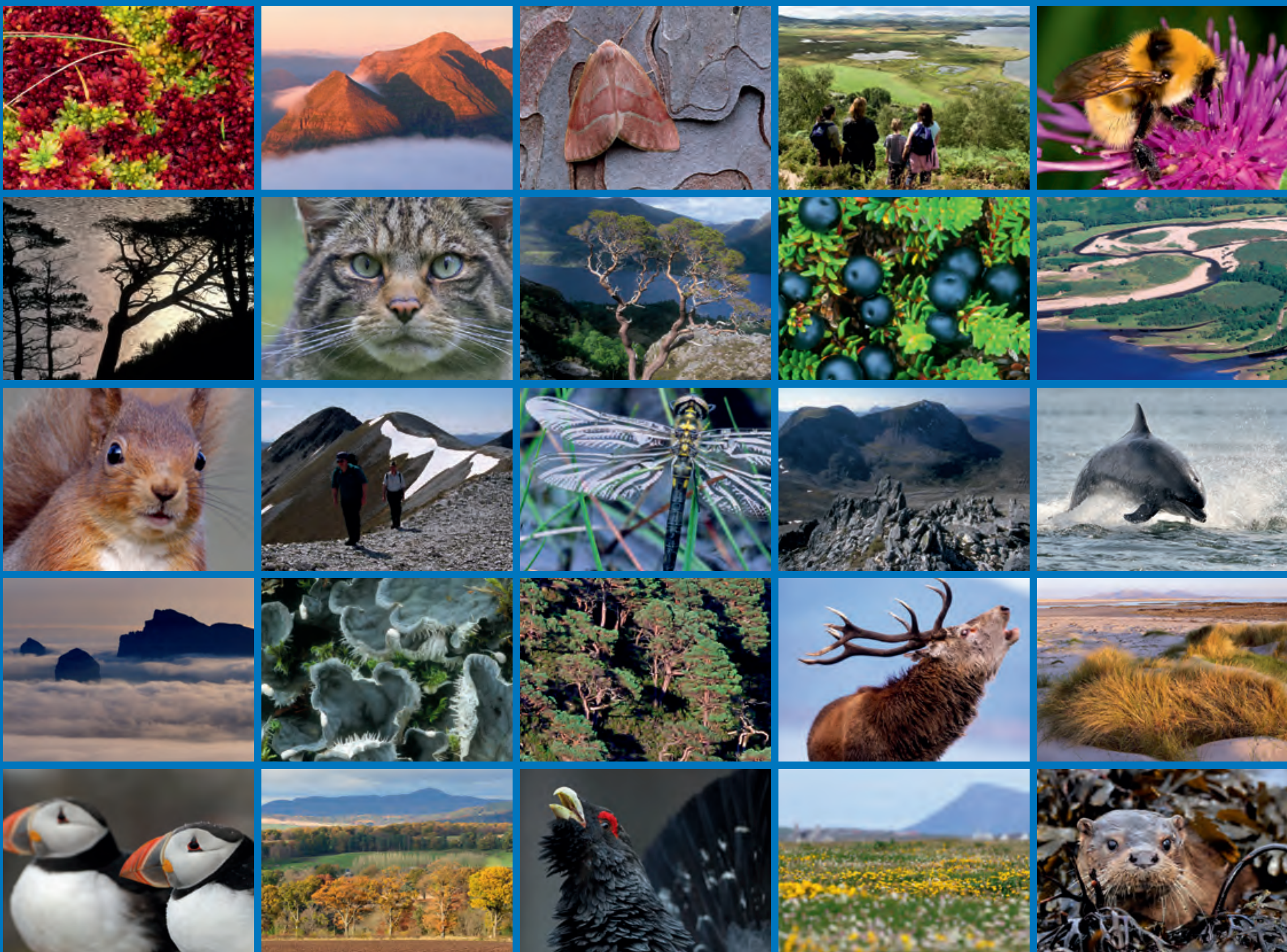
Scottish Natural Heritage
Commissioned Report No. 795

A review of approaches to adaptive management



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COMMISSIONED REPORT

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A review of approaches to adaptive management

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Summary

A review of approaches to adaptive management

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Keywords

Adaptive management; review; guidance.

Background

Adaptive Management (AM) was first developed by fisheries scientists in the 1970s and 1980s and has since been developed for a wide range of terrestrial species (Walters, 2001). AM has been developed as a tool for managing a wide range of cases where management aims to improve the status of an endangered or threatened species to cases where the aim is to limit the impact of an overabundant species.

Definition of adaptive management:
Adaptive management is an iterative process for continually improving management by learning from how current management affects the system. AM is therefore based on monitoring and evaluating past management and devising alternative actions that can be tested against desired objectives.

The aim of this project is to review approaches to adaptive management in order to help shape SNH's conservation management work and, in particular, to inform its developing role in wildlife management and invasive non-native species.

Main findings

- Adaptive management (AM) is a tool to support effective decision making, through learning from system responses to past actions and adapting management strategies accordingly.
- AM provides a framework for managing natural resources. It is based on the principle of an iterative cycle of learning from past experience and adapting actions to environmental change. To achieve an iterative learning cycle, AM explicitly includes the development of management goals, monitoring to evaluate the success of management strategies and iterative modifications of the management actions. AM recognises that knowledge is not complete so allows management to advance with incomplete and therefore uncertain knowledge.
- While the idea is simple and straightforward, the actual implementation of AM has proved challenging. In many cases, uncertainty may lead to undesirable outcomes or inertia because stakeholders fail to agree on appropriate management actions. AM has a huge potential to reduce this uncertainty by learning and applying alternative management strategies.

- AM depends on monitoring to determine if the desired goals are being achieved. Furthermore, AM requires an interaction between people involved, the system and the ecological resource. Bridging the gap between stakeholders with different perspectives and objectives relating to the resource in question can be challenging. A fundamental component of AM is that managers should be willing to try out alternative management actions to reduce uncertainty through experimentation. The main advantages of AM are that it provides a mechanism for decision makers to adapt management to a changing environment and that it takes into account management alternatives and explicitly addresses uncertainties and minimise risks in the system.
- This review brings together the experiences and expertise of many people that have used AM around the world; it serves as a summary of the knowledge available for further discussions about case studies in Scotland.

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Table of Contents **Page**

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1. INTRODUCTION

Adaptive Management (AM) is a framework for managing natural resources and is based on the principle of an iterative cycle of learning from past experience and adapting actions to environmental change. To achieve an iterative learning cycle, AM explicitly includes the development of management goals, monitoring to evaluate the success of management strategies and iterative modifications of the management actions. AM recognises that knowledge is not complete so allows management to advance with incomplete and therefore uncertain knowledge. AM depends on monitoring to determine if the desired goals are being achieved. Furthermore, AM requires an interaction between people involved, the system and the ecological resource. Bridging the gap between stakeholders with different perspectives and objectives relating to the resource in question can be challenging. A fundamental component of AM is that managers should be willing to try out alternative management actions to reduce uncertainty through experimentation. The main advantages of AM are that it provides a mechanism for decision makers to adapt management to a changing environment and that it takes into account management alternatives and explicitly addresses uncertainties and minimise risks in the system. Despite the simplicity of the idea and the fact that the concept has existed for more than two decades, AM is still surprisingly little practiced.

This review focuses on the lessons that can be learned for implementing AM for wildlife management in Scotland. First we review the obstacles and reasons for failure to implement AM. Then, based on this we suggest a framework for deciding whether AM is appropriate for a given case study and finally present a process-orientated flowchart of the steps involved in successful AM.

1.1 Experience from and obstacles to AM for species management

In this first part of the report, we will focus on four main obstacles to AM for species management: uncertainty, monitoring, social-ecological synthesis and experimentation.

1.1.1 Uncertainty

Understanding and dealing with uncertainty is central to effective decision-making in management and conservation of natural resources but has often been ignored or dealt with on an ad hoc basis (Regan et al., 2002). The term itself is very broad and can be vague. If we are to tackle and overcome the obstacle of uncertainty in AM, it is useful to understand and break down the term into different components.

Here we follow the definitions of (Milner-Gulland and Rowcliffe, 2007) who divide uncertainty up into:

- process uncertainty,
- measurement uncertainty,
- structural uncertainty, and
- implementation uncertainty.

Process uncertainty recognises that natural systems are inherently variable. For example, the weather and climate differ from year to year and between areas which may lead to variability in birth and death rates between years. For example, (Johnson et al., 2014) use a mean of 0.951 and standard deviation of 0.019 for the survival of pink-footed geese to calculate a new survival rate for each year in their model (5 year example: 0.97, 0.96, 0.94, 0.95, 1.00). This type of uncertainty is incorporated in field data and can be represented using statistical techniques such as mean values with their standard errors, standard deviations or confidence limits. **Measurement uncertainty** stems from the imprecise measurement itself, for example measuring the weight of an animal or the temperature of a lake but can also arise from estimating parameters (e.g. survival rates of birds) from a range of data (e.g. mark-recapture, GPS tagged individuals). **Structural uncertainty** comes from an incomplete understanding of the system or the situation. For example, one might expect that the increase or decrease in numbers of a certain species or population is linear whereas it is actually following a non-linear (e.g. quadratic or cubic) trend. This would mean that an initial slow increase is misinterpreted as a slow change that can be linearly predicted relatively far into the future, whereas it is actually the beginning of a steep increase in numbers (Di Fonzo et al., 2013). Finally, **implementation uncertainty** is where it is unclear whether the decisions made can actually be translated into action and whether the people involved in this action have understood what is required, have the capacity to implement it, and finally have been provided with the incentives to implement the actions.

We will outline below different tools that can help AM to tackle various uncertainties: measurement uncertainty can be addressed in monitoring, structural uncertainty through experimentation and modelling and implementation uncertainty by collecting social data from the people involved. Process uncertainty, for example because of climatic variability, is the only uncertainty that AM is not able to address.

1.1.2 Monitoring

Monitoring is crucial to reduce uncertainty because it can capture process uncertainty (e.g. changes in weather affecting wildlife) and measurement uncertainty (e.g. repeated monitoring for validation). However, there has recently been an increasing realisation that monitoring for AM can be complex and inadequate (Legg and Nagy, 2006). If done badly, monitoring can misinform managers and waste valuable resources and thus form barriers for an AM approach. Because AM recognises that the resource and species to be managed is affected by and affects people, evidence to support management aims is unlikely to be just ecological and it is necessary to monitor social and economic dynamics.

The first step in monitoring is to consider the aims, the indicators that would measure progress towards the aim, the range of methods available to measure the indicator and the system and the species involved. The aim of monitoring can often be divided into estimating accurate population size and estimating the population trend. If the aim is to measure the trend then it is important that monitoring is precise (repeatability of estimates) but not necessarily accurate (how close is the estimate to the true value); precision often leads to a significant reduction in resources needed compared to carrying out accurate estimates of population size (Nuno et al., 2013a, Nichols and Williams, 2006). Furthermore it is important to ask over what time period can the changes of interest be detected. For example, Bunnefeld et al. (2013) show that for a species with slow life history, such as a large ungulate in Africa, it would take up to ten years to have enough confidence in the estimated trend to set hunting quotas sustainably. Not only the amount of data matters, it is also crucial to collect data that can be linked to the change in the actual population increase or decrease. For example, Katzner et al. (2006) showed that using the proportion of occupied territories was not a good indicator of population change for eagles in Kazakhstan whereas adult survival has a more direct effect on the population trends and is thus a better indicator to monitor.

A key feature of AM is the recognition that management is dealing with a socio-ecological system, so that there are social and economic issues as well as ecological ones that need to be addressed if management is to be effective. Failure to address socio-economic factors is one of the main obstacles for effective AM implementation. Therefore, AM should monitor the social and economic as well as the ecological goals so that management actions can be revised in response to undesirable changes in social and economic indicators. For example, loss of income from a perceived loss of grazing land might affect farmers' willingness to tolerate the increase in goose numbers resulting from goose conservation management, possibly leading to non-cooperation from farmers and a subsequent breakdown in the sustainable management of geese despite understanding the ecology of the system. Social science techniques have been developed that are especially suited to monitor the effect of management actions on local people's wellbeing and livelihoods and thus reduce the uncertainty about whether the AM project is successful and socially sustainable. The main techniques for monitoring the socio-economic impacts are participatory rural appraisal (PRA), questionnaire surveys, and direct observations (Milner-Gulland and Rowcliffe, 2007). PRA involves interviews with key informants in a community and community mapping to get information on land use issues. This method can be used for example when information is needed relatively quickly and the inclusion of local communities can empower them (Cornwall and Pratt, 2011). Questionnaire surveys are often in the form of prepared questions together with open discussions to obtain other information relevant to the particular context in which management is occurring (semi-structured interviews). This technique is useful when more resources are sufficient to gather information from large numbers of people affected by management actions. Direct observations can include prices for agricultural produce over the season or differences between years, payments for ecosystem services received, household income or taxes paid. A direct observation technique called participant observation has been used in AM; participant observation follows a key person in the course of their activities to develop an understanding of motivations, attitudes and barriers to changes (Allan and Curtis, 2005). A combination of direct observations and questionnaire surveys can overcome the problem that attitudes estimated from questionnaires do not always translate into behaviour and activities people are involved in (Heberlein, 2012). For example, a survey carried out in Sweden by the same author showed that 84 people that did not hunt had a negative attitude towards hunting, which makes sense. However, there were 337 people that had a positive attitude towards hunting (e.g. enjoyed eating game meat) but did not hunt either. The analysis showed that attitudes explained less than 10% of the variation in hunting participation.

One outcome of policy goals for wildlife is that people may disagree with new regulations and laws implemented which can lead to non-compliance and illegal behaviour. The AM process is, in principle, a mechanism to reduce this risk by allowing management actions to be revised if changes in social and economic indicators are undesirable. This means that monitoring needs to be planned in advance to detect the changes that may lead to non-compliance and illegal behaviour, particularly in rural areas where it may be hard to enforce wildlife and environmental laws and detect these behaviours. The true extent of illegal activities is hard to quantify due to the cryptic nature of the behaviour (Gavin et al. 2010), but there is a range of methods developed to achieve this. These include law-enforcement records, key informants and self-reporting (Gavin et al. 2010). Recently a range of indirect questioning methods has been developed to elicit the extent of illegal behaviour and their incentives while protecting their anonymity (St John et al., 2010, St John et al., 2012, Cross et al., 2013). The idea behind these methods is that people are more likely to give honest answers when their anonymity is protected (Lensvelt-Mulders et al., 2005) which has been tested in, for example, health insurance fraud (Bockenholt and van der Heijden, 2007). Nuno et al. (2013b) have used an indirect questioning technique in villages on the border with the Serengeti National Park in Tanzania to assess the proportion of people involved in illegal behaviour and their educational and economic circumstances; people with higher education and a full time job are more likely to hunt bushmeat because they are able to pay the fees if they are caught.

In summary, monitoring ecological and socio-economic aspects can reduce uncertainty of knowing whether AM programmes will succeed but it is crucial to go through a process of identifying the aims and objectives of management and the indicators to be monitored that inform the success of management.

1.1.3 Social-ecological synthesis and conservation conflicts

Social-ecological synthesis as a conceptual framework is a fundamental concept in AM because virtually all management and conservation challenges involve people as well as the resources or species being managed (Keith et al., 2011). AM is often applied in case studies that face trade-offs between different land management types (for example agriculture vs. wetlands) and there is only one outcome and winner in such a situation. Most often these conflicts arise when stakeholders have opposite views representing for example, farmers or conservationists. One key challenge is that consensus and cooperation in many of these situations is often not possible (Colyvan et al., 2011, Redpath et al., 2013). To agree on a management plan and implement it, it is crucial that all key stakeholders are included in the AM process to work towards minimising conflicts and the socio-economic impacts need to be recognised and possibly compensated for. AM can be used as an approach to help find a way through intractable conflict by bringing stakeholders together to examine the evidence and co-develop their knowledge which will help in reducing conflicts.

An inclusive approach should aim to test different management approaches to provide evidence of what works and of the nature and size of the trade-offs that are inherent if the conflict only has one winner.

1.1.4 Barriers to experiments

AM is all about learning from system responses to past actions and updating management strategies accordingly. The ideal way to disentangle many confounding factors such as variation in weather differences between years and the effect of management is to test alternative strategies against each other in an experimental set up with replication. However, the time and resources required and the spatial area needed to conduct an experiment often make them unfeasible for providing timely evidence to inform new management directions. Furthermore, institutional barriers can play a role where the context requires multiple stakeholders to agree on an experimental procedure across an area characterised by multiple ownership, (Keith et al., 2011). The use of appropriate knowledge in AM is a fundamental principle and in some cases, experts, such as scientists have demonstrated the capacity and knowledge to analyse complex data sets which has been accepted by stakeholders leading to successful AM implementation. For example, in the case of duck harvesting in the US and goose management in Norway, scientists have been crucial in analysing the data obtained from experiments. Importantly, in both these cases stakeholders accepted these data as a knowledge base for the decision-making process (Tombre et al., 2013, Nichols et al., 2007) and this may not always be the case in other situations.

2. WHERE IS AM APPROPRIATE, FEASIBLE, SUCCESSFUL?

2.1 Appropriate

AM is used as a framework for decision-making in complex systems that are affected by uncertainty. AM is therefore a process of understanding and reducing some of the sources of uncertainty. In virtually all cases where population abundance is estimated, uncertainty remains but it is important to understand and tackle this uncertainty. An example where AM can be most effective in reducing uncertainty is when estimating population abundance. For example, catch per unit effort (CPUE) has been useful in estimating trends of population sizes in fishing, bag and shooting data (Williams et al., 2002) . AM can be helpful by removing different proportions as part of an experiment which can be used to calculate CPUE.

Although some scientists (Rist *et al*., 2013) restrict the appropriateness of adaptive management to ecological uncertainty, most studies now show that uncertainty surrounding people is equally difficult to assess. Reducing uncertainty about how people behave in the system and whether they follow new rules and regulations can be crucial to planning AM, especially when behaviour is socially accepted but illegal. For example, in a study on farmers killing carnivores in South Africa, St John et al. (2012) used an indirect questioning technique and showed that farmers believing their peers are involved in killing protected carnivores, increased their likelihood to be involved in carnivore killing. AM can help to reduce the uncertainty of illegal behaviour by building understanding of the motivations of people's behavior in order to design more appropriate interventions that should have a higher likelihood of success.

While AM is able to address a range of uncertainties as outlined above, some remain outside the appropriateness of AM. For example, process uncertainty due to climate change and variation in weather from year to year resulting in changes in fecundity or survival is impossible to reduce through AM because it is affected by many external drivers that cannot be controlled in the system to be managed and often involve delayed feedbacks.

Thus for AM to be appropriate, it is necessary to address the social and ecological obstacles and uncertainties and this can be achieved through further studies and experiments. Experiments can be carried in natural systems by applying different management regimes to different areas. For example, AM of US waterfowl applies one of three different hunting regulations (liberal, moderate or conservative based on daily bag limits and hunting season) to each of the four US waterfowl flyways (Nichols et al., 2007). Therefore, in some situations, the resources available for managing wildlife may be most usefully directed towards the collection of social and economic information rather than focusing on collecting more knowledge on the ecological aspects of the resource to be managed.

2.2 Feasible

The next question is whether the AM approach is feasible, which has two parts, resources and management flexibility. Before embracing an AM approach, clarification is required as to whether enough resources (funding and personnel) are available to carry out AM. This should include planning for testing alternative strategies (carrying out experiments) and monitoring the outcome of these.

Management flexibility is a more complex topic but equally important. Institutional fragmentation, lack of leadership or conflicts within or between stakeholders can lead to a breakdown of decision-making processes and finally of the feasibility of the AM approach. Furthermore, goals and objectives of stakeholders might be set in stone and be rigid rather than flexible and adaptive. Therefore, developing a more flexible approach is a prerequisite if stakeholders are to take an adaptive approach to the issue at hand and to each other if they are to utilize the new insights gained from monitoring alternative management strategies and to develop new actions (Redpath et al., 2013). Multicriteria decision analysis can be used to establish a common ground and the nature of the differences, which can contribute to more flexible approaches in adaptive management, especially where conflicts between stakeholders create a barrier. Davies et al. (2013) used four case studies to explore the approach and showcase its general applicability: tourism and commercial and subsistence use of protected areas in Tobago, conservation and management of Ruaha National Park in Tanzania, forest managers and reindeer herders in Finnish Lapland and moorland management and hen harriers in Scotland.

2.3 Successful

The first step when asking whether AM was a success is to check whether the main prerequisites of appropriateness and feasibility were complied with. Without these, AM approaches are doomed to be unsuccessful. If AM is appropriate and feasible, the next step should be to set up measurable indicators appropriate to the goals that can be monitored given the limited funds available. The first criterion for success should be that uncertainty is reduced and it is important that this applies both to the ecological and socio-economic uncertainty. It is important to understand whether there is reduced uncertainty in the knowledge on how the ecosystem responds to the management actions and reduced uncertainty as to how people's socio-economics, livelihoods and wellbeing are affected by management strategies. The steps described here can be found in Annex 1 as outline guidance on how to carry out AM.

3. HOW TO DO IT

The most important message from the literature on successes and failures is that AM is a process rather than a strict or prescriptive guideline. AM can be summarised by 4 main phases: i) setting clear management objectives, ii) testing alternative solutions iii) monitoring and iv) structured decision-making. First, overall *objectives* and targets for tackling the challenge or conflict need to be agreed. The system and context should be evaluated: the issues and challenges need to be identified and relevant knowledge and data should be collated. At this stage, potential synergies (win-win) between different stakeholder objectives, trade-offs and conflicts with potential lose-lose outcomes should be assessed. Second, for AM to work, actions and their *alternative actions and solutions* have to be chosen. A conceptual model is needed at this stage to clearly predict the response of the system to the different management actions based on stakeholder experience and knowledge and if possible a mathematical model is created to test these predictions quantitatively. The action plan and its uncertainties are decided and discussed at this stage and should consider all parts of the system so that the social, economic and ecological components are taken into account to avoid the pitfall of AM failure because the plan only addresses ecological or economic factors in isolation. The third phase – *monitoring* - requires clear indicators of social, economic, ecological and biodiversity change. A conceptual model or mathematical model should investigate the most cost-efficient methods to achieve effectiveness. Often it is only necessary to know the trend, which requires precision (repeatability) rather than an accurate estimate of the population size. Knowing the uncertainty together with the estimates will then feed back into the assessment part of the AM approach. A *structured decision-making* process uses the knowledge gained from experimentation and monitoring to evaluate the outcomes against the objectives. Structured decision-making provides a tool to adapt objectives and alternative management plans and solutions.

3.1 Tools

The following section presents a range of tools that can help to explore alternative management scenarios. Please also see Annex 1 for guidance on how the tools fit with the AM cycle and Annex 2 for an AM workshop report with SNH staff.

3.1.1 Game theory

Decision-making for conservation and management of natural resources is often on a continuum between conflict and cooperation and game theory can be helpful to move between the two extremes. In game theory the outcome of a conflict situation can be a win or lose for the parties involved, which is called zero sum because if one party gains the other loses. However, there are also possibilities of win-win situations or lose-lose situations, which are non-zero sum outcomes. The contribution of game theory is to make stakeholders aware that there are opportunities to get away from a win-lose situation and to move towards alternative outcomes where both parties may gain or compromise on their goals to achieve a more robust, conflict-free outcome (Redpath et al., 2013).

3.1.2 *Multi criteria decision analysis*

Multi-criteria decision analysis is a decision support tool that decomposes complex systems into smaller units and takes into account that most natural systems are social-ecological systems and thus are bound to have multiple, often competing, objectives (Davies et al., 2013). The core idea is that multiple criteria for success are defined, weighted and ranked and that management options are scored against these criteria. This process allows combining scores and ranks into a value, which can be used to discuss management actions, outcomes and criteria for success among stakeholders. This can reduce conflicts between stakeholders by linking action, outcomes and objectives and thus showing the trade-offs between different objectives.

3.1.3 *Expected value of perfect information*

AM is ideally suited to address and take into account various uncertainties. But knowing that resources are limited, which uncertainty should be tackled first is an important question. The theory of Expected Value of Perfect Information addresses the challenge of prioritising among a range of factors contributing to uncertainty (Runge et al., 2011). EVPI is the difference between the expected value of an optimal action after the new information is available and the expected value of an optimal action before the information is available. This can be measured in monetary terms or as utility (social services, cultural values etc.) and thus is flexible enough to be used in different circumstances and different aims of management and conservation. For example, Runge et al. (2011) used EVPI for the management of whooping cranes (*Grus americana*) to decide whether habitat restoration, minimizing human disturbance or killing parasites (black flies) would be the best action under monitoring and parameter uncertainty. Habitat restoration came out as the best option as it had a direct positive effect on reproductive success in whooping cranes which monitoring showed was non-existent in previous years. Reducing the uncertainty to zero according to the EVPI would increase performance by 20% measured as the reproductive success of the cranes.

3.1.4 *Management strategy evaluation*

One successful approach to bring together social and ecological dynamics and to reduce uncertainty is the management strategy evaluation (MSE) framework which was developed first for fisheries and has since become the dominant approach within the field (Butterworth and Punt, 1999). Management Strategy Evaluation (MSE) creates models wherein a range of alternative management scenarios can be developed based on the dynamics of the natural world and the social relationships of stakeholders. MSE is then able to predict the effect of multiple scenarios and management actions on the social-ecological system, which can be compared to targets. MSE models the whole system including the dynamics of the social-ecological system, the monitoring process, the assessment and decision making process, and the stakeholders implementing the decisions. This allows for evaluating multiple targets, which can also involve trade-offs. Thus, MSE can elicit trade-offs and non-consensus outcomes of conflicts by using scenarios rather than single solutions to target-setting and environmental management. In fisheries, the application of the MSE framework has, in many cases, led to a better commitment to the agreed procedure by all stakeholders because of its transparency and ability to demonstrate the effects of assumptions about all components of a management system (Smith et al., 2008). Recently the framework has been extended to include more realistic trade-offs between socio-economic and ecological sustainability through explicitly modeling resource-user decision-making (Bunnefeld et al., 2011, Little et al., 2009). This has now been tested for trophy hunting of a large ungulate, the mountain nyala in Ethiopia, and of lions across Africa (Bunnefeld et al., 2013, Edwards et al., 2014). The most impressive real world success of the MSE approach is that it has helped to cut down from several weeks to less than two days the time needed to negotiate between fishermen, conservationists and the tourist industry to decide on the resource use around the Great Barrier Reef in Australia (Smith et al., 2008)

In the case of trophy hunting (mountain nyala and lions) there are two conflicting objectives. First, there is the objective to stop the population decline and ensure the recovery of the species; lions have seen a steady population decline in the last 10 years and for the mountain nyala we know from a monitoring study carried out in 2011 that there are only 3000-4000 individuals left. The second objective is to increase the revenue brought in from hunting to pay for conservation actions (monitoring, habitat protection from agriculture and deforestation, anti-poaching). The MSE approach can be used to find strategies that allow increasing the quota for hunting when population numbers are increasing (e.g. due to protection of land from encroachment and poaching). Thus, the initially competing objectives of population recovery and increasing income from hunting can be linked through carefully setting quotas. While this task seems straight forward, it becomes more difficult when considering uncertainty. Both studies are among the first to acknowledge that there are major uncertainties around the estimates of the population abundance. In the case of lions, many hunting areas lack any long-term population abundance data but sometimes data on off-takes exist (Packer et al., 2011). Scientific monitoring of mountain nyala is now carried out regularly in the Bale Mountains National Park in Ethiopia but most hunting areas are only visited for an inspection every two years (Kinahan and Bunnefeld, 2012). The two studies are among the first to recognise that uncertainty is high in these case studies and that this needs to be taken into account and tackled when making decisions. In both case studies, the accurate population size of lions and nyala is unknown and indirect measurements are instead used to determine the trend of the population. Indirect measurements are the catch per unit effort, i.e. the searching time it takes to find and shoot a lion as a measure of relative change in abundance from one year to the next. An index of the relative change in the number counted has been used in the model; this monitoring programme has been proven more cost effective and feasible than a full monitoring programme to determine the exact population size of nyala or lions. Running simulations of the model under various degrees of monitoring budget and uncertainty reveal minimum investment to make informed decisions. A further important precautionary principle in the model was that only small changes in the quota are allowed from one year to the next in order not to overexploit the population. The best rate of quota change (e.g. 10%, 20%, etc.) can be determined through a simulation approach in the MSE framework. In conclusion, the MSE approach is able to suggest strategies that can balance competing objectives when uncertainty is high.

3.1.5 Hard vs. soft targets

In the conservation and management literature, there has been a call for hard targets, where the aim is to achieve a quantifiable change in the system. Conservationists often favour hard targets because success can be measured after a certain time frame. For example, for the Russian/European barnacle goose the reduction of the population should have a target to be able to assess the success of the action aimed at reducing the population size (Williams and Madsen, 2013). An example of a soft target would be the aim of reducing the population size of a conflict species without risking extinction to alleviate the pressure on landowners because this would allow further negotiations between stakeholders. In fact, in the case of Svalbard pink-footed geese the Norwegian government has set no upper target for the population size but rather have set upper targets for the damage these species cause (Williams and Madsen, 2013). In the same study, farmers raised the issue that it is even unrealistic to reduce the population size but it might be a better target to control the growth. Thus soft targets allow measuring some form of reduction in socio-economic pressure without jeopardizing the conservation status of a species. The approach of setting hard targets has been criticised because they are often unrealistic and unachievable, inflexible and override stakeholder judgement and it is almost impossible to include the complexity of social-ecological systems when setting hard targets (Carwardine et al., 2009).

3.2 Two case studies

3.2.1 Case study 1 – Adaptive Harvest Management of duck hunting in the United States

In 1995, the US Fish and Wildlife Service started to use an adaptive management approach for ducks. The AM framework consists of formulating objectives, carrying out alternative management actions, predictive modelling and a monitoring programme. The objectives are formulated as objective functions and formal statements that can be translated into a mathematical function. For example the objective of the duck hunting is to maximise long term cumulative harvest penalized for when population size falls below a minimum set by the management plan. Each year different areas in the US receive one of the three alternative harvesting regimes (liberal, moderate, conservative) limiting the number of hunter days and season length. A range of four predictive models is used each year to predict the population size of ducks. The models reflect variation in density-dependent reproductive rates and levels of hunting intensity interacting with natural mortality (additive vs. compensatory). Each year monitoring is carried out by governmental and private partners. A review after 12 years of using AM for ducks showed that two factors have been crucial for the success: (1) an iterative learning approach where all elements are annually reviewed and updated and (2) a close collaboration between stakeholders and scientists (Nichols et al., 2007). Hunter satisfaction and social science approaches have been discussed and suggested as a way forward to set objectives but have so far not been implemented.

3.2.2 Case study 2 – Adaptive management of pink footed geese in Norway

Russian/European barnacle geese and Svalbard pink-footed geese numbers have doubled or tripled over the last few decades. Along the flyway, many European countries share the increase in goose numbers and the different staging areas are affected to a varying extent. Countries affected by rising geese numbers include the UK, Belgium, The Netherlands, Denmark and Norway. A recent paper by Tombre et al. (2013) outlines the process of using AM to manage the two goose populations as a response to the increasing numbers but also the spatial expansion of the geese. The AM project involves three main groups of stakeholders: conservationists (Birdlife Norway, Directorate for Nature Management), stakeholders with agricultural interests (Farmer's Union) and hunters (Norwegian Association of Hunters and Anglers). At the start of the AM project, stakeholder incentives, objectives and roles were identified, which lead to a clear understanding of the conflict between different stakeholders. A range of tools was put in place to make decisions on the different potential actions: compensation, hunting and scaring. A species distribution model was developed to predict the goose distribution in time and space and to form a basis for compensation payments. An optimal hunting model to reduce population size was developed for the autumn season. Since geese were feeding on private land, famers and landowners were directly involved in the management and data gathering. Farmers were actively participating in the experiments to estimate the success of scaring schemes and devices, which were then fed into the goose distribution model. Scientists provided knowledge on the population estimates and grazing intensity; all stakeholders accepted this knowledge as a solid base for negotiations and decisions. To resolve the conflict between the different stakeholders, a compensation scheme, hunting quotas and a scaring scheme was initiated. Targets and action plans were developed for all three schemes and all stakeholders agreed that conflicts could only be mitigated by reducing the population size as well as using compensation payments and scaring. By using an AM approach, objectives, targets and action plans are reviewed every year and decisions are based on the latest information from monitoring and are flexible to change. The study finds that these are important aspects in a successful AM.

4. REFERENCES

Allan, C. & Curtis, A. 2005. Nipped in the bud: Why regional scale adaptive management is not blooming. *Environmental Management,* 36**,** 414-425.

Bockenholt, U. & Van der Heijden, P. G. M. 2007. Item randomized-response models for measuring noncompliance: Risk-return perceptions, social influences, and self-protective responses. *Psychometrika,* 72**,** 245-262.

Bunnefeld, N., Edwards, C. T. T., Atickem, A., Hailu, F. & Milner-Gulland, E. J. 2013. Incentivizing Monitoring and Compliance in Trophy Hunting. *Conservation Biology,* 27**,** 1344-1354.

Bunnefeld, N., Hoshino, E. & Milner-Gulland, E. J. 2011. Management strategy evaluation: A powerful tool for conservation? *Trends in Ecology & Evolution,* 26**,** 441-447.

Butterworth, D. S. & Punt, A. E. 1999. Experiences in the evaluation and implementation of management procedures. *Ices Journal of Marine Science,* 56**,** 985-998.

Carwardine, J., Klein, C. J., Wilson, K. A., Pressey, R. L. & Possingham, H. P. 2009. Hitting the target and missing the point: target-based conservation planning in context. *Conservation Letters,* 2**,** 3-10.

Colyvan, M., Justus, J. & Regan, H. M. 2011. The conservation game. *Biological Conservation,* 144**,** 1246-1253.

Cornwall, A. & Pratt, G. 2011. The use and abuse of participatory rural appraisal: reflections from practice. *Agriculture and Human Values,* 28**,** 263-272.

Cross, P., St John, F. A. V., Khan, S. & Petroczi, A. 2013. Innovative Techniques for Estimating Illegal Activities in a Human-Wildlife-Management Conflict. *Plos One,* 8.

Davies, A. L., Bryce, R. & Redpath, S. M. 2013. Use of Multicriteria Decision Analysis to Address Conservation Conflicts. *Conservation Biology,* 27**,** 936-944.

Di Fonzo, M., Collen, B. & Mace, G. M. 2013. A new method for identifying rapid decline dynamics in wild vertebrate populations. *Ecology and Evolution,* 3**,** 2378-2391.

Edwards, C. T., Bunnefeld, N., Balme, G. A. & Milner-Gulland, E. J. 2014. Data-poor management of African lion hunting using a relative index of abundance. *Proc Natl Acad Sci U S A,* 111**,** 539-43.

Heberlein, T. A. 2012. Navigating Environmental Attitudes. *Conservation Biology,* 26**,** 583-585.

Johnson, F. A., Jensen, G. H., Madsen, J. & Williams, B. K. 2014. Uncertainty, robustness, and the value of information in managing an expanding Arctic goose population. *Ecological Modelling,* 273**,** 186-199.

Katzner, T. E., Bragin, E. A. & Milner-Gulland, E. J. 2006. Modelling populations of long-lived birds of prey for conservation: A study of imperial eagles (*Aquila heliaca*) in Kazakhstan. *Biological Conservation,* 132**,** 322-335.

Keith, D. A., Martin, T. G., Mcdonald-Madden, E. & Walters, C. 2011. Uncertainty and adaptive management for biodiversity conservation. *Biological Conservation,* 144**,** 1175-1178.

Kinahan, A. A. & Bunnefeld, N. 2012. Effectiveness and cost efficiency of monitoring mountain nyala in Bale Mountains National Park, Ethiopia. *Endangered Species Research,* 18**,** 105-114.

Legg, C. J. & Nagy, L. 2006. Why most conservation monitoring is, but need not be, a waste of time. *Journal of Environmental Management,* 78**,** 194-199.

Lensvelt-Mulders, G. J. L. M., Hox, J. J., Van der Heuden, P. G. M. & Maas, C. J. M. 2005. Meta-analysis of randomized response research thirty-five years of validation. *Sociological Methods & Research,* 33**,** 319-348.

Little, L. R., Punt, A. E., Mapstone, B. D., Begg, G. A., Goldman, B. & Williams, A. J. 2009. An agent-based model for simulating trading of multi-species fisheries quota. *Ecological Modelling,* 220**,** 3404-3412.

Milner-Gulland, E. J. & Rowcliffe, J. M. 2007. *Conservation and sustainable use: a handbook of techniques,* Oxford, Oxford University Press.

Nichols, J. D., Runge, M. C., Johnson, F. A. & Williams, B. K. 2007. Adaptive harvest management of North American waterfowl populations: a brief history and future prospects. *Journal of Ornithology,* 148, S343-S349.

Nichols, J. D. & Williams, B. K. 2006. Monitoring for conservation. *Trends in Ecology & Evolution,* 21**,** 668-673.

Nuno, A., Bunnefeld, N. & Milner-Gulland, E. J. 2013a. Matching observations and reality: using simulation models to improve monitoring under uncertainty in the Serengeti. *Journal of Applied Ecology,* 50**,** 488-498.

Nuno, A., Bunnefeld, N., Naiman, L. C. & Milner-Gulland, E. J. 2013b. A Novel Approach to Assessing the Prevalence and Drivers of Illegal Bushmeat Hunting in the Serengeti. *Conservation Biology,* 27**,** 1355-1365.

Packer, C., Brink, H., Kissui, B. M., Maliti, H., Kushnir, H. & Caro, T. 2011. Effects of Trophy Hunting on Lion and Leopard Populations in Tanzania. *Conservation Biology,* 25**,** 142-153.

Redpath, S. M., Young, J., Evely, A., Adams, W. M., Sutherland, W. J., Whitehouse, A., Amar, A., Lambert, R. A., Linnell, J. D. C., Watt, A. & Gutierrez, R. J. 2013. Understanding and managing conservation conflicts. *Trends in Ecology & Evolution,* 28**,** 100-109.

Regan, H. M., Colyvan, M. & Burgman, M. A. 2002. A taxonomy and treatment of uncertainty for ecology and conservation biology. *Ecological Applications,* 12**,** 618-628.

Rist, L., Campbell, B. M. & Frost, P. 2013. Adaptive management: where are we now? *Environmental Conservation,* 40**,** 5-18.

Runge, M. C., Converse, S. J. & Lyons, J. E. 2011. Which uncertainty? Using expert elicitation and expected value of information to design an adaptive program. *Biological Conservation,* 144**,** 1214-1223.

Smith, A. D. M., Smith, D. C., Tuck, G. N., Klaer, N., Punt, A. E., Knuckey, I., Prince, J., Morison, A., Kloser, R., Haddon, M., Wayte, S., Day, J., Fay, G., Pribac, F., Fuller, M., Taylor, B. & Little, L. R. 2008. Experience in implementing harvest strategies in Australia's south-eastern fisheries. *Fisheries Research,* 94**,** 373-379.

St John, F. A. V., Edwards-Jones, G. & Jones, J. P. G. 2010. Conservation and human behaviour: lessons from social psychology. *Wildlife Research,* 37**,** 658-667.

St John, F. A. V., Keane, A. M., Edwards-Jones, G., Jones, L., Yarnell, R. W. & Jones, J. P. G. 2012. Identifying indicators of illegal behaviour: carnivore killing in human-managed landscapes. *Proceedings of the Royal Society B-Biological Sciences,* 279**,** 804-812.

Tombre, I. M., Eythorsson, E. & Madsen, J. 2013. Stakeholder involvement in adaptive goose management: case studies and experiences from Norway. *Ornis Norvegica,* 36**,** 17-24.

Walters, C. J. 2001. *Adaptive management of renewable resources,* Caldwell, N.J., Blackburn Press.

Williams, B. K., Nichols, J. D. & Conroy, M. J. 2002. *Analysis and management of animal populations: modeling, estimation, and decision making,* San Diego, Academic Press.

Williams, J. H. & Madsen, J. 2013. Stakeholder Perspectives and Values when Setting Waterbird Population Targets: Implications for Flyway Management Planning in a European Context. *Plos One,* 8.

ANNEX 1: ADAPTIVE MANAGEMENT APPROACHES – THE AUTHORS' SUGGESTED OUTLINE GUIDANCE

Synopsis

Adaptive management (AM) is a tool to support effective decision making, through learning from system responses to past actions and adapting management strategies accordingly. While the idea is simple and straightforward, the actual implementation of AM has proved challenging. In many cases, uncertainty may lead to undesirable outcomes or inertia because stakeholders fail to agree on appropriate management actions. AM has a huge potential to reduce this uncertainty by learning and applying alternative management strategies.

These guidelines are designed to help identify when AM is appropriate, feasible and successful and the tools that are relevant to carry out and implement AM. These guidelines links closely with "A review of approaches for adaptive management" and more detail and explanation on each of the bullet points can be found in the review document (Bunnefeld, N., Redpath, S., & Irvine, J., 2014).

1. <u>Evaluation (Figure 1)</u>

1.1. When is AM appropriate?

AM is used as a framework for decision making in complex systems that are affected by uncertainty. AM is a process of understanding and reducing some of the sources of uncertainty. Before an AM project is started, it is crucial to ask whether AM is appropriate. It can be used:

- When uncertainty in the ecological or socio-economic system prevails and can be tackled through monitoring and experimentation
- NOT when the uncertainty is unaffected by an experiment or a project's management activities, e.g. where the key source of uncertainty is climate change uncertainty

1.2. When is AM feasible?

Before embracing an AM approach, clarification is required as to whether AM is feasible and especially whether enough resources are available and whether management flexibility exists to carry out AM

- Are appropriate resources and funding available?
- Are alternative management actions suggested and possible for different areas to learn in a few years about system responses to different actions? Are ecological experiments considered, developed and funded to tease apart different factors affecting the system?
- Is a monitoring programme developed and funded to be able to learn and adapt over the years? This involves setting up measurable indicators appropriate to the goals that can be monitored given the limited funds available.
- Is the project management system flexible enough to adapt?
    - Can institutional fragmentation between different departments or areas of expertise be overcome to enable/allow adaptation?
    - Is leadership and ownership of who makes decisions and carries out AM actions clearly set out?
    - Are goals and objectives formulated in a way that they are flexible to adapt?

1.3. *When is AM successful?*

Assuming the prerequisites of appropriateness and feasibility are met, the first criteria for success should be that ecological and socio-economic uncertainty is reduced. Is there less uncertainty in:

- Ecological uncertainty; the knowledge of how the ecosystem responds to the management actions and
- Socio-economic uncertainty; people's socio-economics, livelihoods and wellbeing are affected by management strategies.

2. <u>The tools to carry out AM (Figure 1)</u>

2.1. *Setting clear objectives together with stakeholders*

Overall objectives and targets for tackling the challenge need to be agreed. The system and context should be evaluated: the issues and challenges need to be identified and relevant knowledge and data should be collated

- What is the existing knowledge about the system?
  - What ecological (e.g. reproductive rates, harvest rates, catch per unit effort etc) data is available?
  - What social data is available (who hunts, what is the social impact of the animals) what is the economic data available (cost of hunting, cost of damage etc)?
- Where is the uncertainty in the system and can the data be used to reduce this or does new data need to be collected?
- Identify the stakeholders and include them in the AM process
- Identify management issues
- Decide on the main objective
  - Tools to set objectives can include:
    - Face to face interviews
    - Group discussions

2.2. *Decide on management actions and their alternatives*

For AM to work, actions and their alternative actions and solutions have to be chosen. This can be done as part of an experimental set up or by applying different actions to different areas or sites in a system. A conceptual model is needed at this stage to predict system responses to the different management actions. It will be based on stakeholder experience and knowledge. If possible a mathematical model is created to test these predictions quantitatively. These decisions are often best made through group discussion with individuals suggesting alternatives and their advantages to the group. The group can:

- Ask: Are multiple sites affected and can different management actions be applied to different sites?
- Agree actions: Where and when and how long to carry out AM?
- Encourage experimentation with the system to learn from the action and compare with the 'business as usual' activities

2.3. *Develop a monitoring programme*

Monitoring is an essential element of AM and focuses on the indicators defined earlier. A conceptual or mathematical model should investigate the most cost-efficient methods to achieve effectiveness; often, it is only necessary to know the trend, which requires precision (repeatability) rather than an accurate estimate of, for example, the population size. Knowing the uncertainty together with the estimates will then feed back into the assessment part of the AM approach.

- Ecological monitoring
  - Decide on the appropriate indicator (population trends, absolute numbers, a surrogate such as habitat quality)
- Socio-economic monitoring.
  - Decide on the indicators relevant to the socio-economic impacts
  - Collect data on attitudes and motivations of the different stakeholders in order to understand how they may react to particular management interventions
- Is monitoring cost-efficient and effective, i.e. does data collected from monitoring deliver measurable indicators of system change in the most cost-efficient way based on monitoring costs? Consider alternatives at this stage and repeat the AM tools check list.

2.4. Build a structured decision-making framework

A structured decision-making process uses the knowledge gained from experimentation and monitoring to evaluate the outcomes against the objectives. Structured decision-making provides a tool to adapt objectives and alternative management plans and solutions.

- Collate and interpret data from ecological and socio-economic monitoring
- Make decisions for management actions using a decision making tool (e.g. game theory, multi-criteria decision analysis, expected value of perfect information, management strategy evaluation)
  - Identify trade-offs, synergies and win-win situations of management actions
  - Choose management actions based on decision making tools
- Use expert knowledge to make predictions based on qualitative approaches (expert opinions) on the social, economic, ecological and biodiversity changes
- Adapt goals, objectives and actions
- Start from 2.1 to set clear management objectives and from 1.1 if unsure whether AM is still appropriate, feasible, successful

More information on how to do it, tools and practical experience can be found on the following websites:

- Adaptive Management website of the US Department of the Interior http://www.doi.gov/initiatives/AdaptiveManagement/index.html
- The Open Standards for the Practice of Conservation http://cmp-openstandards.org

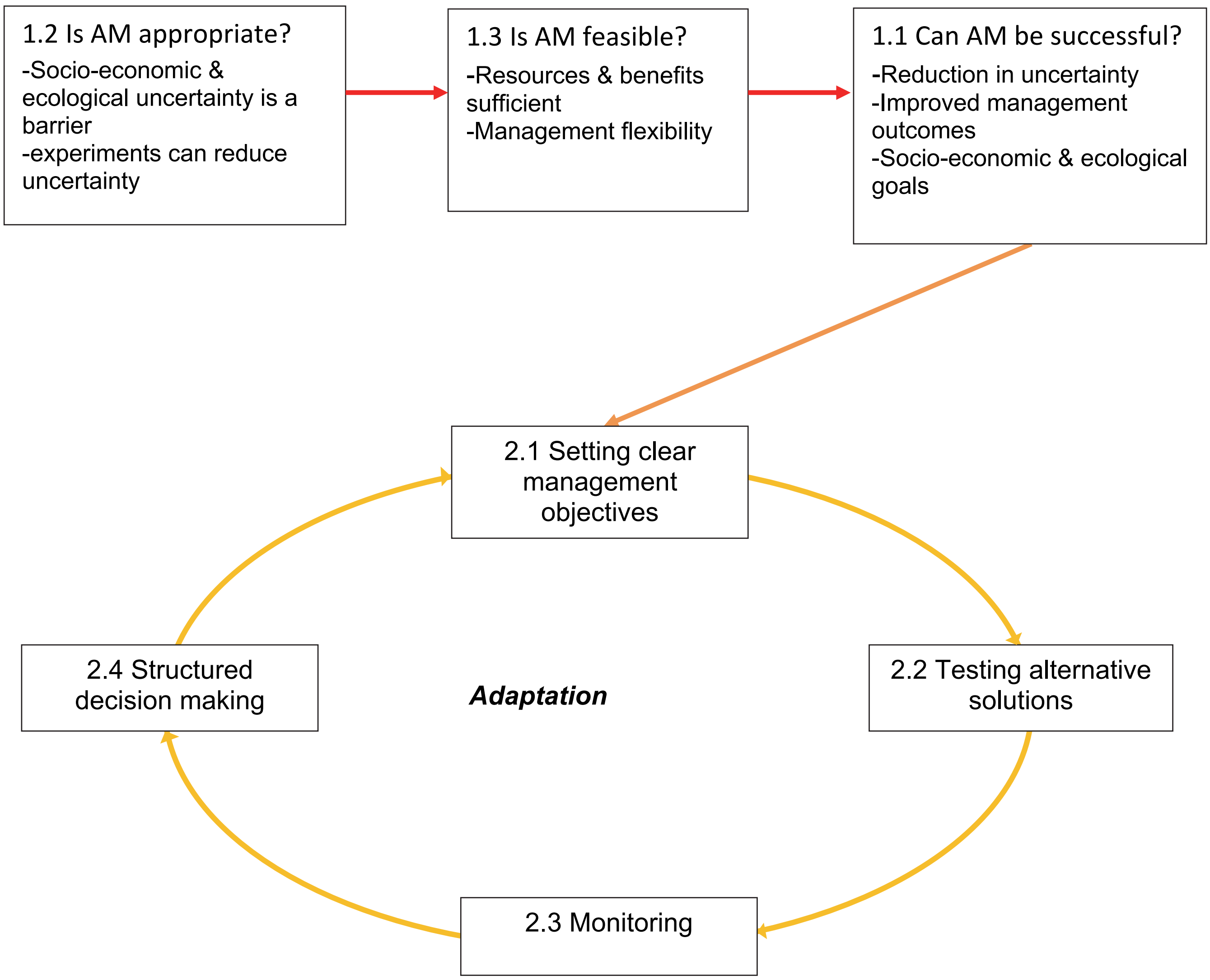

Figure 1. The checklist before engaging in adaptive management: is AM appropriate, feasible and can it be successful. The tools to carry out adaptive management comprise setting clear management objectives, testing alternative solutions, monitoring and structured decision-making. All aspects of the cycle include adaptation and learning from previous experience.

ANNEX 2: ADAPTIVE MANAGEMENT WORKSHOP

Held at SNH Battleby office, Perth 29/03/2014

The aim of the workshop was to familiarise SNH staff with the adaptive management (AM) framework and to identify potential barriers. In order to do this the workshop was divided into 3 main sessions: i) presentation of a summary of the review of adaptive management, ii) breakout groups discussing the application of the adaptive management framework to three species/systems (geese, white tailed eagles and beaver) and iii) plenary discussion of the general barriers for adaptive management arising from the species/system case studies.

The species/systems break out groups produced i) a list of points on how adaptive management could work in their specific systems and ii) identified potential barriers to engaging with and implementation of adaptive management. The discussion is described below.

How Adaptive Management could work in a specific system

The groups were asked to follow the AM stages using the case studies as a focus. The stages include identifying the key stakeholders, setting objectives, identifying alternative management actions, developing monitoring protocols and structured decision-making.

All groups developed objectives, management actions and monitoring but the eagle group also identified key stakeholders during the workshop, it became clear that setting objectives with competing views from different stakeholders can be a challenge. A useful step towards tackling this is to identify the stakeholders in the system explicitly and to engage them right at the start of AM process, i.e. already at the stage where objectives are defined. Management actions included the direct management of the system (habitat management, species management) but also risk assessment. AM actions should be interventions that can be learned from, for example applying alternative actions to compare outcomes.

Monitoring was ongoing in all three case studies and included both ecological monitoring of the focal species as well as the impact on agriculture and other land use; monitoring feedback from stakeholders; economic and social impact and monitoring economic variables (e.g. market sales of meat).

Structured decision making was less clearly worked out in the three case studies - partly because of a lack of time and spending more time on other parts. A structured decision making approach presents a challenge because for it to be useful to AM it needs to incorporate ecological and socio-economic knowledge and data and should be evidence based, transparent and repeatable.

Barriers to Adaptive Management

The following summary of the barriers discussed during the workshop follows the structure of the Review of Adaptive Management document.

Uncertainty

Reducing uncertainty is one of the aims of an AM approach. However, uncertainty can be an obstacle for both engaging in AM and implementing it. During the workshop two main issues with uncertainty emerged. First was the length of time it will take to achieve a result and uncertainty of the associated costs of a project of unknown length. Second, a barrier for starting AM projects was the uncertainty in terms of risk of unintended or unwanted outcomes from potential management actions on the system in terms of the ecological and socio-economic consequences.

Monitoring

Monitoring is a key component of AM in providing the evidence for the effectiveness of actions on the objectives. However, the levels of information required from monitoring and the associated costs can prevent AM being initiated, implemented or continued. Concerns have been raised during the workshop that the local managers are expected to set up an extensive monitoring scheme that might exceed the available funding; thus AM is not started to avoid costs that exceed funding levels. Furthermore, the costs of monitoring can create resistance to becoming involved in, and committed to, a long-term project.

Social-ecological barriers

AM recognises that social and economic factors need to be considered when setting objectives and designing actions. The discussions highlighted the general feeling that it is hard to set management objectives and that this prevents the initiation and implementation of AM. The main reason for this is the large number of stakeholders who often have conflicting interests, for example conservationists and ornithologists, livestock farmers, government agencies, tourist industry, rural communities and politicians. It is perceived to be difficult to formulate competing objectives that represent the interests of the different stakeholders. Thus, starting the AM process and implementing AM can be hindered by conflicts between stakeholders, low levels of willingness to compromise and the lack of understanding of other stakeholder's incentives. These can be summarised as lack of trust and lack of transparency among competing interests.

Furthermore, bureaucracy as well as policies at a national level can build barriers to developing an AM approach at a local level. Political inertia was also mentioned as another barrier. This is linked to a lack of clarity over who has the ownership of the management actions and the associated challenges.

Experimentation

Experimentation is a key feature of AM. This is different to trying one approach and then trying another. It means perturbing the system and learning from the monitoring how the system responds by making use of the data, which should help reduce uncertainty. Ideally this means applying an action to part of the system and comparing it with another area where the action is not applied. However, there was a general feeling that there is a lack of opportunity for experimentation in the case studies discussed. In relation to this, in some cases, it was felt that there is also a lack of evidence that AM experiments will work to achieve the objectives. It was also perceived that there is a lack of capacity to deliver the management actions (experiment) in order to achieve the objectives.

Finally, although AM should reduce uncertainty and increase effectiveness through implementing management actions based on inclusive stakeholder engagement in objective setting, this can lead to problems with managing raised expectations of stakeholders as well as public relations issues in relation to the communication of alternative scenarios and actions based on experimentation that may not be clear to the wider public.

Summary

Participants were in principle supportive of using an AM approach to managing wildlife and also felt that managing habitats as well as individual species using this approach should be considered. The workshop raised participants' knowledge and understanding of the AM process as distinct from current wildlife management approaches. However, issues with implementing AM were also identified. From the first session, participants experienced how complex even abstract objective setting can be when there are competing objectives representing different stakeholders. While monitoring and including stakeholders was worked through in some detail in all groups, decision making and testing alternative solutions was less well explored.

The second exercise focusing on the barriers of AM highlighted the need to improve social science skills to understand the social impacts that wildlife and wildlife management can have and how these impacts affect stakeholders. The breakout groups also clearly highlighted that monitoring the impact of management on wildlife and biodiversity as well as on the socio-economics of people needs the appropriate funding to build social capital by learning from true adaptive process

Adaptive management is all about reducing uncertainty and adapting action by learning from the past. Most natural systems are nowadays coupled social-ecological systems and for AM to be successful it needs to take into account all parts of the system.

In general, the participants agreed that a useful next step would be to engage one of the case studies in an adaptive management process as a learning exercise and to develop best practice in this methodology.

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