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CONTRIBUTED PAPERS

Application of decision tools to ethical analysis in biodiversity conservation

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Abstract

Achieving ethically responsible decisions is crucial for the success of biodiversity conservation projects. We adapted the ethical matrix, decision tree, and Bateson's cube to assist in the ethical analysis of complex conservation scenarios by structuring these tools so that they can implement the different value dimensions (environmental, social, and animal welfare) involved in conservation ethics. We then applied them to a case study relative to the decision-making process regarding whether or not to continue collecting biomaterial on the oldest of the two remaining northern white rhinoceroses (*Ceratotherium simum cottoni*), a functionally extinct subspecies of the white rhinoceros. We used the ethical matrix to gather ethical pros and cons and as a starting point for a participatory approach to ethical decision-making. We used decision trees to compare the different options at stake on the basis of a set of ethical desiderata. We used Bateson's cube to establish a threshold of ethical acceptability and model the results of a simple survey. The application of these tools proved to be pivotal in structuring the decision-making process and in helping reach a shared, reasoned, and transparent decision on the best option from an ethical point of view among those available.

KEYWORDS
Bateson's cube, conservation ethics, decision tree, ethical analysis, ethical matrix, northern white rhino

Resumen

Que se logren decisiones éticamente responsables es crucial para el éxito de los proyectos de conservación de la biodiversidad. Adaptamos la matriz ética, el árbol de decisión y el cubo de Bateson para apoyar con el análisis ético de escenarios de conservación compleja mediante la estructuración de estas herramientas de tal manera que puedan ejecutar las diferentes dimensiones de valor (ambiental, social y bienestar animal) involucradas en la ética de la conservación. Después aplicamos las herramientas a un estudio de caso relacionado con el proceso de toma de decisiones respecto a si se debe seguir o no recolectando material biológico del rinoceronte blanco del norte (*Ceratotherium simum cottoni*) más viejo (una subespecie funcionalmente extinta) de los dos que existen. Usamos la matriz ética como un punto de partida para una estrategia participativa para la toma ética de decisiones y para recopilar los pros y contras éticos. Usamos el árbol de decisión para comparar las diferentes opciones en juego con base en un conjunto de deseos éticos. Usamos el cubo de Bateson para establecer un umbral de aceptación ética y modelar los resultados de una encuesta simple. La aplicación de estas herramientas demostró ser central en la estructuración del proceso de toma de decisiones y en el apoyo para lograr una decisión compartida, razonada y transparente sobre la mejor opción a partir de un punto de vista ético entre aquellos disponibles.

PALABRAS CLAVE

análisis ético, árbol de decisión, cubo de Bateson, ética de la conservación, matriz ética, rinoceronte blanco del norte

【摘要】

做出符合伦理的决策对于生物多样性保护项目的成功至关重要。本研究改进了伦理矩阵、决策树和贝特森方块模型, 并通过这些工具的结构化, 将其用于保护伦理涉及的不同价值维度(环境、社会和动物福利), 以协助复杂保护情景的伦理分析。接下来, 我们将该方法应用到关于是否继续采集仅存的两头北方白犀牛(*Ceratotherium simum cottoni*) (白犀牛的一个功能性灭绝亚种) 老年个体生物样本的决策过程的案例研究之中。我们使用伦理矩阵收集了伦理方面的利弊因素, 并将其作为参与式伦理决策方法的出发点, 并使用决策树比较了基于一系列伦理需求的不同选择。此外, 我们使用贝特森方块模型建立了一个伦理上可接受性的阈值, 并对一项简单的调查结果进行了建模。结果表明, 这些工具的应用在构建决策过程和帮助站在伦理角度、从现有选项中最优地达成共同、合理且透明的决策方面发挥了重要作用。**【翻译:胡怡思;审校:聂永刚】**

关键词: 保护伦理, 伦理分析, 决策树, 贝特森方块模型, 伦理矩阵, 北方白犀牛

INTRODUCTION

Achieving ethically responsible decisions is crucial for the success of biodiversity conservation projects. At all levels of the decision-making process, hard choices and trade-offs need to be addressed (McShane et al., 2011) and conflicts must be mediated, lest they lead to failure (Catalano et al., 2019; Redpath et al., 2013). However, the path to ethically responsible decisions can be torturous. The ethics of conservation is multidimensional and encompasses many value contexts (Biasetti & de Mori, 2020; Minteer & Collins, 2005a, 2005b). Besides the many facets of environmental and biodiversity values (Chan et al., 2016; Pearson, 2016), conservation action needs to take into account the welfare of the animals involved (Hampton et al., 2018; Johnson et al., 2019) and equity and justice for and well-being of people (Chan et al., 2007; Shoreman-Ouimet & Kopnina, 2015). For these reasons, conservation decision-making is often ethically complex and requires careful analyses.

We considered three decision tools, the ethical matrix (EM) (Mepham, 1996; Mepham et al., 2006), the decision tree (DT), and Bateson's cube (BC) (Bateson, 1986, 2005; Driscoll & Bateson, 1988), and we adapted them for the ethical analysis of conservation decision-making. We then applied these tools to a case study to show how they can be used to reach reasoned, transparent, and shared ethical decisions. We sought to show how these tools can provide a systematic way to unpack ethically complex situations and identify the main nodes of the decision-making process; help structure the discussion; provide a guide for collecting information; offer a starting point for participatory processes; and, given their standardized form, be used to check consistency and compare cases.

TABLE 1 General ethical matrix for conservation decision-making (from Biasetti & de Mori, 2021)

Stakeholders	General ethical principle of well-being	General ethical principle of autonomy	General ethical principle of fairness
Ecological entities	conservation	freedom from human intervention	equal treatment in relation to conservation
Animals	health and functioning absence of negative affective states and allowance of positive ones	living natural lives and opportunity to exert species-specific behaviors	equal treatment in relation to welfare
People	psychological and physiological welfare sustainable social, economic, and cultural welfare	freedom of choice capacity to exercise fundamental aspects of one's persona self-determination	equal and fair treatment

All the tools we considered were either developed for ethical analysis (EM and BC) or have some established history of application to this end (DT), and their structure allows for taking into account different dimensions of value when analyzing a scenario. For these reasons, their application to conservation ethics seems particularly promising. Although the EM has already been tailored to conservation (Biasetti & de Mori, 2021), here we used it as a checklist for gathering ethical pros and cons and as a starting point for a participatory approach. DTs have also been used in conservation (starting with Maguire et al., 1987), but to the best of our knowledge, not in the ethical analyses of conservation efforts. Although the application of BC to conservation has been advocated (MacMahon et al. 2012), it is underused, and its potentialities are still not fully explored. In addition to their separate applications, we considered the tools' integrated use in a participatory decision-making process.

THE TOOLS

Ethical matrix

The EM is a conceptual tool used to identify the value demands involved in a complex scenario. It was introduced by Mepham (1996) in the context of food ethics and it has since been applied to several fields, including conservation (Biasetti & de Mori, 2021; Biasetti et al., 2021). It consists of a table listing general ethical principles in the first row and involved stakeholders in the first column. The remaining cells are filled with the value demands descending from the application of the principles to each stakeholder.

The general ethical principles in an EM are usually well-being, autonomy, and fairness and are derived from a simplified version of the ethical approach known as principlism (Beauchamp, 2010; Beauchamp & Childress, 1985), the purpose of which is to reflect the pluralism of common morality. Stakeholders in the EM for conservation (Table 1) can be ecological entities, individual animals, or people. A filled EM provides a detailed picture of the various demands related to the case coming from environmental ethics, animal ethics, and social ethics.

To fill an EM, it is necessary to identify the specific stakeholders and the category they belong to. Then, the general ethical principles are applied to obtain the value demands. The general EM in Table 1 can be used as a starting template to guide the process, which can be conducted top-down by experts, bottom-up in a participatory process, or with both methods.

A completed EM can be used as a starting point for discussion in a decision-making process in conservation because it provides participants with a checklist of the ethically relevant interests which they can then analyze and determine whether they can be met. The compiled EM can also be used to gather the ethically relevant pros and cons of the options at stake by using the value demands as a yardstick. This makes it possible to anticipate the impact of different choices on stakeholders and to compare them.

Decision trees

DTs are flow-chart-like schemes employed, among other uses, to predict outcomes. A DT starts with a main decision node as the entry point, followed by as many branches as there are options to be discussed. Additional decision and chance nodes representing probabilistic events that may exert a relevant influence on a course of action form the crown of the tree, the branches of which culminate in end nodes that define a set of possible outcomes. When probabilities are assigned to chance nodes and payoffs to end nodes, it becomes possible to identify reasonable choices in face of uncertainty on the ground of the expected values of outcomes.

In an ethical analysis of conservation, DTs are useful for comparing different options on the basis of a set of preestablished ethical desiderata. Chance nodes represent the probability of achieving or not achieving a specific desideratum. Payoffs assigned to end nodes reflect the importance of the desiderata achieved along that branch. The finished DT recapitulates the courses of action that can occur and identifies the available choice that, in face of uncertainty, should provide the expected ethical best outcome. To achieve this result, it is necessary to have previously established the ethical desiderata of the analyzed scenario. Generally speaking, in a DT, the analysis becomes more realistic by incorporating more probabilistic events. However, the analysis also becomes more complicated and runs the risk of being obfuscated by trivial details. For this reason, ethical desiderata should be picked carefully to represent the most important values at stake.

After identifying the ethical desiderata, the end nodes are ranked. In standard DTs, this is done by assigning payoffs mea-

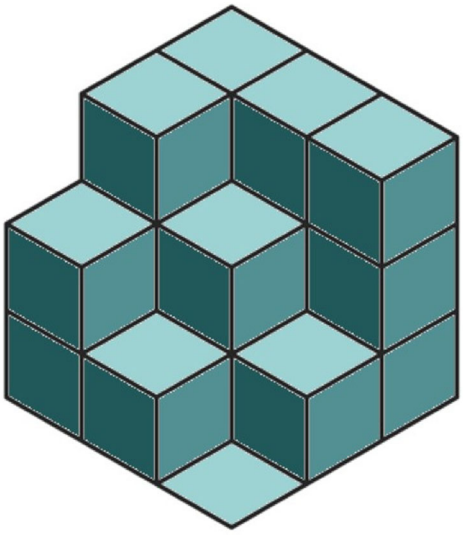

FIGURE 1 The Bateson Cube displays the possibile combinations between 1 and 3 scores attributed along three dimensions. High scores represent high standards. Acceptable scenarios are represented by clear space. On one of the axes, at least a medium score is needed for the scenario to be acceptable.

sured in utility or other common metrics. This is not usually possible for a DT built for the ethical analysis of conservation scenarios because the values involved—such as protecting a species, guaranteeing animal welfare, respect fairness—do not share a common metric. However, incommensurability does not equate with incomparability, and ethical desiderata can be ordered lexically. In this way, it is possible to rank end nodes based on the expected realization of certain values.

Bateson's cube

The BC is a model for decision-making that displays the possible combinations between scores attributed along three dimensions. It was developed by Bateson (1986) to assess the ethical acceptability of scientific research involving animal experimentation (Driscoll & Bateson, 1988). The idea behind BC is that the acceptability of research that can harm animals depends on its scientific quality and usefulness for people. In this way, the BC puts together three value dimensions related to a project: scientific value, social value, and the welfare of the animals involved. In the original description of BC, these are denoted as scientific quality, medical benefit, and the likelihood of suffering (Bateson, 1986; Driscoll & Bateson, 1988).

When applying BC, a score from 1 to 3 is assigned to each dimension. The model then shows whether the combination is acceptable or not. The higher the chances of harming the animals, the higher the scientific quality and usefulness of the intervention has to be for it to be acceptable. Figure 1 shows a BC. Each small cube is one of the possible combinations of scores assigned along the three dimensions. The empty part of the BC represents the acceptable combinations, and the solid part the unacceptable. Along a dimension (that of animal welfare in the original BC), more than the minimum score is required for the intervention to be considered acceptable.

In a decision-making process in which options are evaluated according to ethical criteria, the use of BC provides a way to assess each available option according to its acceptability. The BC can then be used to rank the options, based on the scores obtained. A more detailed ranking can be obtained by establishing a lexical ordering between dimensions.

When applying this tool to conservation, its dimensions must be adapted. The scientific value of the research, for instance, cannot be understood exclusively in terms of the quality of the research. In the original BC, this accounted for the fact that much research conducted on animals does not have a direct and visible benefit for people, but it can still have value in itself (i.e., as scientific research trying to satisfy human curiosity) or for its eventual effects on more directly beneficial research. Both elements—scientific value and the possibility of eventual beneficial effects—are also part of conservation projects. However, they do not define the core of the mission of biodiversity conservation. This can be described as the maintenance and, eventually, the restoration of the natural diversity of life at all biological levels, from ecosystems to genes. When applying the BC to assess conservation, then, it is important to understand the dimension of scientific quality in terms of the capacity to fulfill this mission.

Similarly, social value cannot be understood merely as the estimated medical benefits, as in the original cube. Rather, this dimension should be conceived in its most general and literal sense, that is, as the set of all socially relevant consequences of the analyzed scenario. Finally, animal welfare should be recognized as a multifactorial notion, and suffering, understood as the presence of negative affective states, as only one of its possible meanings (Fraser, 2008). Allowance of positive affective states is another important meaning, as are health and functioning. Furthermore, given the context of conservation, where animals do not live in strictly controlled laboratory environments, the possibility of living natural lives and exercising species-specific behaviors (Bracke & Hopster, 2006) needs also to be taken into account. Once adapted in this way, the BC can be used to analyze conservation efforts starting from the three ethically relevant dimensions usually involved: protection of biodiversity, animal welfare, and impact on people.

CASE STUDY

To show the potentialities of these tools, we applied them to a case study of the decision-making process regarding whether or not to continue collecting biomaterial on the oldest of the two last northern white rhinoceroses (NWR) (*Ceratotherium simum cottoni*), a functionally extinct subspecies of the white rhinoceros (*Ceratotherium simum*).

We know of only two NWR in the world, both are female and neither can carry a pregnancy to term. Thus, the NWR is presently considered "functionally extinct" (Emslie, 2020), and the only chance to revert this state relies on the advancement of scientific techniques (Hildebrandt et al., 2021a; Saragusty et al.,

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2016). The strategy adopted by the Biorescue project—an international consortium led by the Leibniz Institute for Zoo and Wildlife Research—combines advanced assisted reproductive technologies and stem-cell-associated techniques (Hildebrandt et al., 2018). Both approaches involve the use of biomaterial from living as well as from deceased individuals, in the form of cryopreserved gametes (Hermes et al., 2018) and fibroblast cultures derived from skin samples. The ultimate goal is to establish a self-sustaining and genetically healthy population to be reintroduced into the wild. Short-term goals include collecting additional biomaterial from the remaining individuals, creating viable embryos, and developing methods and protocols for successful embryo transfers in southern white rhinoceros (SWR) (*Ceratotherium simum simum*) recipient cows.

However, questions arose as to the suitability of Najin, the oldest of the two NWRs, as a donor of genetic material. At the time, Najin was 32 years old, had a number of health problems, and no embryos had ever been obtained from her oocytes. It was hence decided to start a decision-making process to discuss, both from a scientific and ethical standpoint, three options: continue performing ovum pickup (OPU) procedures on Najin while constantly monitoring her health conditions and reopening the decision-making process in case of a change in conditions; remove genetic material from Najin a final time by performing an ovariectomy; or stop using Najin as an oocyte donor.

Scientific information

Najin has weak hind legs and several documented reproductive tract pathologies described in white rhinoceroses (Hermes et al., 2006)—including a small leiomyoma in the cervix, multiple small leiomyomata in both horns of the uterus, a uterine adenoma in the right horn, and a septet-cystic neoplastic structure with a diameter of 25 cm in the left ovary.

An OPU in rhinoceroses is a relatively novel procedure that involves gonadotropin-releasing hormone (GnRH) stimulation, general anesthesia with an etorphine-free protocol, and transrectal ultrasound-guided oocyte recovery (Hermes et al., 2009; Hildebrandt et al., 2018). Oocyte harvesting from Najin and her daughter Fatu began on August 22, 2019. Interventions are planned with a minimum of 3 months pause between them to provide the animals with a safe interval to recover (Biasetti et al., 2022; de Mori et al., 2021). When the decision-making process was started after the fourth procedure, further OPU procedures on Najin were suspended. Before the suspension, 10 oocytes were collected from Najin from which no blastocyst-stage embryo was generated. In the same period, 34 oocytes were collected from Fatu in four procedures, and five embryos were generated (Hildebrandt et al., 2021b).

Najin was born in 1989. Ovarian response to GnRH stimulation before OPU in white rhinoceroses aged more than 30 years in the European OPU program has so far been very poor ($n = 5$). This suggests that female rhinoceros after this age enter reproductive senescence in which GnRH stimulation becomes less effective. Moreover, further GnRH stimulations in Najin might promote uterine tumor growth, induce malignancy, and accelerate the growth of the cystic formation in the left ovary.

Abdominal surgery on rhinoceroses is extremely challenging; the complete success of an ovariectomy is very uncertain and the procedure is risky for the animal. This intervention—to the best of our knowledge—has been attempted in white rhinoceroses three times, twice in an SWR (Bronx Zoo and San Diego Safari Park) and once in an NWR (San Diego Safari Park). Removal of ovarian tissue was done endoscopically. Only one animal survived the intervention and only for a short period. No oocytes were collected in a reported case of ovariectomy of a 32-year-old SWR (Pennington & Durant, 2019).

Ovarian tissue harvested postmortem in senescent females has so far not yielded promising results in terms of oocyte retrieval or residual ovarian cortex. The fibrotic state of the ovaries of older, senescent females resulted in zero oocytes and limited amounts of germinative tissue harvested. However, this small but very limited germinative tissue removed during the procedure may become useful once in vitro follicle culture—a technique that has already been successful in some species (e.g., cats [Fassbender et al., 2007])—is developed for NWR (Hildebrandt et al., 2021a).

Ethical aspects

The relevant ethical aspects involved in the decision are the need to respect Najin's welfare, and, indirectly, that of Fatu; the need to preserve Najin's life for intrinsic and extrinsic reasons; and the need to foster the cause of biodiversity conservation. To respect Najin's welfare, three complementary goals must be pursued: assure her physical health and functioning; minimize eventual unpleasant affective states while allowing for normal pleasures; allow the development and performance of natural life functions according to her needs. It must be also taken into account that eventual harm to Najin's could also have a negative impact on Fatu, given their social bond.

Intrinsic reasons for respecting Najin's life stem from the need to respect life in itself. Extrinsic reasons stem instead from the importance Najin has acquired for people who have developed a feeling of connection and affective bonds (of varying degrees) with her—from those who care for her daily to conservationists and the interested public.

There are several instrumental and noninstrumental reasons for conserving this subspecies from the standpoint of biodiversity conservation. The existence value of a taxon is already in itself an important reason for investing in its conservation. Furthermore, because great herbivores, such as rhinoceroses, are important ecosystem engineers (Owen-Smith, 1988), their disappearance can cause further ecological impoverishment (Cromsigt & te Beest, 2014; Waldram et al., 2008). Moreover, the success of the project could have a positive impact on the storytelling of biodiversity conservation, attracting new support, talents, and resources to its cause.

Ethical desiderata

We identified three primary ethical desiderata relative to the decision to be made: avoid major and minor accidents and obtain oocytes. Major accidents are defined as those that threaten the life of the animal. This desideratum follows from all three ethical aspects. Major accidents, besides being life-threatening, may be sources of welfare impairment and may compromise the chances of success of the conservation effort. Minor accidents are those that threaten the welfare of the animal but not her life. This desideratum follows mainly from the ethical aspect of respecting the welfare of the animal, but good animal welfare is also usually relevant to the success of conservation programs involving animal breeding (Greggor et al., 2018). Obtaining oocytes includes direct harvesting and in vitro methods (Hildebrandt et al., 2021a). This desideratum originates from the ethical aspect of conserving biodiversity.

Decision-making process

The participatory decision-making process occurred from March to October 2021. It started with semistructured interviews conducted by members of the Ethics Laboratory for Veterinary Medicine, Conservation and Animal Welfare of Padua University among the other members of the Biorescue consortium ($n = 20$) to individuate options and collect scientifically relevant information. A first draft document was prepared and distributed for collecting further observations and ideas. The tools were then applied to the case. Drafts of EM for each option were circulated among the members of the consortium for them to check and add items. Similarly, a sketch of the DT was discussed among all members. The task of estimating the probability of realizing the end node for each branch was assigned to the veterinarians in charge of performing the interventions. Finally, definitions were provided by members of the Ethics Laboratory for Veterinary Medicine, Conservation and Animal Welfare of Padua University for each dimension of the BC.

A second draft was prepared and presented during a meeting of the consortium in Ol Pejeta, Kenya. Further data were collected after the meeting through an online survey distributed among members of the consortium ($n = 20$). Provided with all the relevant information through the draft document and the meeting, participants were asked to consider how likely was, in their opinion, the occurrence of the three desiderata (avoiding major accidents, avoiding minor accidents, and obtaining oocytes) for each of the three options at stake. Response options consisted of a labeled 6-point Likert scale (1, extremely unlikely, to 6, extremely likely). The answer "I do not know" was also an option. The survey was based on an anonymous, computer-assisted self-completion questionnaire conducted with Google Forms. An email of invitation was used to distribute the link to the survey. Participants completed the self-administered questionnaire individually from July 19–23, 2021. The elaborated data were used to assess the three options through the BC. A final technical report was prepared and made available in October 2021 (Biorescue, 2021).

APPLICATION OF EM

Three kinds of stakeholders were included in the final EMs: biodiversity, Najin, and people involved, including staff performing the procedures, legal and economic managers of Najin, keepers, and all members of the consortium (Tables 2–4). Pros and cons were obtained by using the general template in Table 1 as a checklist.

APPLICATION OF THE DT

The starting decision node D_1 branched into the three individuated options—continue to perform OPU (branch B_1), perform ovariectomy (branch B_2), and stop all procedures (branch B_3) (Figure 2). The B_1 and B_2 branches were further extended by three chance nodes representing the ethical desiderata: avoid major accidents (AMA), avoid minor accidents (ama), and obtain viable oocytes (OO). The B_3 branch was extended with the OO chance node.

The tree has 14 end nodes. Four of these lead to a new decision node identical to the one at the start. If the decision to carry out the OPU procedure on Najin gives rise to a course of action in which no major welfare accident occurs, then the starting question arises again. In all other cases, the decision-making process is concluded.

The end nodes were ranked to match their desirability (Figure 3). The ranking was based on each node's capacity to satisfy four desiderata: avoid major accidents, avoid minor accidents, possibility to repeat the procedure, and collect viable oocytes. The four desiderata are lexically ordered, meaning that the higher-ordered desideratum trumps lower-ordered desiderata (i.e., avoiding major welfare accident trumps satisfaction of all other three desiderata). The desideratum possibility to repeat the procedure was added to reflect the option value in the decision to perform the OPU procedure.

Desiderata were ordered lexically based on their capacity to comply with the ethical aspects described above. Avoiding a life-threatening situation, for example, is important from the standpoint of respecting the life of the animal, but it also avoids possible suffering and ensures the ultimate success of the conservation project. Similarly, ensuring compliance with a good level of welfare, in addition to being a commendable objective in itself, is also important from the standpoint of conservation.

Probabilities for each outcome were determined by ranking the probability of occurrence of the associated events (unlikely, very unlikely, extremely unlikely, likely, very likely, and extremely likely). At each bifurcation following an event node, the branches were classified according to this scale by the veterinarians in the consortium.

For branch B_1 (continue OPU), chances of major accidents were estimated likely. If the cyst growth is further stimulated

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TABLE 2 Ethical matrix collecting ethical pros and cons concerning the first option discussed (continue performing ovum pick-up)

	Well-being	Autonomy	Fairness
Biodiversity	*conservation* pro: Not giving up on this option means at least leaving an open door for opportunistic harvesting after preliminary ultrasound screening. cons: The age, health conditions, and history of past procedures are not encouraging regarding the possibility of collecting new oocytes. Furthermore, no viable embryo has ever been obtained from oocytes collected from Najin in the past. A serious accident could damage the project.	*freedom from human intervention* pro: No clear pro. con: To insist on this path without reasonable expectations of obtaining oocytes and embryos and with the possibility of damaging the animal would be a form of conservation obstinacy—in analogy with therapeutic obstinacy in human medicine.	*equal treatment relative to conservation* pro: No clear pro. con: No clear con. The transrectal OPU protocol, which could be used in the future also for other taxa of rhinos or large mammals, can still be improved.
Najin	*health and functioning; Absence of negative affective states and allowance of positive ones* pro: No clear pro. con: The GnHR stimulation may worsen preexisting health conditions. Cyst growth may lead to a scenario where the life of the animal is seriously threatened by the possibility of a rupture. As prolonged standing sedation is not recommended due to the weak hind legs, preliminary screening for opportunistic OPU has to be done during a short time window.	*living natural lives and species-specific behaviors* pro: no clear pro. con: GnHR stimulation may worsen preexisting health conditions.	*equal treatment in relation to welfare* pro: No clear pro because the current levels of veterinarian screening could be maintained even if OPU procedures are suspended. con: No clear con.
People involved	*psychological and physiological welfare; sustainable social, economical, and cultural welfare* pro: No clear pro. con: A serious accident could cause stress and grief in people close to the animal.	*freedom of choice; capacity to exercise the various fundamental aspects of one's own persona, self-determination* pro: No clear pro, because stopping interventions on Najin does not mean completely stopping this kind of interventions on other white rhinoceros (e.g. Fatu) , with all that can follow from the point of view of knowledge transfer and capacity building. con: a serious accident could damage the professional profile of the people involved.	*equal and fair treatment* No clear pros or cons.

by hormones, there is a mechanical risk that the wall will rupture, an accident that occurred in another NWR, Nabire. The released content of the cyst may be life-threatening for the animal. Chances of minor accidents were similarly estimated likely because the growth of the cyst, even in a nonlife-threatening situation, is still a welfare impairment, as is the manipulation of the animal due to the condition of her legs. Chances of obtaining viable oocytes through OPU were estimated as extremely unlikely based on past results and data on the performance of animals of the same age range as Najin.

For branch B_2 (ovariectomy), the possibilities of major accidents happening were estimated as very likely because of discouraging known precedents. Similarly, the chances of minor accidents were estimated as very likely because of the invasiveness of the intervention and the need for prolonged recovery. Chances of obtaining oocytes were instead estimated as likely because the techniques required for obtaining oocytes from the germinative tissue eventually harvested from the ovaries, while not yet developed for rhinoceroses, have been developed for other mammals.

For branch B_3 (do not perform OPU or ovariectomy), chances of obtaining oocytes were assessed as possible (thanks to the possibility of postmortem harvesting of ovarian tissue for future use in vitro follicle production) yet extremely unlikely.

Situation analyses

By cross-checking the chance of realization of an outcome with its ethical ranking (Figure 3), it was possible to weight its effective value. The expected realization of the best ethical outcomes for branches B_1 and B_2 was rather low. In particular, the best outcome for B_1 had the lowest chance of realization, and the best outcome for B_2 had the second lowest chance of realization. For both branches, the end nodes with the highest chances of realization failed to satisfy most of the desiderata. For B_1, the most probable outcome was the worst scenario of a major accident paired with no oocytes. For B_2, this worst scenario had the second highest estimated chance of happening, and the most probable outcome was a major accident (Figure 4).

TABLE 3 Ethical matrix collecting ethical pros and cons concerning the second option discussed (ovariectomy)

	Well-being	Autonomy	Fairness
Biodiversity	*conservation* pro: There is the possibility of obtaining biomaterial from which to extract or produce gametes. con: Extraction of biomaterial can be done postmortem. Chances of obtaining oocytes depend on technology (in vitro follicle culture) not yet fully established for NWR. A serious accident could damage the project.	*freedom from human intervention* pros: No clear pros. Con: To insist on this path without reasonable expectations of obtaining oocytes and embryos and with the possibility of damaging the animal would be a form of conservation obstinacy—in analogy with therapeutic obstinacy in human medicine.	*equal treatment in relation to conservation* No clear pros or cons.
Najin	*health and functioning; absence of negative affective states and allowance of positive ones* pro: Ovariectomy would solve some of the health conditions relative to the genital apparatus. con: Invasive surgery is needed to perform the intervention. Similar interventions in the past show that this is a life-threatening procedure.	*living natural lives and species-specific behaviors* pro: Ovariectomy would solve some of the health conditions relative to the genital apparatus. cons: Recovery from the procedure could be long and hard. Removal of the ovaries may have adverse physiological effects.	*equal treatment in relation to welfare* pro: No clear pro. cons: Similar interventions in the past show that this is a life-threatening procedure. Even if it succeeds, it will require a long recovery process. It is not clear whether it would be fair, given this, to attempt the intervention on Najin, especially considering her age, because the risk of surgery and postsurgical complications is increased.
People involved	*psychological and physiological welfare; sustainable social, economical, and cultural welfare* pro: No clear pro. con: A serious accident could cause stress and grief in people close to the animal.	*freedom of choice; capacity to exercise the various fundamental aspects of one's own persona, self-determination* pro: No clear pro. con: A serious accident could damage the professional profile of the people involved.	*equal and fair treatment* No clear pros or cons.

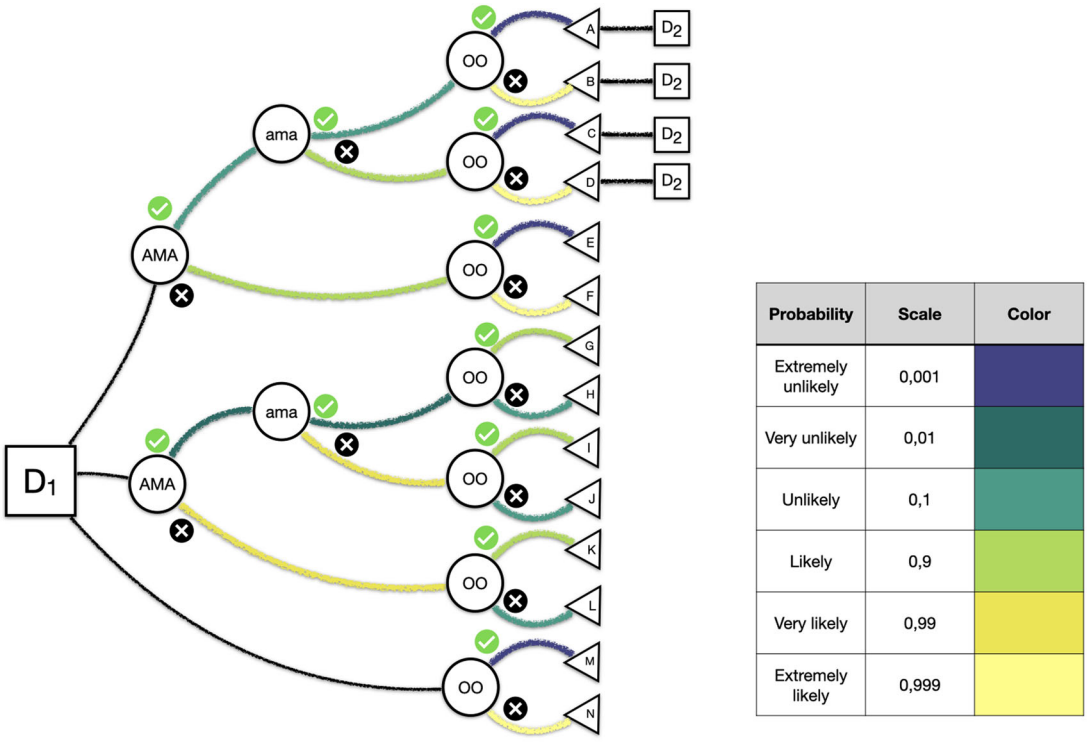

FIGURE 2 Final decision tree for Najin regarding whether to continue to perform OPU (branch B_1), perform ovariectomy (branch B_2), or stop all procedures (branch B_3). Abbreviations: AMA, avoid major accidents; ama, avoid minor accidents; OO, obtaining viable oocytes.

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TABLE 4 Ethical matrix collecting ethical pros and cons concerning the third option discussed (no further collection procedures)

	Well-being	Autonomy	Fairness
Biodiversity	*conservation* pros: Najin's role in the project could still be crucial, thanks to her social competence, which would be vital to transmit to the next generation of NWR. Postmortem collection of ovarian tissue would still be possible, with some chance to obtain oocytes in the future through in vitro follicle culture. con: There is no immediate chance of obtaining oocytes suitable for in vitro embryo production	*freedom from human intervention* pro: Stopping the intervention if the estimated risks are higher than estimated chances of success would be a responsible choice and a demonstration of a nonhybristic attitude. con: No clear con.	*equal treatment in relation to conservation* pro: No clear pro. con: No clear con. The transrectal OPU protocol, which could be used in the future for other taxa of rhinoceros or large mammals, can still be improved.
Najin	*health and functioning; absence of negative affective states and allowance of positive ones* pro: No specific welfare risks. This is the least risky choice. Con: No clear con. Tumor growth will likely still continue.	*living natural lives and species-specific behaviors* pro: Ending any type of intervention in the animal would mean allowing it to conclude the last arc of its existence in a more peaceful way—also considering how much Najin has already given to the cause of the survival of its taxon. Con: No clear con.	*equal treatment in relation to welfare* pro: The regular veterinary screening the animal has undergone in recent years can still continue. Con: No clear con.
People involved	*psychological and physiological welfare; sustainable social, economical, and cultural welfare* pro: This is the least risky choice. Con: No clear con.	*freedom of choice; capacity to exercise the fundamental aspects of one's own persona, self-determination* pro: No clear pro. Con: No clear con, because stopping procedures on Najin does not mean completely stopping this kind of interventions on other white rhinoceros (e.g. Fatu), with all that can follow from the point of view of knowledge transfer and capacity building.	*equal and fair treatment* No clear pros or cons.

Fatu DT

A DT was also built for Fatu (Appendix S1) with the same procedures, and it was used to control consistency and coherence in the decision-making process.

APPLICATION OF BC

The three dimensions of the cube were defined as avoiding a major accident, which in addition to damaging the welfare of the animal also puts her life at risk, with all that can follow for the people involved; avoiding a minor accident that damages the welfare of the animal; and obtaining oocytes.

High scores were used for high possibilities of satisfying the desiderata, and low scores were used for low possibilities. On the axis avoiding major accidents, at least a medium score was considered necessary (but not sufficient) for the result to be acceptable.

Scores were determined based on the data collected in the online survey. Sixteen participants completed the survey (response rate 80%). Descriptive statistics were used to examine the results (see Appendices S2 & S3), and for each scenario, measures of central tendency were used to identify which scenario variants were considered the most likely by the respondents. The 6-point Likert results were converted into a 3-point scale and used to evaluate the acceptability of each option through the BC. Based on mode and mean scores, the options of continuing to attempt the OPU procedure on a regular basis or performing an ovariectomy were deemed not ethically acceptable (with a worse result for ovariectomy). Ceasing to use Najin as a living donor of oocytes was instead considered acceptable.

DISCUSSION

The final decision on Najin's future role in the project was to discontinue any further oocyte collection procedures (including the possibility of ovariectomy). The application of the tools was pivotal in reaching the decision. The EM highlighted numerous cons and a few pros for the options of continuing to perform OPU or attempting ovariectomy and a single substantial con (reducing opportunities for oocyte collection) with some partially counterbalancing pros for the choice of discontinuing all procedures. The DT showed that by choosing one of the first two options, the courses of events that most satisfied the ethical desiderata had a low probability of realization, as opposed to some of the courses of events that lead to ethically unsatis-

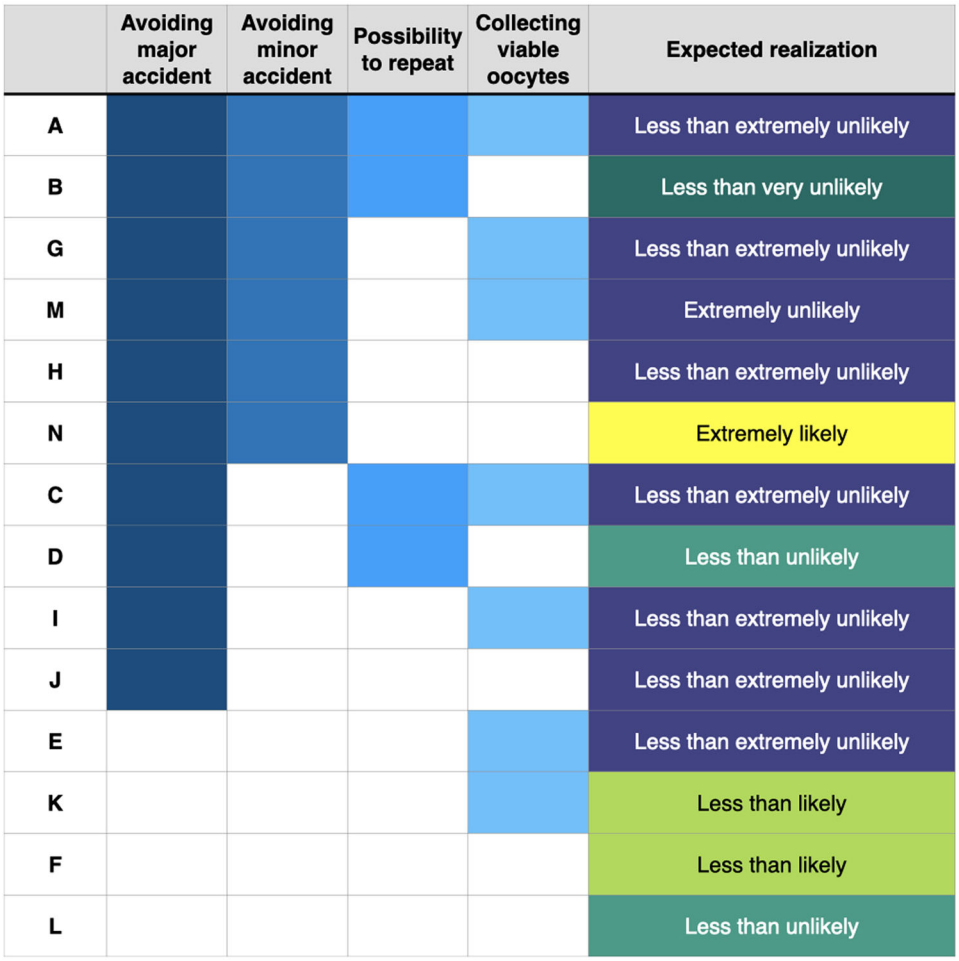

FIGURE 3 Ranking and chances of realization of end nodes of the decision tree used to analyze from an ethical standpoint the three possibile conservation interventions on Najin. End nodes are listed from the ethical best (high) to worst (low) according to their capacity to satisfy the lexically ordered desiderata. Lexical ordering of desiderata goes from left (dark blue, higher lexical order) to right (light blue, lower lexical order). Chances of realization of each nodes is recapped in the rightmost column.

factory outcomes. Analyses of the survey data modeled on BC showed that only the option to suspend interventions on Najin and to reshape her role in the project outside of oocyte donation was considered ethically acceptable.

The case study demonstrated the value these tools add to participatory decision-making in conservation. In particular, it showed the capacity of these tools to structure the processes and provide an organized framework for gathering relevant information and analyzing the available options.

Through the application of the tools, it was possible for participants to reflect on the ramifications of possible decisions and construct a shared, transparent, and reasoned justification for the chosen option. However, the tools did not determine the final choice. There are different and sometimes conflicting ethical approaches to conservation (Biasetti & de Mori, 2020; Gamborg et al., 2012). Biodiversity conservation can intersect various dimensions of value, and which of these to prioritize depends on underlying assumptions. The tools we applied here do not espouse a particular approach. They are not prescriptive, meaning that their structure does not reflect a specific value ordering. Instead, they are built to be compatible with different underlying value choices and to recognize the pluralism of views in conservation ethics.

Integrating the tools in the decision-making process

Combining the tools gave a robust structure to the decision-making process, allowing analysis of the available options from different angles, a compilation of different points of view, and articulation of a transparent decision-making process in which all elements that led to the final choice were organized and made explicit. The use of EM provided participants with a map of the value demands so they could easily compare the ethically relevant issues raised by each of the three options. The application of DT made it possible to identify the ramifications of the three options, classify them on the basis of their possibility of realization and ethical desirability, and combine data on the two latter aspects. Finally, the use of BC made it possible to model the data collected in the survey, establish a simple threshold for ethical acceptability, and adjudicate the three options accordingly.

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End-node	Expected realization	Drawbacks
	OPU	
F	Less than likely	Major accident, no oocytes. Worst scenario for B_1, highest estimated chance to happen if procedure is repeated
D	Less than unlikely	Minor accident, no oocytes. Possibility to repeat the procedure is nearly worthless as chances of obtaining oocytes remain low
B	Less than very unlikely	No oocytes. Possibility to repeat the procedure is nearly worthless as chances of obtaining oocytes remain low
E	Less than extremely unlikely	Major accident
C	Less than extremely unlikely	Minor accident
A	Less than extremely unlikely	No accidents, oocyte retrieved. Best scenario for B_1, lowest estimated chance to happen
	OVARIECTOMY	
K	Less than likely	Major accident
L	Less than unlikely	Major accident, no oocytes. Worst scenario for B_2, second highest estimated chance to happen.
I	Less than extremely unlikely	Minor accident
J	Less than extremely unlikely	Minor accident, no oocytes
G	Less than extremely unlikely	No accidents, oocyte retrieved. Best scenario for B_2, second lowest estimated chance to happen
H	Less than extremely unlikely	No oocytes
	NO FURTHER INTERVENTION	
N	Extremely likely	No oocytes
M	Extremely unlikely	

FIGURE 4 End node analysis of the decision tree used to analyze from an ethical standpoint the three possibile conservation interventions on Najin.

By using the tools together, it was possible to integrate inputs from different participants and data collection methods. The pros and cons of the EM were collected in an unstructured manner, allowing participants to exchange information, opinions, and ideas. Estimation of the probability of realization of the chance nodes of the DT was carried out by the veterinarians in charge of the procedures. Scoring on the dimensions of the BC cube was provided again from all participants, this time in a structured manner, via a survey, to counteract the eventual influence of factors like personality and status.

Finally, the integrated use of tools gave a solid organization to the participatory decision-making process. Filling the EM was the starting point, building the DT was the central part, and modeling the BC was the conclusion. In addition to setting the pace, the tools were instrumental in collecting and framing the pieces of information and ideas that emerged during all phases in the decision-making process. In this way, it was made easier to build a technical report in which the scientific facts and ethical desiderata behind the choice were presented transparently and clearly.

Strengths and limitations

The usefulness of using an EM to support a participatory process is well known (Kaiser & Forsberg, 2001; Kaiser et al., 2007). The structure of the EM encourages the participants to imagine themselves in the shoes of others, ensuring, as much as possible, a plural and comprehensive collection of the relevant value demands.

Here, demands from the general template (Table 1) were used as a checklist to collect the ethical pros and cons of each option. The advantage of using an EM to build pros and cons list is twofold. First, the EM provides a structured frame for collecting and organizing the items in the list. Second, due to the pluralistic and comprehensive nature of the checklist provided by the EM, the resulting pros and cons list is compiled from a wide range of value perspectives. This kind of EM can be very useful when it comes to analyzing competing choices because it can be used to compare the different degrees of compliance of the analyzed options with the value demands on the template. This can be useful for understanding how the options differentially

affect stakeholders. By comparing the EMs in our case study, for example, it was clear that the option that most respects the welfare of Najin was to cease all further intervention. However, unless the different value demands and the degree of compliance are ranked or scored, the analysis that can be carried out remains qualitative.

The potential of DT in conservation was recognized early on (Maguire et al., 1987; Maguire, 1991), although it remains an underused tool (Canessa et al., 2016), which, to the best of our knowledge, has never been employed before for the ethical analysis of biodiversity conservation decision-making. Application in the case study shows how the DT can be employed to analyze different options on the basis of a set of previously identified ethical desiderata. Building a DT, however, is never a neutral process because it is necessary to identify and select different pieces of information. More specifically, it is necessary to identify options, anticipate possible interfering events, establish their probability, and evaluate outcomes. Wrongful assumptions or estimations may lead to skewed representations of outcomes. For these reasons, DTs are vulnerable to bias and epistemic limitations and may fail to identify the best option (Regan et al., 2005). To obviate in part these limitations, a key point of the construction of the DT (estimating the possibility of realization of each chance node) was carried out by a restricted group of participants in charge of the procedures.

There are three limitations in the design of this specific DT. The first is that probabilities of realization of chance nodes are assigned through a simple scale. The second is that the DT does not take into account a possible course of events in which both major and minor accidents happen. In this case, a simplification was preferred, to reduce the number of possible outcomes, considering that a course of action in which a major accident occurs is already a really bad outcome per se. Finally, the tree is not complete. For example, the possibility that Najin might contribute to the conservation of the taxon by transmitting some of her social skills and competencies to the next generation of NWR was not included. Including this element would have required making acceptable estimates of the life expectancy of the animal and of the time still required to see the birth of an NWR calf. This would also have required the inclusion of an additional chance node at the end of several branches, multiplying in this way the number of outcomes.

In any case, it is doubtful that by refining the DT to avoid the previous limitations, it would be possible to obtain more optimistic evaluations regarding the OPU and ovariectomy options. In fact, by including in the analysis the capacity of Najin to contribute to the conservation efforts by transmitting her skills to the next generations, the expected outcomes for the first two options would likely appear even worse.

To check the final results, a DT was also built for Fatu (Appendix S1). In this DT, although the possibilities of realization of chance nodes concerning ovariectomies remain unvaried, the option of continuing performing OPU procedures fared better than the option of discontinuing every intervention. By comparing the two DTs, it is possible to show that, given the same goals, desiderata, and set of choices, yet different circumstances, it is ethically acceptable to support different courses of action for the two females.

The use of the BC in conservation has been advocated (McMahon et al., 2012), but, looking at the literature, it remains severely underutilized (but see Hickling, 1994). The BC, however, as shown by its application in the case study, is a very powerful tool thanks to its ease of use and the comprehensibility with which it represents the threshold of ethical acceptability in a three-dimensional scenario. The three comparative dimensions are not commensurate (Bateson, 2005), but this is not a negative aspect of the tool, the goal of which is to propose a practical rule to assess ethical acceptability based on a reasonable mediation between different points of view. Thus, the BC is useful in participatory decision-making processes because it is easy to apply and visualize, as long as what is represented by its dimensions has been established previously. Adapting the dimensions used in the original BC to the specific situation was an essential step toward exploiting the full potential of this tool. In this case, the three ethically relevant dimensions (scientific value, animal welfare, and social value) were made to coincide with the desiderata identified in the participatory decision-making process. By adopting the ranking between desiderata already employed for the DT, it was possible to order all the possible combination of scores in the BC to establish the worst and best outcomes among acceptable and unacceptable results. Scores modeled on the BC for each option confirm the expectations derived from the application of the other two tools, showing the consistency of the decision-making process.

Although the use of surveys can be a valid alternative to other usual methodologies for obtaining scores for the BC—like evaluation by committees—the sample must be chosen to contain only experts and stakeholders. In this way, however, the sample is often destined to be numerically small, as in this study, where the number of respondents was 16 people.

Tools like the EM, DT, and BC supply a flexible yet solid structure for ethical analyses in conservation and can assist in reaching balanced decisions, in which all the necessary factors are collected, considered, and scrutinized and the value choices are reasoned and made clear. In this way, these decision tools can contribute to the communication and responsible implementation of a project and hence to its success. As the case study showed, conservationists will increasingly need to address complex scenarios requiring ethical investigation. The need to refine the tools we employ for this task will increase over time.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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