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Perspective

Defining the burden of proof in conservation

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ABSTRACT

Conservationists often must take action in the face of uncertainty about the costs and benefits of different options. Although this uncertainty can be paralyzing when the stakes are high, there is obviously a cost to inaction as well as action, and decision makers need to be encouraged to act when appropriate. Many other fields of human endeavor such as law, medicine, and public safety have formally developed the "burden and standards of proof" that decision makers have to meet in choosing to take action. In this paper, we review the standards developed in these other fields to help define a similar framework for conservation. Specifically we propose that a conservation decision maker must assume the burden of proof when there is a decision to act that substantially affects others, in which the decision maker has professional standing, where there is not immediate urgency, and where there is some, but not complete certainty about the outcomes of acting versus not acting. Once these initial tests have been met, in situations in which the decision maker is more worried about the consequences of not acting, then a relatively low standard of proof is required for taking action. If the decision maker is concerned with the consequences of acting in error, but the action is relatively reversible, then a medium standard of proof is required. And finally, if there are concerns about the consequences of acting in error, but the action is relatively irreversible, then a high standard of proof is required.

Contents

1. Introduction

Suppose you are a concerned citizen who comes across a small tortoise in the middle of a busy roadway and has to decide whether to move the animal to one side of the highway. You have heard that these tortoises have strong senses of territoriality and direction, and that if you move it to the wrong side, it will just return and attempt to cross the entire road. But if you leave it on the roadway, it will almost certainly be run over by a vehicle.

Or suppose you work for a fish and wildlife agency and while visiting an authorized construction site, you discover a remnant population of rare, but not legally protected, fish in a pond that is literally about to be filled in. You have to decide before the bulldozers come, whether to capture all the fish and try to move them to another site or hold them in an ex situ setting.

Or suppose that you are the manager of a national park who is trying to solve persistent conflict between the elephants in your park and the farmers in the buffer zone area whose crops are being eaten by the elephants. You need to decide whether you should invest in an expensive fencing system, try to use more traditional techniques to scare off the elephants, attempt to translocate the elephants, or use the funds to compensate the villagers for their

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losses. It is not clear which, if any, of these techniques will solve the problem.

Or suppose you work for an agency charged with managing one of the last remaining wild populations of an endangered marsupial that is being wiped out by an introduced pathogen. You have to decide whether to capture all the animals you can find to start a captive breeding population, thus causing the population to become extinct in the wild, or to try to protect them *in situ*.

Or suppose you work for a water management agency that governs the operations of a dam on a reservoir. You have to decide whether your agency should change the patterns by which you release water from the dam to more accurately match the river's natural hydrologic cycles, or in a more extreme action, remove the dam from the river system altogether. Although these actions will presumably benefit the riparian ecosystem, they will also potentially reduce the amount of water available for crop irrigation.

Or finally, suppose that you are the head of a government environmental agency trying to manage exotic, invasive rats that are overrunning the ecosystems in your country and driving many bird species to the brink of extinction. Some genetic researchers claim that they have engineered a virus that will specifically target and kill off the rats. Once released, however, it will not be possible to control this virus. You have to decide whether to give them a permit for this work.

Each of these situations involves making conservation decisions that affect other people and species in the face of uncertainty about the costs and benefits of different options – including the option of whether to take action at all. This uncertainty can be paralyzing, in large part because no manager wants to be responsible for having made the wrong decision when the stakes are high. But there is obviously a cost to inaction as well as action. Decision makers, both as individuals and in groups, need to be encouraged to act when appropriate. To this end, are there general principles that can be invoked to help guide these decisions and help decision makers ensure that they are making their decision according to acceptable and understood ethical, moral, and professional standards?

Conservationists are not the only professionals who need to make consequential decisions in the face of uncertainty. For example, judges and juries deciding legal trials, medical doctors deciding on treatment options for an ill patient, police officers deciding whether to shoot a hostile suspect, and many others all have to act without complete information, knowing that the results of their decisions will have effects beyond themselves. Many of these fields have formally developed the "burden and standards of proof" that decision makers in each field have to meet in choosing to take action.

We believe that conservation would benefit from a careful examination of the potential role of the burden of proof in our field. In this paper, we first briefly provide a brief examination of standards developed in other fields, and then use these results to propose a framework for considering the burden of proof for conservation that can stimulate discussions around this topic within our community and hopefully lead to the development of formal professional standards for making critical decisions such as described above. We wish to emphasize that this is not a comprehensive review of the very substantial literature on burden of proof and decision theory, nor are we experts in this field. As such we have provided sketches of other disciplines that are useful only in helping conservation practitioners think about their own discipline. We use this framework to formulate a proposition for consideration by the field of conservation biology. There are of course, many dimensions to the "practice of conservation," with decisions being taken daily by park rangers, customs officers, academic scientists, government officials and NGO program managers, amongst others. Despite this heterogeneity we feel that a common practice such as we outline would be valuable for the field in providing a framework around which conservation practitioners from different backgrounds can reach agreement, or at least develop modified versions to meet their particular needs.

2. Factors affecting the burden and standards of proof in different fields

The concept of "burden of proof" (Latin: *onus probandi*) goes back in the Western world at least as far as ancient Roman law. In the Anglo-American legal tradition, it is narrowly defined as the obligation of one party in a legal proceeding to shift the accepted conclusion away from an oppositional opinion to one's own position, or in effect, to prove a disputed assertion or charge. The party that does not carry the "burden of proof" carries the "benefit of assumption" meaning that they need no evidence to support their claim (Wikipedia.org/legal burden of proof). In addition to defining who must prove the case, the concept of burden of proof also more broadly encompasses the threshold or "standard of proof" that is required to be met (Wikipedia.org/legal burden of proof).

The concepts of burden and standards of proof have permeated scientific and philosophical discourse, forming one of the cornerstones of the field of decision theory and choice under uncertainty (Leiss and Hrudey 2005, Roeser et al. 2012). A common formulation is that "those who want a change from the status quo should bear the burden of proof (Scott 2005, p. 54). Interestingly, however, burden of proof is not an empirically definable matter. As Brown (1996, p. 125) states, "the burden and standard of proof that should be required in risk assessment-based regulatory action is an ethical question, not a scientific question."

So how does this legal and academic concept get translated into actual decision making? To examine this question, we reviewed the burden and standards of proof across a number of fields of human endeavor including law, medicine, public safety, military, business, engineering, and science/academia. Our selection of these fields and the specific decisions being made within each was neither exhaustive, nor part of a formal sampling frame, but rather an attempt to find useful analogs that could inform conservation practice. In each of these fields, we assessed the degree to which the field had more or less formal standards of proof, and then looked at specific factors that might potentially affect this burden of proof.

Our review of these fields suggests that there are seven parameters that need to be addressed when thinking about the burden and standards of proof for conservation as shown by the columns in Table 1. These parameters can be subdivided into two basic descriptions of the decision, four "independent variables" and one "dependent variable."

Nature of Decision – the first two of these parameters relate to the nature of the decision itself:

1. What is the **decision** being made in each case? For example, should a suspect be convicted of a crime, should a doctor treat a patient with a new experimental therapy, or should an academic be granted tenure? In each of these cases, a decision is being made that has important consequences for individuals or entities other than the decision maker. By contrast, in cases in which either the decision primarily affects the decision maker (a private firm choosing to invest in a new product, an artist choosing a subject for their artwork) and/or does not have major consequences (a consumer choosing a brand of cereal), there does not seem to be a need for a formally defined "burden of proof."

Table 1
Case studies of burden and standard of proof in different fields.

Nature of decision		Independent conditions under which decision is made				Dependent variable
Field example of decision	Decision maker	Urgency	Certainty	Consequences of error Type I. action/ Type II. inaction	Irreversibility of Type I error of action	Established burden and standard of proof
Law						
Criminal cases: Convict suspect of crime?	Jury of peers	Months to years	**Medium to high:** Each case unique, circumstantial to very precise (e.g. DNA) evidence	**I-High:** innocent person in jail **II-Medium:** Criminal goes free "Better 10 guilty men go free than one innocent man be convicted"	**Medium:** Appeal, could release	**High:** "beyond a reasonable doubt" which is interpreted as "moral not mathematical certainty that excludes all reasonable hypotheses except guilt"
Capital cases: Did suspect commit crime and should death sentence be imposed?	Jury of peers + judges in appeal	Decades	**Medium to high:** Each case unique, circumstantial to very precise (e.g. DNA) evidence	**I-Very high:** innocent person executed **II-High:** Serious criminal goes free "Better 10 guilty men go free than one innocent man be convicted"	**Very high:** No redress	**(Very) High:** Same principles as for criminal case, but given even more scrutiny
Civil suits: Is the defendant liable?	Jury of peers	Months to years	**Low to high:** Can involve many actors/ details; class action suit with many replicated actors	**I-Medium:** Innocent party pays damages **II-Medium:** Victim uncompensated	**Medium:** Appeal, transfer funds	**Medium:** "preponderance of the evidence – more probable than not"
Medicine and Public Health						
Decision to treat minor injury with established therapy (e.g. splint broken bone)	Doctor	Hours to days	**Very high:** Problem and treatment well known	**I-Medium:** Cost of therapy wasted and side effects **II-High:** Curable condition not treated	**Medium:** Stop treatment	**Medium:** Heal the patient but "do no harm"
Decision to treat terminal disease with experimental therapy (e.g. new cancer drug)	Doctor (? and others)	Days to months	**Low:** Novel therapy	**I-Medium:** Cost of therapy wasted and side effects **II-Very high:** Patient dies of disease; no knowledge gained	**Medium:** Stop treatment	**Low:** Heal the patient but "do no harm"
Decision to recommend public health measure (breast cancer screening for women in their 40s)	Gov't agency	Years	**Medium:** Need to balance health outcomes with economic factors	**I-High:** Cost to individuals and society of unnecessary treatment **II-High:** Some patients sick or die prematurely	**High:** Money spent	**High:** "Evidence based" The controversy here is over values – whether society should be more worried about Type I versus Type II errors.
Military and Public Safety						
Launch nuclear warheads	National security team	Minutes	**Medium:** Lots of data but minimal time to evaluate	**I-Very high:** Launch unprovoked nuclear attack and retaliation **II-Very High:** Lose ability to counterattack	**Very high:** Undoable	**Not applicable:** Rules of engagement
Shoot suspect in dark alley who may have gun	Police officer	Seconds	**Low:** No time to collect information	**I-High:** Innocent bystander wounded or dead **II-High:** Officer wounded or dead	**Very high:** Bystander wounded or dead	**Not applicable:** Rules of engagement
Hurricane evacuation	Civil defense agency	Hours to days	**Medium:** Complex system and need to weigh safety versus costs	**I-High:** Major economic disruption; desensitization of public **II-Very High:** Many people injured / die	**High:** Money spent	**Low:** "Better safe than sorry"

(*continued on next page*)

Table 1 (*continued*)

Nature of decision		Independent conditions under which decision is made				Dependent variable
Field example of decision	Decision maker	Urgency	Certainty	Consequences of error Type I. action/ Type II. inaction	Irreversibility of Type I error of action	Established burden and standard of proof
Engineering						
Decision to build a bridge to a given set of specs	Engineer	Months to Years	**Very high:** Can quantify benefit-cost analysis	**I-High:** Bridge fails II-Medium: No bridge built	**High:** Money spent	**Not applicable:** "Does it work? What is benefit-cost? Will it meet standards?"
Science/Academia						
Accept scientific result	Researcher	Days	**High:** Can generally estimate error	**I-High:** Damage reputation **II-Medium:** Miss key result, get scooped	**Medium:** Retract article	**High:** "95% confidence interval"
Offer tenure	Department	Months	**Medium:** some data	**I-High:** Get lousy colleague for life **II-Medium:** Lose great colleague and get sued	**Very High:** Cannot fire colleague	**High:** "Get it right"
Conservation Cases from this Paper						
Remove tortoise from roadway	Concerned citizen	Seconds to minutes	**High:** Small system	**I-Medium:** Tortoise may reattempt entire crossing, but maybe at quieter time **II-Very High:** Tortoise run over	**Medium:** Tortoise may be run over	**Not applicable:** Good Samaritan rules
Remove fish from pond ahead of bulldozers	Agency staffer	Hours to Days	**High:** Small system	**I-Medium:** Fish may die in new site **II-Very High:** Fish die when pond removed	**High:** Can try another site	**Not applicable:** Rules of engagement
Invest in specific elephant control methods	Park manager	Months	**Low:** Complex system without clear strategy	**I-???:** Unknown **II-???:** Unknown	**???:** Unknown	**Not applicable:** Adaptive management
Capture endangered marsupials facing pathogen	Agency staffer	Months	**High:** Problem well understood	**I-Medium:** Captive breeding established, but goes awry **II-Very high:** Pathogen drives population to extinction	**Low:** Population can be restored	**Low:** Just do it
Change water flow patterns from dam	Agency staffer	Months	**Medium to high:** Problem reasonably well understood	**I-High:** Farmers lose water for crops **II- High:** Riparian system loses viability	**Low:** Water flow can be restored	**Medium:** Think before acting
Release biocontrol virus in invasive rat population	Agency leader	Months	**Medium:** Lots of potential for surprise	**I-High:** Virus attacks other organisms **II- High:** Rats overrun endangered bird populations	**High:** No control once virus is released	**High:** Study the problem carefully and prepare a formal impact assessment

2. Who is the **decision maker**? Is it a judge, a jury, a doctor, a review board, or just a concerned citizen? In almost all of the examples listed in our table where there is a formal burden of proof, the decision makers are "professionals" authorized by society to be making the decisions of interest. The decision maker can be one individual, or sets of individuals playing different roles in the system (e.g., judge, jury, prosecutor, and defendant's attorney). But in most cases, these professionals generally explicitly belong to, or are recognized by an agency, organization, and/or professional association that establishes the code of conduct for that profession. The one exception it the "jury of peers" which while not composed of professionals, is certainly formally authorized by society to be making the decision of interest.

Independent Conditions Under Which Decision is Made – the next set of parameters relate to the conditions, or "independent variables" under which the decision is being made:

3. What is the **urgency** of the decision? On what timeframe is the decision being made? For example, the decision of a police officer to shoot a hostile suspect may need to be made in split seconds, whereas a decision to convict a suspect in a capital case may take place over decades. This variable is expressed in our table as seconds, minutes, hours, days, weeks, months, years, or decades.
4. What is the **degree of certainty** in the decision? For example, is this an engineering problem or medical treatment of a broken bone in which probable outcomes of taking action, inaction,

and/or alternative actions can be accurately assessed? Or is it more like deciding a complex civil lawsuit, or whether to evacuate a region for a hurricane in which there is a great deal of uncertainty surrounding the decision? In general, the degree of certainty is a function of the complexity of the system in which the decision is being made, the evidence base that informs the decision, the knowledge of the decision maker, and the degree to which the decision lends itself to mathematical analysis and quantification. This variable in categorized in our table as being "low" to "very high."

5. What are the **relative consequences of errors of action and inaction**? Who bears the costs of making the wrong decision? In some cases, such as executing an innocent suspect or publishing a scientific result that is not correct, the relative costs of taking action where no action is warranted (Type I error) greatly outweigh the costs of choosing not to act when action is warranted (Type II error). In other cases, such as giving an experimental treatment to a terminally ill patient or evacuating a city in the face of an oncoming hurricane, the costs of Type II errors greatly outweigh the costs of Type I errors. And finally, in some cases such as deciding when to offer cancer screening to the public, or deciding to launch or not launch nuclear weapons in the face of an enemy attack, it is challenging to weigh the consequences of Type I versus Type II error. This variable in categorized in our table as being "low" to "very high" for both the consequences of a Type I and a Type II error.
6. How **irreversible** is the decision? If the wrong decision is made, how easily can it be undone? For example, putting a criminal suspect in jail is obviously more reversible than capital punishment. We rated the irreversibility of the decision as being "low" to "very high."

Dependent Variable: Established Burden of Proof – finally, taken together, the above factors help shape the final "dependent variable":

7. What is the established **burden and standard of proof** within the field for that decision? Specifically, is the burden of proof on the decision maker and if so, what is the standard that the decision maker needs to meet? We categorized the standard of proof as being "low" to "very high." Where possible, we also tried to capture the essence of the established standard of proof in each field. For example, "beyond a reasonable doubt" in criminal cases as opposed to "more probable than not" in legal civil cases.

3. Analysis of the burden and standard of proof in different fields

Our next step was to examine how each of the independent variables contributed to the burden and standard of proof in each field. Our sample size and the categorical nature of our assessments precluded a statistical analysis of the effect of each of our independent variables on the standard of proof. As a next-best alternative, we qualitatively looked for correlation between our independent variables and the relative strength of the burden of proof in each field. We found that no one variable seems to correlate with the relative burden of proof. Instead, it seems that different variables are "binding" on different fields and that as a result, members of each field have developed a burden and standard of proof that encapsulates their core ethical values.

For example, in the criminal legal cases, the key concept that drives the establishment of a relatively high standard of proof is "better 10 guilty men go free rather than 1 one innocent man be put in jail." The Anglo-American legal tradition puts a premium on avoiding the consequences of a Type I error, thus requiring a high burden of proof ("beyond a reasonable doubt...moral not mathematical certainty"). Furthermore, this burden of proof increases when the result is undoable (capital punishment versus a jail sentence). In the legal civil cases where the result is primarily about financial payments that could always be undone, there is a much lower burden of proof ("more probable than not") (Lewis LaRue, personal comment, Wikipedia.org/legal burden of proof).

In the medical field, the key phrase that drives the establishment of a lower standard of proof is to attempt to cure the patient but also to "do no harm." Thus, in the case of a doctor choosing to treat a broken bone with a proven therapy, or treat an individual terminally ill patient with an experimental therapy, the choice to be made is obvious. This choice becomes much more difficult, however, when the costs and benefits of a therapy are more uncertain, or when the viewpoint shifts to a public agency that needs to weigh the social costs and benefits of approving a new controversial therapy.

In the public safety and also the military fields, one of the critical drivers is the urgency of the situation in terms of deciding how to respond to a criminal with a gun, evacuate a city in the path of an oncoming hurricane, or even whether to launch nuclear warheads. As a result, these fields tend to work out "rules of engagement" in advance that provide guidance to practitioners as to how to respond to these crisis situations when decisions need to be made very rapidly, thus obviating the need for a formal burden of proof.

In engineering, the relatively high certainty of outcomes surrounding many decisions means that the field does not need a formal burden of proof. For example, engineers can calculate with a great deal of precision whether a given investment in a bridge will meet pre-defined safety standards, whether it will stand up to storm events or earthquakes of a certain magnitude, and even the range of uncertainty around different investment options. As a result, the standard for taking action can be "Does it work" or "Does it pass a benefit-cost analysis?" and as such, there is not really a need for a formal burden of proof. Or at least, the decision about setting the burden of proof lies in establishing the safety standard itself, rather than in each individual engineering project.

Finally, in academia as in the law, a strong value against making Type I error leads to high standard of proof embodied by the 95%+ confidence level considered the standard in statistical tests. Likewise, the relative irreversibility of firing a tenured professor versus an employee of private firm also increases the burden of proof required in these personnel decisions.

4. Defining the burden and standards of proof for conservation

Building on the above analyses and Table 1, we set out to create a framework for what the burden and standards of proof might look like in conservation. This framework takes the form of a decision tree as shown in Fig. 1. The decision tree helps a conservation practitioner facing a particular decision to act or not act by posing a simple set of questions.

The first question is whether your decision to act **substantially affects others**. There are obviously some decisions in the conservation world, such as the choice of logo for an organization, or choosing whether to invest an organization's time in a potentially controversial project, that only really affect the organization itself and thus do not require any formal burden of proof. For the most part, however, even without a biocentric world view, conservation decisions clearly affect many people and as such, need to be taken with appropriate precautions. And if the definition of "others" is expanded to include the existence rights of all species and ecosystems then, most conservation decisions would presumably meet this test.

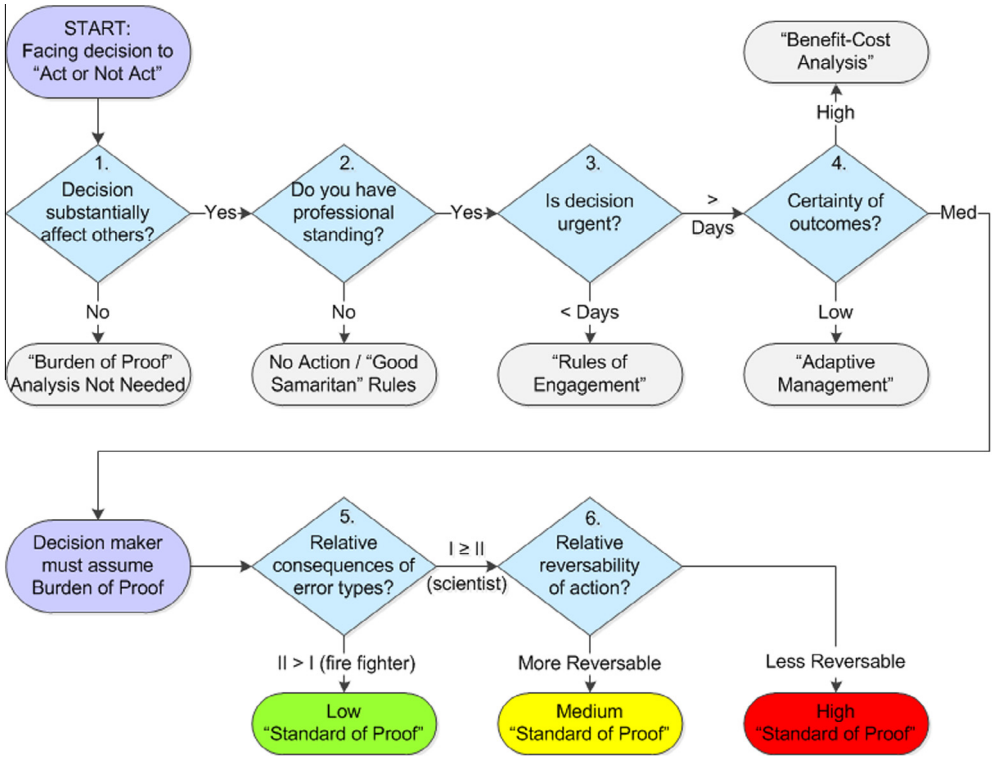

Fig. 1. Proposed decision tree for determining the burden and standard of proof.

The second question is whether you have the **professional standing** to make this decision to act. There is no professional association of conservation practitioners as there are for doctors or lawyers. And many conservation initiatives include a wide range of practitioners and stakeholders with varying degrees of professional credentials. But there are many professionals who jobs involve delivering conservation outcomes. If you are a park ranger, land manager, agency biologist or other conservation professional, or you are the land or resource owner/manager and you have the authority to take the action at hand, then you have professional standing. If you do not have appropriate professional standing, then you should generally not attempt to take any action. Note however, that just as society has created "Good Samaritan" rules that protect members of the public who act in good faith to help a traffic accident victim, the citizen who moves a tortoise out of a busy roadway should be considered in a similar fashion.

The third question is the **urgency** of the decision. If the decision is one that needs to be made within a matter of seconds, hours or days, such as whether to shoot a hostile criminal suspect, or the need to move the fish ahead of the bulldozers, then it is probably necessary to develop "rules of engagement" that outline parameters for making these decisions. We do not know of any such rules in general use in conservation. In most conservation situations, however, it seems like almost all decisions are made on longer time frames and therefore have a lower sense of urgency.

The fourth question relates to the **certainty of outcomes**. If you are facing a decision in which not a great deal is known about the system and/or there is low certainty about the results of taking action, such as the case with the crop-raiding elephants, then you should adopt an adaptive management approach in which you use active or passive experimentation to test what actions might work (Lee 1993; Salafsky et al. 2002). If there is a medium level of certainty, however, then you now carry the burden of proof and need to meet the appropriate standard of proof. Note, however, that if you are facing a decision for which there is a great deal known about the system, and the effects of the action can be predicted with high certainty, such as building a bridge or treating an invasive weed with herbicide, then the decision can be made purely on the basis of benefit-cost analysis, without reference to a burden of proof.

Once you get to the second row of Fig. 1, you must now assume the burden of proof. The fifth question relates to the **consequences of errors of action versus inaction**. If you are in a situation like the doctor providing experimental treatment to a terminally ill patient or the agency managing the marsupial population almost certain to be wiped out by the pathogen, then the consequences of inaction are much more grave than the consequences of a wrong action. In these cases, you have defined a low standard of proof for the action and you can unhesitatingly take action. If, however, the consequences of an erroneous action exceed or equal the costs of inaction, you need to meet a higher burden of proof.

Finally, the sixth question is about the **relative reversibility of the action**. If the action can be relatively easily reversed such as adjusting the timing of release of water from the reservoir, then you need to meet a medium standard of proof, meaning you should probably carefully think about the issues before acting. If, however, the action is less reversible, such as physically removing the dam from the river, or releasing the genetically altered virus designed to target the exotic rats, then taking action requires meeting a high standard of proof. This last case is essentially invoking the "precautionary principle" (Cooney 2004; Ahteensuu and Sandin 2012) and requires you to undertake appropriate scientific investigations and/or prepare an appropriate formal impact assessment.

5. Conclusions and next steps

In summary, we propose that a decision maker must assume the "burden of proof" when there is a decision to act that substantially affects others, in which the decision maker has professional standing, where there is not immediate urgency to the decision, and where there is some but not complete certainty about the

outcomes of acting versus not acting. Once these initial tests have been met, in situations in which the decision maker is more worried about the consequences of not acting, then there is a relatively low standard of proof for taking action. If the decision maker is concerned with the consequences of acting in error, but the action is relatively reversible, then a medium standard of proof is required. And finally, if there are concerns about the consequences of acting in error, but the action is relatively irreversible, then a high standard of proof is required.

Once the appropriate burden of proof has been established, the next question is what does it mean to satisfy this burden? Given that many conservation projects already spend too much time on planning versus action, we certainly do not want to add yet one more bureaucratic requirement to the project planning and implementation cycle. And we certainly recognize that the choice of taking action is often influenced more by resource availability and constraints rather than moral considerations. Nonetheless, it is our hope that the flow chart will help practitioners to think about their specific situation and then unless a high burden of proof is warranted, make and then implement their decision with confidence. If a higher burden of proof is required, then practitioners and/or the people who authorize their work might require a reasonable analysis of the situation, and or an appropriate impact assessment, or more formal structured decision making process (Gregory et al., 2012) that appropriately brings science into the picture. We also hope that this framework will more broadly help guide the ongoing conversation about the role of science in decision making in conversation.

The framework presented in this paper needs to be tested and improved by applying it different conservation situations. It is possible that the framework may need to be adjusted for different subsets of conservation practice such as managing highly endangered species versus broad scale spatial planning. In addition, this framework may need to be adapted for special circumstances. For example, it may be harder to decide whether to take actions designed to mitigate extremely low frequency, but high risk threats like oil spills or earthquake, what Taleb (2007) has termed "black swans." Likewise, the burden and standards of proof concepts presented in this paper draw heavily on an Anglo-American legal tradition. Different cultures may require different standards of proof. Hopefully, however, this work can lead to the development of a formal standard for the burden of proof in conservation.

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