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Article

Training Conservation Practitioners to be Better Decision Makers

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Abstract: Traditional conservation curricula and training typically emphasizes only one part of systematic decision making (*i.e.*, the science), at the expense of preparing conservation practitioners with critical skills in values-setting, working with decision makers and stakeholders, and effective problem framing. In this article we describe how the application of decision science is relevant to conservation problems and suggest how current and future conservation practitioners can be trained to be better decision makers. Though decision-analytic approaches vary considerably, they all involve: (1) properly formulating the decision problem; (2) specifying feasible alternative actions; and (3) selecting criteria for evaluating potential outcomes. Two approaches are available for providing training in decision science, with each serving different needs. Formal education is useful for providing simple, well-defined problems that allow demonstrations of the structure, axioms and general characteristics of a decision-analytic approach. In contrast, practical training can offer complex, realistic decision problems requiring more careful structuring and analysis than those used for formal training purposes. Ultimately, the kinds and degree of training necessary depend on the role conservation practitioners play in a decision-making process. Those attempting to facilitate decision-making processes will need advanced training in both technical aspects of decision science and in facilitation techniques, as well as opportunities to apprentice under decision analysts/consultants. Our primary goal should be an attempt to ingrain a discipline for applying clarity of thought to all decisions.

Keywords: conservation; curriculum; ecology; education; decision analysis; decision making; decision science; natural resource management; sociology; training; uncertainty; values

1. Introduction

Biological conservation is often disparaged for its preoccupation with planning at the expense of implementation [1,2], for failing to evaluate the effectiveness of on-the-ground actions [3,4], and for engaging in reactive, "alternative-focused" thinking rather than proactive "values-focused" decision making [5,6]. Consequently, there are an increasing number of pleas to treat conservation more as a business, in which there is a mandate for efficiency and accountability [7,8]. Treating conservation as a business in turn requires a systematic approach to decision-making and clear performance measures to evaluate the effectiveness of actions.

Part of the difficulty in realizing this vision, we believe, is that conservation practitioners sometimes forget that conservation is primarily a human enterprise rather than a scientific one, whereby people, often representing diverse interests, must define what constitutes desirable outcomes. Like all decision-making, conservation involves predicting the outcomes of alternative choices, and then valuing those outcomes [6]. While the former is the objective role of scientists, the latter is the subjective role of decision makers (and ultimately of society).

Not surprisingly, most people who eventually become conservation practitioners are educated largely in the environmental sciences [9,10], with little training in decision-making beyond perhaps scientific hypothesis testing. That is, traditional natural resource management curricula and training have emphasized only one part of systematic decision making (*i.e.*, the science) at the expense of preparing conservation practitioners with critical skills in values-setting, working with decision makers and stakeholders, and effective problem framing. In our view, conservation practitioners are too often heard suggesting that we should "let the science decide" or that we should "get the politics out of management". These views represent a fundamental misunderstanding of decision making in general and of conservation practice in particular, where the diverse values of stakeholders may conflict with those of the conservation biologist.

In natural resource management, such conflicts are more the rule than the exception—whether they are between human well-being and conservation values (e.g., competing interest groups) or even between competing conservation objectives (e.g., potential negative impacts to native wildlife resulting from efforts to eradicate an invasive species). A failure to recognize the existence of multiple values, and often the need to make difficult and explicit tradeoffs among these values, can result in conservation practitioners emphasizing the promise of win-win solutions or failing to acknowledge the political and social realities of managing a common-pool resource [11]. In either case, by not addressing the reality that decision-making often necessitates sacrificing value on one objective to increase performance on another, the practitioner reduces the transparency of, and excludes potentially influential stakeholders from, the decision process. In doing so, the chance of making decisions that cause dissatisfaction among stakeholders increases, implementation is less likely to proceed, and resources are unnecessarily wasted [12]. Thus, we suggest that conservation practitioners could benefit from a greater familiarity with the social sciences, which can be used to help understand stakeholders and their values, the cognitive biases of decision makers, risk attitudes, governance structures, and all the other non-biological components that make up much of the complexity of conservation decision-making. But this is only part of the solution; we argue that conservationists primarily trained in environmental sciences need to become more familiar with the basic concepts and tools of decision science. Expertise in decision science can help conservation practitioners successfully navigate the interplay of science and values that is inherent in all conservation problems.

In this article we first describe decision-making in conservation, and demonstrate how the application of decision science is relevant to conservation problems. We then suggest how conservationist practitioners can be trained to be better decision makers, as well as describe what we see as needs to nurture the application of decision science in conservation.

2. Decision Making in Conservation

The relationship between conservation research and management is increasingly criticized as inefficient at best and dysfunctional at worst [8]. Conservation planners tend to be preoccupied with the development of assessments (e.g., status of the resource) [1], often in the absence of clearly framed decision problems with unambiguous choices and values. More often than not, once a conservation problem or concern is identified there are calls for new studies to help resolve the uncertainty typical of such problems [7]. However, exactly how the new information is to assist the decision maker is rarely contemplated. Nor is there a realization that to conduct a study while deferring on-the-ground action is itself a choice with consequences. The result has been an "implementation crisis" in conservation [1], in which conservation assessments are rarely translated into action [2]. As Gregory, Failing, Harstone, Long, McDaniels and Ohlson [7] suggest, we believe that "environmental managers have to start thinking more like decision makers and shift from a study culture to a decision culture."

Having been directly involved in resource management throughout most of our careers, we are all too familiar with the way in which resource-management decisions are often made, where trust is placed in the experience of the decision maker and priority is given to past policies. Although the experience of resource managers is clearly valuable, systematic analyses focused on problem formulation, management objectives, alternative actions, explicit predictions, and key sources of uncertainty are needed to avoid cognitive biases [13] and to clearly document the decision process. To be sure, a systematic and deliberative approach to decision making does not always produce good outcomes, but it should produce better outcomes on average than an unstructured process based on heuristics and intuition [14]. This is especially so when problems are complex, conflict among decision makers produces gridlock, or processes become stranded because of lack of appropriate follow through. If nothing else, the application of decision science to resource conservation is an effective mechanism for providing the transparency and accountability that is increasingly demanded by stakeholders and the courts [4,15,16], even though we acknowledge that transparency and accountability are not always regarded as desirable by decision makers.

Those concerned with resource conservation routinely face a wide variety of decision problems, including the assignment of priorities and allocation of funds, the securement of habitat through purchase or other incentives, the restoration or enhancement of habitat, the management of populations through stocking, translocation or take, and the design and conduct of monitoring programs. Ultimately, all of these decision problems constitute irrevocable allocations of resources concerning "what to do, where, and when" [17]—questions that we believe can best be approached through careful problem framing that involves the identification of decision alternatives, outcomes, and values [7,8,18,19].

A critical yet difficult aspect of this process is defining and framing a decision problem. The management of natural resources increasingly necessitates thinking about complex interactions among diverse ecological systems (e.g., terrestrial, marine and air) as well as human engineered systems (e.g., economic, governance and societal) that span ever larger scales of geography, time and human enterprise. The management of a particular situation is context specific, whereby conservationists need to comprehend the various interactions of these diverse, connected systems and bound the system of interest to be managed. It is now well recognized that when thinking about the environment and managing natural resources there is a need to consider multiple systems of interest, levels of action and human perspectives of the situation at hand [20–22].

Natural resource management is a human enterprise and in recent years there has been increased focus on the governance and management of the environment as a socio-ecological system [23]. Furthermore, the complex and dynamic nature of environmental problems requires flexible and transparent decision-making that embraces a diversity of knowledge and values [24]. Structured decision analysis acknowledges the need to account for different perspectives in terms of valuing the outcomes of decisions. Stakeholder participation in environmental decision-making has been increasingly embedded into natural resource management and various participatory processes sought to help better manage social-ecological systems [25].

3. What Is Decision Science and How Can It Be Used in Conservation?

Decision science has been widely used in business and government decision-making [26], but its application to problems in conservation has mostly been a phenomenon of the last two decades [27]. Though decision-analytic approaches vary considerably, they all involve: (1) properly formulating the decision problem; (2) specifying feasible alternative actions; and (3) selecting criteria for evaluating potential outcomes [28]. Traditional approaches to decision-making, which tend to focus largely on alternatives and predicted outcomes, can be distinguished from decision-analytic methods that emphasize fundamental values and the multiple-objective tradeoffs inherent in natural resource management [6,18]. The emphasis on values rather than outcomes helps decision makers understand whether disagreements are over predicted outcomes or how those outcomes are valued [29], and it clarifies the role for analysts and scientists in resource decision making as "honest brokers" rather than as advocates of a particular course of action [30]. Multi-criteria decision analysis that accounts for outcomes and values is now increasingly used in natural resource management, and is seen as contributing to better decisions through a formal structuring of decision problems that accommodates a plurality of stakeholder values [27,31–33] (Table 1).

Systematic thinking for any decision problem can be addressed by decomposing the problem into a small number of discrete steps, each supported by general rules or axioms derived from decision theory [15,34]. This approach is beneficial on two fronts: (1) the decomposition of a complex problem into distinct components simplifies the problem, provides greater clarity, and helps identify the true impediments to decision making; and (2) the tenets of decision science provide a means to combine the information developed in each step into a logical and coherent framework for making a decision. Four steps can be generalized for any decision problem: (1) define and frame the decision problem; (2) predict or assess the possible outcomes of each decision alternative; (3) evaluate the preferences of the decision maker(s) with respect to those outcomes; and (4) integrate (reconstruct) the components from the preceding steps to compare alternatives so the best one can be selected [15]. Next, we briefly describe each step and their related axioms.

Table 1. Examples of the application of decision science to conservation problems.

Resource problem	Goal	Source
Harvesting	Sustainable use	[35–38]
Translocation	Endangered species persistence	[39]
Pest management	Control	[40,41]
Management of human disturbance	Endangered species occupancy	[42]
Fire management	Biodiversity conservation endangered species persistence	[43–45]
Forest management	Endangered species persistence	[46]
Reservoir management	Water supply	[47,48]
Landscape design	Endangered species persistence	[49–52]
Allocation of conservation resources	Biodiversity conservation	[19]
Reserve design	Multiple species persistence	[53]

Defining the decision problem involves understanding the context of the problem, specifying objectives, and generating alternative management actions. Defining the decision problem may seem obvious, but it is often the case that no clear articulation is made of what is actually to be decided. By assuming that the decision problem is clearly understood by all involved, unnecessary conflicts and a lack of clear direction on how to proceed can result. In addition to specifying management objectives and describing alternatives to achieve those objectives, problem framing includes explicitly identifying the decision maker(s) and others affected by the decision (*i.e.*, stakeholders), characterizing the frequency and timing of the decision, and recognizing important constraints and key sources of uncertainty. At this stage, the scale and scope of the problem should be clearly articulated to ensure that the temporal, spatial and organizational scales of the decision context are compatible with those of the management objectives [6], and help determine the appropriate investment to make in framing and analyzing the decision. Many of the challenges and failures in conservation and management may be attributable to a mismatching of scale between available alternatives, resource objectives and the socio-ecological processes under consideration [54,55]. Guiding axioms for problem framing include: (1) at least two distinct alternatives can be specified and only those alternatives put forth will be available to consider and select; and (2) possible outcomes of each alternative can be described on the scale of the attributes or performance metrics specified for each objective.

Of particular concern in problem framing is the notion that “the decision context and the fundamental objectives that frame a decision situation must be compatible” [6]. Thus, the decision alternatives must be sufficient to describe all the ways in which objectives (values) can be achieved, and objectives must be sufficient to fully evaluate the alternatives under consideration. This requirement highlights the central role of scale in problem framing, especially as it concerns the need to ensure that the perceived scale of the problem is matched with the scale at which conservationists (or society) can address it [54–56].

Although a decision problem may have a relatively narrow focal scale for implementation of alternatives, a consideration of both smaller and larger scales may be necessary to adequately predict and value outcomes. Unfortunately, we believe that many of the discussions of scale in conservation are unfocused and wide ranging. More than anything else, decision analysis promotes contextual thinking—*i.e.*, recognizing the precise nature of the decision problem, defining the larger ecological and social context in which it is embedded, and identifying and evaluating alternatives.

Due to the science-focused nature of many traditional natural-resource-management training programs, this critical first step in decision-making is often daunting to conservation practitioners. In particular, the specification of unambiguous management objectives is a challenging aspect of decision analysis. We believe natural resource managers can benefit by formulating SMART objectives; *i.e.*, those that are specific, measurable, achievable, relevant, and time-bound [57]. SMART objectives have several advantages as they are (a) specific and clearly defined, which makes the objectives tangible and understandable; (b) measurable, which enables efficient evaluation of whether the objectives are being met; (c) achievable, as unachievable goals waste resources and demotivate participants; (d) relevant, which increases the likelihood of obtaining the necessary support, and finally (e) time-bound, because of the resolve required to execute tasks. However, the process of setting SMART objectives can be difficult for many environmental issues due to divergent stakeholder values and disputes regarding the benefits (and costs) of reaching the objective. These issues must be countered by a logical and coherent process for setting the objectives to minimize the risk of stalled decision processes [58].

Finally, we note that there has been an increasing interest in accounting for both direct and opportunity costs in specifying conservation objectives [59–61], but exactly how these costs are eventually to be traded off against conservation benefits is less clear. Some authorities have argued that cost-benefit analysis differs from decision analysis in that the former focuses on willingness to pay while the latter emphasizes the values of alternative courses of action [62]. In those cases, where benefits can be monetized [63], maximizing the net benefit is an obvious objective. But where that is not possible, two alternatives are possible: (1) maximizing the benefits for a fixed budget; or (2) minimizing the cost for a fixed level of benefit. These alternatives do not require that costs and benefits be placed in the same currency, yet they acknowledge that conservation costs have to be part of the business model.

Following the articulation of objectives, alternatives and other problem-framing considerations, the next step in a structured decision process is predicting possible outcomes of implementing any of the alternatives under consideration. The outcomes of any management alternative should be described in terms of the consequence to each objective, using the specified performance metrics. However, it is rarely possible to predict the outcome of a decision with a high degree of certainty. Thus, models can be used to assign probabilities to the set of possible outcomes for each alternative action. Models can be quantitative expressions that describe system behavior and define the functional relationship between actions and objectives, or they can be more qualitative, conceptual descriptions derived from expert judgment or traditional knowledge [50]. Regardless of their form or the origin of the data used to characterize these relationships, models must predict the outcomes of each potential action with respect to the stated objectives and, ideally, explicitly describe the degree of uncertainty associated with each prediction. The decision-analytic principle guiding this step states that there exists any number of techniques to specify the probabilities for each possible outcome resulting from implementing any of the available decision alternatives [15]. As some decision scientists have recognized, however, there are situations where uncertainty is so great that developing probabilistic models of system behavior is impossible or inappropriate; in such cases, alternative methods of robust decision-making must be used (e.g., information-gap decision theory [64]).

Specifying the relative preferences of the decision maker(s) with respect to possible outcomes is a critical step of a structured decision process. Regardless of whether addressing a single- or multiple-objective decision problem, this step is concerned with the pervasive need to evaluate tradeoffs. Considering tradeoffs involves balancing possible benefits gained on one objective with losses on another (for multiple objective problems), as well as examining the risk attitudes of the decision maker(s). Because the outcome(s) of a decision can almost never be guaranteed, quantifying the risk attitudes of a decision maker allows the analyst to evaluate the tradeoff between potential benefits of any alternative and the negative impacts if an undesirable outcome were to occur. For example, a risk-averse decision maker may trade an "optimal" alternative (*i.e.*, that with the highest expected net benefit) for one with a lower expected return if the latter is more certain (*i.e.*, likely to produce the anticipated outcome). Quantifying values and risk are both concerned with the subjective preferences of the decision maker(s) and, as mentioned previously, are largely beyond the purview of ecological sciences or the traditional training of natural resource managers. Thus, addressing this component of a decision process often requires the expertise of economists and other social scientists. Decision analysts typically construct a utility function that aggregates the values specified under each objective and a function that describes risk attitudes across all possible outcomes. The utility function consists of a "value model" for each objective that relates the desirability of every possible outcome and a risk function that quantifies the relative level of risk preference over all possible outcomes or "states of nature." Decision theory asserts that all outcomes are not equally valued and that the relative preference for any outcome can be specified by the decision maker(s).

Finally, the analyst seeks to "solve" the decision problem by integrating the components addressed via the previous steps. The axioms of decision theory provide us with assurance that we can reconstruct these elements in a logical and defensible manner such that the selection of a preferred alternative is consistent with both the preferences (values) of the decision maker(s) and our understanding of the likelihoods of possible consequences for each alternative. By simplifying the problem into its component parts, the likelihoods of outcomes for each alternative are separated explicitly from how those outcomes are valued, and the individual components are addressed by applying the appropriate analytical tools. In this final step, each alternative is evaluated by synthesizing the relative magnitude of anticipated benefits and risks of the potential outcomes (*i.e.*, via the utility function) with the probability of each outcome occurring, given that alternative is implemented. The resulting quantity is often referred to as the "expected utility", recognizing the expectation is taken over uncertain outcomes. By integrating probabilities and utilities, the identification of the preferred alternative by the highest expected utility reflects trade-offs among the relative preference for each objective, the likelihood that the alternative will produce a desired outcome, and the risks of an unintended consequence associated with selecting that alternative. The axioms that support this step are intended to ensure consistency and confidence with regard to the comparison of alternatives, and that alternatives with higher expected utility are more preferable than those with lower expected utilities [15].

Through our experience in serving as decision analysts, we have often found it useful to apply a prescribed set of steps described by the acronym "PrOACT" to structure and analyze natural resource decision problems [65]. PrOACT comprises the same components as outlined in the steps above, but further decomposes the decision problem by identifying steps to: define the *Pr*oblem, specify *O*bjectives (e.g., using SMART), create *A*lternatives, predict *C*onsequences and evaluate *T*rade-offs (*i.e.*, compare alternatives). By explicitly recognizing objectives and alternatives as distinct steps unique from the problem definition, this approach puts additional emphasis on the early, subjective stage of a decision analysis. By doing so, we stress the importance of careful problem framing and characterization of values when engaging in a decision analysis. This approach also encourages greater multidisciplinary involvement by the decision maker(s), stakeholders, economists and other social scientists, thereby fostering ownership of the process and increasing the chances that the analysis results in greater clarity of the problem for all concerned (and, secondarily, that the recommended alternative is accepted and implemented).

Finally, we note that an important aspect of the trend toward formal decision analysis in natural resource management has been the increasing application of methods to analyze dynamic decisions [66–69]. Dynamic decision problems are ubiquitous in conservation, including sustainable harvesting, the management of habitat disturbance, the control of invasive plants and animals, and even the development of terrestrial reserve systems. The dynamic management problem involves a temporal sequence of decisions, where the optimal action at each decision point depends on time and/or system state [66]. The goal of the manager is to develop a decision rule (or management strategy) that prescribes management actions for each time and system state that are optimal with respect to the decision maker's objective(s).

A key consideration in dynamic decisions of natural resource problems is the uncertainty attendant to decision outcomes, which adds to the demographic and environmental variation of stochastic resource changes. This uncertainty may stem from errors in measurement and sampling of ecological systems (partial system observability), incomplete control of management actions (partial controllability), and incomplete knowledge of system behavior (structural uncertainty) [70]. A failure to recognize and account for these uncertainties can significantly depress management performance and in some cases can lead to severe environmental and economic losses [71]. In recent years there has been an increasing emphasis on methods that can account for uncertainty about the dynamics of ecological systems and their responses to both controlled and uncontrolled factors [69,72].

An incomplete understanding of system dynamics and its response to management is an issue of special importance in adaptive management. Multiple hypotheses and associated models are used to characterize this uncertainty, and comparisons of model predictions with observations from a monitoring program are used to compute a distribution of model-specific probabilities that serve as indicators of model credibility [35,67]. Important advances have followed from the recognition that these probability distributions are not static, but evolve over time as new observations of system behaviors are accumulated from the management process, thus constituting a formalization of learning. Indeed, the defining characteristic of adaptive management is the attempt to account for the temporal dynamics of uncertainty in making management decisions [72–74].

4. Making Better Decision Makers

Not everyone involved in conservation is in a decision-making role, and those that do make decisions need not be bona fide decision analysts. Just as conservation triage [12] requires the prioritization and trading-off of limited resources to achieve the greatest net benefit, developing an effective strategy to build capacity in decision science requires the efficient allocation of training methods and materials to reach the desired audience with the needed skills. There is, however, considerable benefit if all those involved in natural resource management have a basic understanding of the principles and tools of decision science. It is our belief, therefore, that effective training should begin with as inclusive an audience as possible—including decision and policy makers, stakeholders, scientists, and students—and first focus on conveying general principles of decision making that are applicable to all decisions. Then, skill-development in particular methods, analytical tools and skills for specific classes of problems can be directed and refined based on the needs and interest of the particular audience. Our primary goal should be to ingrain a discipline for applying clarity of thought to all decisions. This approach will provide the foundation for addressing those complex conservation decisions that are more likely to produce undesirable outcomes without such clarity.

Beyond an understanding of the basic principles of decision science, the kinds and degree of training necessary depend very much on the role conservationist practitioners play in a decision-making process (Table 2). Skinner [62] defines the various roles as participant, decision maker, facilitator, and decision analyst/consultant. Participants include stakeholders and others knowledgeable about the problem, scientists and other subject-matter experts. They require a basic understanding of the decision process and how their contribution supports the decision (e.g., scientists must understand that decisions are ultimately values-based and their role is to predict consequences and address uncertainty). Participants perhaps need only a short course (one to two days) introducing the concepts of decision science, so they can bring issues, content, and ideas to the process in a constructive manner. Decision makers are those with the legal authority, responsibility or mandate to commit resources for implementing a decision. Those who actually make the decision also need a rudimentary level of training, as well as an understanding of how the inputs and outputs of decision analysis are shaped by the values of stakeholders, the rules and policies of their institutions, and the norms and laws of society. Training for decision makers could include additional material on values elicitation, conflict resolution and regulatory considerations.

Those wishing to serve as facilitators of decision-making processes will need more advanced training in decision science and facilitation techniques, as well as opportunities to apprentice under decision analysts/consultants. The focus of facilitator training should be on guiding group processes, communication and elicitation skills, and understanding the impact of cognitive biases and other psychological “traps” on various elements of decision-making. The role of the decision analyst/consultant is not to make recommendations to the decision maker but rather to lead all participants through a clear and structured process to gain insights on the problem itself. This includes providing transparency in separating values from science or facts, illuminating the risk attitudes of the decision maker and key stakeholders, and recognizing the major impediments to making a robust decision. The analyst must often serve in a number of roles for a decision process: helping to identify and select appropriate participants for effectively conducting a workshop, facilitating often contentious problems, resolving conflicts and managing group dynamics, eliciting values and data from various participants, and applying appropriate methods and tools for analyzing the decision. Thus, analysts require advanced knowledge of the principles and tools of decision science so that problems are framed in a manner that appropriately reflects the context, complexity, and nuances of a decision problem. Additional skills are necessary to lead group processes (including critical stakeholder engagement), to communicate across disciplines, and to mentor facilitators. At a minimum, both facilitators and decision analysts must have a capacity for analytical thinking, expertise in communication, facilitation and elicitation, skill at interdisciplinary team building and problem-solving, and a varied toolbox of decision-analytic techniques.

Table 2. Different roles in a decision-making process require different skills [62].

Role	Activities	Skills
Participant	Contributes issues, content, and ideas	Basics of decision science
Decision maker	Articulates values and makes tradeoffs	Basics of decision science, plus stakeholder engagement, conflict resolution, project management
Facilitator	Manages decision process, helps frame and analyze the decision problem, and serves as apprentice to decision analyst	Advanced techniques of decision science, facilitation, cross-disciplinary communication, and project management
Decision analyst/consultant	Organizes and guides process and mentors facilitators	All of the facilitator skills plus experience consulting on a wide variety of conservation decision problems

Generally speaking, two approaches are available for providing training in decision science, with each serving different needs: formal education and practical training. Formal education is useful for providing simple, well-defined problems that allow demonstrations of the structure, axioms and general characteristics of a decision-analytic approach. Using simple problems permits a focus on the generalities of approaching any decision. Formal training can also be used effectively to focus on developing advanced skills and specific tools. In contrast, practical ("hands-on") training can offer more complex, realistic decision problems requiring more careful structuring and analysis than those used for formal training purposes. Practical training can result in faster learning but requires a higher skill level; mentorship programs that pair experienced decision analysts with less-experienced practitioners (*i.e.*, those with only formal training) is often a useful model.

Who should receive formal education in decision science? Expanding training in decision science for undergraduate and graduate students should eventually result in a change of culture in the practice of natural resource management as students leave academia and enter the workforce. However, the speed at which a "decision culture" infiltrates conservation can be accelerated by expanding efforts to improve decision-making capacity beyond academic programs to bring both formal and practical training to practicing conservation professionals. It is challenging for many conservationists to continue a process of self-development after leaving higher education, but practitioners need to continuously learn and update their knowledge and skills in order to maintain a capacity to meet the complex demands they face. Such skills as the capacity to critically reflect on decisions, learn from their outcomes, and to act with agility in engaging with stakeholders and colleagues from different disciplinary backgrounds are necessary in order to advance creative solutions [75]. This suggests additional strategy considerations for training better decision makers, as each audience comes with its own strengths and particular needs for improving decision analytic skills. To reduce the "practical dissonance" between academics and conservation practitioners [9], a training strategy should attempt to meet the needs of the next generation of wildlife professionals (by "wildlife professional" we mean those professionals involved in any aspect of wildlife management and research, including game wardens, biologists and ecologists, non-governmental wildlife organizations, policy makers, those responsible for human-wildlife interactions, professional hunters, *etc*.) and those currently implementing resource management decisions. Accomplishing this mission requires strong institutional support to create active networks among disciplines (e.g., ecology, law, political and social sciences), as well as to encourage wider engagement with stakeholders. Such networks can enable higher levels of individual and collective learning, often referred to as double- and triple-loop learning [76], which can expand choices and creative possibilities when tackling complex situations. There is also a need for willingness to provide space for experimentation and critical peer review [77], not only to develop better individual decision makers but also to foster the wider application of transformational methods, techniques and processes to improve collective decision-making. The strategy requires a balancing of learning objectives that most effectively targets those areas of decision analysis that are the least familiar to the particular audience, using both formal instruction to teach fundamental concepts and practical application to develop problem-solving skills for more complicated problems and to provide repeated exposure to difficult ideas [10]. We illustrate some particular learning objectives that might be associated with each audience and training approach in Table 3.

Table 3. Learning strategies and objectives for conservation and natural resource students and professionals in decision-analytic concepts and practice.

Level	Formal	Practical
Undergraduate	• Basic decision science concepts • Models, prediction, monitoring • Review decision analysis case studies	• Role playing • Solving simple decisions individually or in small groups
Graduate	• Advanced decision science concepts • Quantitative methods (parameter estimation, uncertainty, Bayesian updating, study design, monitoring, systems modeling, optimization methods, adaptive management) • Social science methods (economic valuation techniques, participatory-process facilitation techniques, behavioral sciences, elicitation methods, social cost-benefit analysis) • Public policy and law	• Stakeholder interaction and facilitation • Objectives elicitation and weighting • Communication and conflict resolution in group settings • Coordination among decision team members (scientists, decision makers, agency personnel, *etc.*) • Leadership and coaching skills • Decision synthesis
Professional	• Basic and advanced decision science concepts • Modeling tools and techniques • Social science methods (psychology and cognitive bias, risk analysis, stakeholder analysis)	• Cross-disciplinary interactions and facilitation • Familiarity with conceptual and quantitative models • Conflict resolution • Leadership & coaching skills • Application to more complex problems

Although many resources are available to develop formal curricula in decision science [7,62,78], limited guidance exists for designing a program of practical training for students and professionals to gain experience in the various roles needed for a decision-analytic process. Two of the authors of this article (FAJ and MJE) have contributed to the development of one such model of institutionalized training in the United States. The National Conservation Training Center (NCTC) is an instructional facility of the U.S. Fish and Wildlife Service established to provide training and professional development for its employees and their conservation partners. NCTC has recruited volunteer federal and academic experts and practitioners of decision science to produce and teach formal curricula in "structured decision making," adaptive management, and the application of specialized decision-analytic tools. Employing only a few curricula managers and training coordinators, the Training Center offers several courses per year (5–10) with free tuition for agency employees and open enrollment for students, academics and other professionals (http://nctc.fws.gov/courses/programs/decision-analysis/resources.html).

A second focus of the NCTC model is on practical training. Twice per year, the training center issues calls for proposals for federal resource managers and their partners to submit existing or planned decision problems for week-long decision workshops. Workshops are commonly held at the training facility (but sometimes regionally) and typically involve three to five individual problems being facilitated concurrently. Two experienced decision analysts (on a voluntary basis) are paired with an analyst-in-training to work closely with each problem team. The analysts, the apprentice and the proposal's author begin a month or more in advance of the workshop to identify appropriate participants and together they begin to frame the problem (see above, Section 3). The decision teams, usually comprising 8–12 participants excluding the analysts, then dedicate a week at NCTC to prototype a complete decision model (*i.e.*, all the PrOACT steps). Requiring that the decision, which is often of moderate complexity, be fully framed in a short period of time compels the participants to refrain from dwelling on any component in great detail. The "rapid prototyping" approach offers a new, broader perspective to team members who in many cases have been mired for years in the nuances and complexities of the problem. The strategy also effectively demonstrates the process by which individual components are finally reintegrated to complete the analysis, thereby providing participants with the understanding and ability to expand the prototype by adding necessary and appropriate detail after the workshop is concluded.

Having multiple teams working concurrently, with regular joint plenary sessions to present and discuss insights and preliminary results, promotes interaction among participants and an opportunity for the analysts to draw on each other's experience and skill sets. To promote transparency and transferability, workshop teams are required to submit a report outlining their progress and initial prototypes (http://training.fws.gov/courses/ALC/ALC3159/reports).

To support its formal training activities, NCTC has produced and made available on-line a set of high-quality instructional videos for select decision-analytic courses (http://training.fws.gov/courses/ALC/ALC3183/resources). Finally, the training center coordinates a practitioners' development program to pair veteran analysts with those seeking additional training, experience and mentorship, with the goal of becoming qualified analysts who can lead workshops and help guide other decision problems. After less than 10 years, this training strategy has produced a significant network of trained, experienced and supported decision analysts who, in addition to their agency and academic duties, routinely serve as volunteer instructors and coaches to improve natural resource decisions being made by government agencies and their partners.

Although it is difficult to quantify the outcomes of a training program of this nature, formal evaluation of curricula and delivery is essential to measure the benefits of these efforts to decision makers and improvements to actual decisions. NCTC conducts a student-evaluation following each training course and has initiated an evaluation study to assess the application of decision science approaches to management in the U.S. Fish and Wildlife Service six-months to one-year after the conclusion of a decision workshop (results not yet published). Several informal indicators related to the training program, however, suggest that some level of impact is being achieved. These include a steady demand for the delivery of training curricula (which has now expanded to be offered regionally), regular requests for decision workshops by both federal and state agencies, and a growing catalogue of published case studies resulting from these workshops (e.g., [50,79–82]).

The NCTC training model is not the only example of a concerted effort to build decision-analytic capacity. Several Units of the U.S. Geological Survey's Cooperative Research Unit Program have developed active programs to teach decision science at the graduate (and sometimes undergraduate) level and work with their state resource agency cooperators to apply formal decision analytic methods to resource management problems. Additionally, a number of wildlife and conservation departments in U.S. universities have begun to incorporate decision science courses in their graduate and undergraduate curricula. One example is the University of Nebraska-Lincoln, which offers a graduate specialization in adaptive management for natural resource science. Finally, numerous international efforts exist to develop and apply new methods and tools in decision science. A primary example is the Australian Research Council's Centre of Excellence for Environmental Decisions (CEED). This network of research institutions and universities is focused on solving global environmental problems through foundational research and the intersection of policy and management. In Europe, the International Research School in Applied Ecology (IRSAE, funded by the Norwegian Research Council) offers a 5-day graduate course in structured decision-making and adaptive management. Additionally, Aarhus University (Denmark) now includes adaptive management as part of the undergraduate syllabus in Wildlife Ecology; this university is now also offering two-day courses in decision science for professionals.

In addition to providing formal and practical training in the methods and applications of decision science, there is also the need to establish a pedagogical culture, whereby the knowledge, skills and processes for teaching these subjects to conservation practitioners are developed and refined. These are related to, but distinguishable from, expertise in these subjects themselves [83]. Instilling a pedagogical culture amongst conservationists for acquiring knowledge and skills is a gradual process and one we believe should start with integrating decision-analysis education and practice into undergraduate academic curricula. Then, in order to continue developing expertise it would be beneficial to maintain and strengthen links between higher education and professional development by encouraging exchanges of knowledge and practical experience between academia and government institutions, for example through an institutional program like that described above, by offering placements for students in government agencies, and by inviting agency personnel to lecture on real-life decision problems [9].

5. Conclusions and Resource Management in Europe

Conservationists increasingly face complex problems and must routinely make important decisions about how to manage the natural environment. Few are taught the art and science of decision-making or develop the knowledge and skills necessary to make systematic, deliberative, and effective decisions. We suggest that a well-designed training program is required to build the capacity of individuals and organizations to analyze decisions using the concepts and principles of decision science, and to help structure those decisions "worth thinking about" (*i.e.*, those with significant consequences and high uncertainty [84]).

The emphasis in decision analysis on framing and reframing of natural resource problems requires conservation practitioners to access the kind of knowledge, expertise, experiences and values that need to be considered as part of the decision-making process. The challenge for conservationists is not only identifying and integrating different stakeholder perspectives and various knowledge sources (either scientific or locally “experienced” based), but developing common means to share and learn from exchanges among stakeholders and different knowledge sources. Collaborating with other professional fields and disciplines (e.g., sociology, economics, law) should assist conservationists develop and employ appropriate means and skills to create new knowledge formats, common languages and tailor how science is communicated with different audiences [21,85,86]. Moreover, such collaborations can be beneficial in determining who should participate, who will benefit, and when is best for them to be engaged in the decision-making process. Using a variety of participatory methods and engaging with stakeholders at different decision points can facilitate collaborative learning over time and ensure a broader engagement and ownership of management processes. In this way relevant stakeholder voices can come through at different stages of a decision making cycle enabling shared understanding to develop. This “social learning” can facilitate the flow of information, knowledge and shared perspectives between stakeholders both horizontally (among groups) and vertically (among institutional levels) [25,87,88].

European governance and decision making related to conservation management has traditionally been delivered by top-down policy approaches and legal instruments. However, there has been a shift in policy development within the EU towards more participatory and multi-scale governance and decision making, as adopted in the Water Frame Work Directive [89]. Increasingly, conservation management in Europe has become a highly complex system of decision points [90], whereby polycentric governance systems, comprised of many agencies and levels of governance, are regarded as yielding higher environmental benefits [91]. Such developments are likely to place high demands on conservation practitioners, who have to then navigate and manage decision-making processes that span multiple governance levels and spatial and temporal scales, as well as engage with non-state-actors in the “delicate process of societal decision making” [85].

Only recently has the European conservation community been exposed to the concepts of structured decision-making and adaptive management [92], and there is a critical need for education and training to foster more applications. More formalized decision-making processes can lend themselves to inclusive, accountable and cost effective decision making, which ultimately can engender greater legitimacy as part of an open and public process of deliberation among a variety of societal actors [93,94]. This will require a multi-tier process of undergraduate and graduate education, along with the training and mentoring of conservation professionals. Development of academic curricula, practical application, mentoring programs and the exchange of trained individuals in management institutions will be an effective way to accelerate this process.

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Author Contributions

All authors contributed to the writing of the manuscript and approved the final version.

Conflicts of Interest

The authors declare no conflict of interest.

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