TRIAGE IN CONSERVATION

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PUBLISHED IN: Frontiers in Ecology and Evolution

frontiers Research Topics

frontiers

ISSN 1664-8714
ISBN 978-2-88945-435-8
DOI 10.3389/978-2-88945-435-8

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TRIAGE IN CONSERVATION

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The Critically Endangered black rhinoceros, *Diceros bicornis bicornis.* Rhinoceros populations are threatened by escalating levels of poaching throughout their range. Photo credit: Guy Castley.

Ecosystems and their constituent species the world over face a barrage of ongoing, and often escalating, threats. Conservation efforts aim to reduce the impact of these threats to ensure that global biodiversity continues to provide essential ecosystem services. As is most often the case, these efforts to protect threatened species and their environments are constrained by limited resources. Conservation biologists have therefore had to increase the efficiency of their conservation practices to deliver the greatest benefit at the lowest cost. This requires decision making using the best available knowledge to prioritise actions. A concept that has received considerable attention in this area is that of conservation triage.

This eBook brings together perspectives from researchers and conservation practitioners who share their views and results in an effort to extend the discussion on this topic. A number of the papers in this eBook tackle the philosophical elements of conservation triage, while others take a more applied approach providing examples from conservation practice globally.

Citation: Hayward, M. W., Baldi, R., Castley, J. G., eds. (2018). Triage in Conservation. Lausanne: Frontiers Media. doi: 10.3389/978-2-88945-435-8

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frontiers in Ecology and Evolution

EDITORIAL
published: 05 January 2018
doi: 10.3389/fevo.2017.00168

Editorial: Triage in Conservation

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Keywords: conservation decision making, trade-off, conservation ethics, biodiversity value, conservation outcome

Editorial on the Research Topic

Triage in Conservation

Making good decisions remains an important aspect of conservation practice, and is typically underpinned by good science (Pullin et al., 2004; Cook et al., 2013; Roux et al., 2015). These decisions are informed by a variety of contexts and values but are also affected by uncertainty (Regan et al., 2005; Nicholson and Possingham, 2007). Conservation triage as a means to improve decision making and prioritize actions is a polarizing issue. Proponents see it as the most logical way of using limited conservation resources (Hobbs et al., 2003; Bottrill et al., 2008), whereas opponents reject the limitations imposed by society (notably governments) and seek adequate funding for the conservation of our natural heritage (Jachowski and Kesler, 2009). While triage has been used successfully to optimize the allocation of limited funds to conservation (Joseph et al., 2009), it is not universally accepted. In essence, this is much the same debate that is raging in broader conservation circles between the economic growth-based or humanitarian model of "new conservation," whereby society and economic growth via the ecosystem services biodiversity provides are used as drivers in an "it pays – it stays" system (Kareiva et al., 2012) and the traditional conservation model, where biodiversity is valued for its own sake and our responsibilities for intergenerational equity (Soule, 2013). New conservation leans heavily on economic neoliberalization, but the merits of this economic model are now being questioned (Tabb, 2003; Altvater, 2009; Merino et al., 2010). It could also be argued that proponents of conservation triage are promoting a realistic (defeatist) solution whereas opponents are being overly optimistic.

This collection of papers in the *Triage in Conservation* topic investigated these issues from a suite of different viewpoints. Several papers investigate the merits of employing triage methods for the conservation of specific issues. These papers emphasize the need to include complexities associated with local context into the decision making process. A central theme for a number of these papers was the prioritization of connectivity conservation efforts, such as Asian elephants *Elephas maximus* facing connectivity and human-wildlife conflict threats (Goswami and Vasudev), seeking funds via a "triage of means" strategy to improve 9,371 km^2 of off-park connectivity for tigers *Panthera tigris* (Mondal et al.), shaping the development process to improve the conservation outcomes of linear transportation corridors in India (Habib et al.). Monitoring activities were also considered in the context of triage, as ongoing monitoring and review of population trajectories facilitates appropriate management and mitigation of pressures impacting these communities. As Wheeler et al. showed there was not widespread support for using triage to allocate monitoring effort in the Arctic. Linked to population level monitoring is the need to re-evaluate performance and the success of conservation interventions for threatened species, particularly if these species have been prioritized. However, Morrison et al. Wheeler et al. showed that common tools to assess population persistence (i.e., PVA) were often not repeatable nor reproducible, thereby undermining their utility in assessing conservation success.

OPEN ACCESS

Edited and reviewed by:
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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *16 October 2017*
Accepted: *11 December 2017*
Published: *05 January 2018*

Citation:
Hayward MW and Castley JG (2018) Editorial: Triage in Conservation. Front. Ecol. Evol. 5:168. doi: 10.3389/fevo.2017.00168

A number of the papers also addressed the philosophical elements of the triage debate. Buckley, Buckley illustrates the problem that conservation triage risks signaling to decision-makers that some extinctions or population losses are acceptable, while Woodcock and Hayward introduce a new issue limiting the value of conservation triage in that the opportunity costs of conservation are likely to change in the future and thereby alter the calculations upon which original triage plans are based. As highlighted by the preceding summaries, conservation triage requires an understanding and integration of local contexts. In conservation, decisions are informed by values, need, available funding, etc. but Wilson and Law propose that conservation triage is essentially an ethical decision. The ethical side of hard-nosed economic rationalization to determine which species to allow to go extinct was investigated in two articles. (Wilson and Law) invoke lessons from medical triage to attempt to bring together the proponents and opponents of conservation triage to conclude that a more diverse set of ethics be considered alongside more open communication of objectives and protocols while acknowledging risks is required for conservation triage to become more acceptable. Conversely, Vucetich et al. highlight that the entire basis of conservation triage on medical triage is ill-founded because the latter pre-supposes limited resource availability whereas the resources available for conservation are not fixed. Furthermore, there is acceptance of the moral value of patients in medical triage, but society does not universally agree on the value of biodiversity, which lead them to conclude that conservation triage is an unhelpful concept (Vucetich et al.).

This Special Issue on *Triage in Conservation* yields examples of where triage can and has worked in conservation. Yet it also highlights practical and ethical problems with the concept of triage. It also offers a route forward to bridge the gap between conservation triage proponents and opponents. The debate around conservation triage remains, but continued communication between protagonists is the only way to move the concept to an appropriate conclusion.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

ACKNOWLEDGMENTS

Firstly, we extend our thanks to all the authors for contributing to the ongoing debate around conservation triage for the Special Topic. We would also like to thank all those who kindly reviewed manuscripts submitted and facilitating discussion on this topic. Enrico Di Minin kindly provided comments on this editorial.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Ecology and Evolution

PERSPECTIVE
published: 19 April 2016
doi: 10.3389/fevo.2016.00039

Triage Approaches Send Adverse Political Signals for Conservation

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Conservation can be analyzed as a political game between advocates and opponents, and games include signals. Triage approaches aim to trade off conservation gains and losses for different species, populations and sites, in an attempt to reduce aggregate net losses. These approaches send a political signal that some local or global species extinctions are socially acceptable. This permits conservation opponents to argue that any species may become extinct where convenient to development interests. Endorsement of triage by any one conservation advocate undermines the efforts and strategies of other conservation advocates. This increases expected aggregate net conservation losses.

Keywords: conservation policy, corporation, landscape, rights, trade-off, economic

OPEN ACCESS

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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *10 December 2015*
Accepted: *01 April 2016*
Published: *19 April 2016*

Citation:
Buckley RC (2016) Triage Approaches Send Adverse Political Signals for Conservation. Front. Ecol. Evol. 4:39. doi: 10.3389/fevo.2016.00039

INTRODUCTION: GAME THEORY APPROACHES TO CONSERVATION POLICY

The aims of biodiversity conservation relate to other species, but the practice of conservation is a human sociopolitical process (Clark et al., 2015; Redford et al., 2015) which can be analyzed using game theory (Simon et al., 1950), as for other politically controversial environmental measures (Buckley, 2013a). Games include signals, either deliberate or inadvertent, accurate or deceptive (Denicolo, 2008; McCain, 2010). The game is played between advocates who consider conservation a high priority, and opponents who do not (Buckley, 2015). Some opponents are declared and explicit, e.g., regarding livestock predators. Many more are undeclared and implicit, interested in economic gain or material consumption irrespective of environmental impacts. Some advocates endorse intrinsic values, pursue outsider politics, and reject compromise. Others endorse instrumental values, pursue insider politics, and accept compromise. Advocate may adopt positions anywhere on this spectrum.

In any game, successful players need power and strategy. Political power is gained either through force, funds or votes, with variable exchange rates. Conservation advocates rely on votes to change policies and legislation. They aim to enlist popular support in marginal electorates, or appeal to politicians who hold a balance of power. To enlist supporters, conservation advocates appeal to either intrinsic or instrumental interests. Intrinsic-value appeals yield "warmglow" payback, immediate but restricted (Martín-López et al., 2007). Instrumental-value appeals provide broader but delayed and uncertain payback.

Conservation practice is driven and constrained by legislation, derived from past politics. Countries with different legislation have implicitly adopted different positions. Strict protection reflects intrinsic values, derived from culture or religion (Haynes, 2008; Smidt et al., 2009; Norris and Inglehart, 2011). Conditional protection, e.g., through trade-offs or offsets, reflect instrumentalist approaches. Different approaches may be either more or less effective under different conditions.

There are shifting alliances between players, and subsidiary games within coalitions. Mining interests, manufacturers of motorized recreational vehicles, and a horseriding association combined to oppose roadless-areas legislation in the USA (Havlick, 2002; McBeth et al., 2007; Wolke, 2007). In November 2015, a US-based hunting organization apparently held closed-door talks with the South African Government to oppose conservation through CITES (Africa Geographic, 2015).

Conservation advocates also form coalitions, with differentiated political positions to attract complementary supporters. If conservation advocates adopt conflicting strategies, however, the political split can be exploited by conservation opponents. One strategy for conservation opponents is to engineer such a split deliberately. Persuading one well-regarded advocate to oppose the majority sends a political signal of doubt and confusion. This is the strategy used by climate-change denialists, and opponents of many science-based policy measures (Beder, 2002).

If any conservation analysts and advocates endorse triage, that creates political signals that damage the effectiveness of other conservation organizations. Advocating triage reduces future resources for conservation, and this outweighs any gains from efficient allocation of current resources. I examine this process for triage of species, subpopulations, and sites.

TRIAGE OF SPECIES

Triage of species means abandoning some to extinction, and allocating resources to those where extinction can be averted most cheaply. This contrasts with the approach adopted under most threatened-species legislation, which invests most on species closest to extinction, even if this is costly and sometimes fails.

Triage of species suffers from both technical and political shortcomings. There is no scientific threshold to abandon a species to inevitable extinction. With active conservation, some species have recovered from very small remnant populations (Jachowski and Kesler, 2008) or a single breeding pair (Jones et al., 1995). Some have survived in the wild for many decades, at very low numbers, after being believed extinct (Meijaard and Nijman, 2014). Species may be rescuable from a single individual, or even a dead specimen (Minteer, 2014). There is thus no scientific rationale to abandon any species as irremediably doomed. Doom derives less from the genetics of small populations, and more from economics and continuing anthropogenic threats. These are powerful real-world political constraints (Game et al., 2013; Doak et al., 2014), but not impossibilities.

The political shortcoming is that acceptance of triage by any one conservation advocate sends a powerful signal that modifies the entire political playing field. The current global social norm is that all species are invaluable, and any extinction is a loss to all humanity. The current political norm is that extinctions are highly abnormal and regrettable events, that sometimes occur despite our best efforts to avoid them. These norms are embodied in government policy and legislation, agency mandates and budgets, and in the practical politics of social license. Countries which have legislation and associated litigation mandating protection of threatened species, send a strong political signal that development or land use change likely to lead to species extinction will be difficult and expensive to achieve. This influences how industry groups, with no interest in conservation, decide what developments to pursue. If such protection is conditional, through trade-offs or offsets, this signal is far weaker, since it is much easier to influence politicians than to overcome definitively worded legislation (Buckley, 1991a).

Opponents of conservation do not currently possess a social license to declare that extinctions are unimportant. They argue only that in limited local circumstances, other social benefits may outweigh impacts on particular populations of threatened species. Livestock graziers generally do not argue that predator species should become extinct. They claim only that they, or government agricultural agencies, should kill individual predators that might attack their livestock (Rust, 2015). Mineral and petroleum developers, and forestry agencies and corporations, do not claim openly that threatened species are unimportant, because they must comply with legislation and with current social constraints and political norms. They do, however, attempt to change these norms. In consultations for a previous Australian Government's policy papers on sustainable development, for example (Buckley, 1991b) one mining industry representative suggested that in his view, 10% of Australia's species could become extinct in the interests of mineral production.

Under species-triage approaches, extinctions would be perceived as a normal part of a human-dominated planet. Laws and agencies shift from attempting to avoid any extinctions at all, to choosing between different extinctions on economic grounds (New South Wales, 2014). Species extinctions are treated like business bankruptcies. If the timescales, discount rates and uncertainty measures used in calculating economic paybacks were the same as for commercial investments or government infrastructure, then triage could soon leave us with no other species than those in current commercial use. This political change far outweighs any potential conservation gains through more efficient allocation of current funds under current political systems.

Advocates of species triage argue that some extinctions are unavoidable, and that fixed, limited and fully fungible resources are therefore best allocated where they are most likely to yield the largest conservation benefit. That is, they perceive conservation essentially as an economic optimization problem; and they act as though politics, society, and legislation are a fixed framework, and they are merely tweaking their own operations within that framework. This is incorrect. Advocating triage changes the entire framework. The current conservation view is that extinctions are abnormal anthropogenic events that occur despite conservation efforts, and that conservation efforts should therefore improve. The triage view is that extinctions are normal events within the functioning of a human-dominated planet: a very different position. If it is seen as acceptable to conservationists that one species should become extinct, that signals that it is equally acceptable for other species to become extinct (Jachowski and Kesler, 2008). This jeopardizes the position of other conservation advocates. In purely pragmatic terms, triage is a poor gambit.

TRIAGE OF POPULATIONS

Many threatened species occur at multiple separate sites. Two terminologies are in use to describe geographically separated groups of individuals. Analyses of population viability and genetics generally refer to site-specific populations, which may or may not experience any genetic linkage, and in aggregate comprise a larger-scale (e.g., global) meta-population. That is, the key consideration is generally the genetic flow between different groups of individuals. Analyses of conservation status based on number of individuals remaining, in contrast, commonly refer to a global population divided into individual subpopulations. The key consideration is commonly the boundary of site-specific conservation management efforts. These two considerations are both important in practical conservation. For convenience, I will refer to geographically distinct groups as populations.

Triage at this scale involves abandoning some groups of individuals to extinction in order to focus resources on conserving other groups within the same species. That is, it aims to conserve some individuals of a threatened species, but not others. Since detailed information on population genetics and conservation threats to individual groups is rarely available, triage approaches at population scale focus on estimated numbers of individuals, geographical locations, and estimated management costs. They argue for concentrating conservation resources on populations which are: larger; nearer the center of the species' range; and cheaper to manage, either for reasons of terrain, biology or politics (New South Wales, 2014).

There are both technical and political objections to this approach. The principal technical objection is that smaller outlying populations may be genetically diverse or distinct from larger subpopulations near the center of a species' range. Without detailed data on population genetics, rarely available in practice, abandoning outlying populations to extinction leads to the risk of losing a larger proportion of a species' overall genetic diversity, than loss of a corresponding number of individuals within a larger and more central population. That is, small outlying populations should be considered more rather than less valuable for conservation. This is indeed the approach taken in most practical conservation efforts, but not in population-triage approaches.

The second technical objection is that, especially for threatened species with few individuals remaining, there is always the risk of catastrophic events devastating particular local populations. Such events may be natural, anthropogenic, or a combination. Examples include: disease outbreaks; fires or floods; legal or illegal habitat clearance or destruction; poaching, hunting or harvesting; or war or other armed conflict. It is because of such risks that practical species conservation programs devote efforts and resources to translocating individuals so as to establish or re-establish breeding populations in multiple areas well separated from each other. There are many such programs currently in place (Rhinos Without Borders, 2015). These are measures to reduce the all-eggs-one-basket risk. Triage of populations, in contrast, increases that risk.

The political objection to population-scale triage is that it legitimizes gradual reductions in species range and number of individuals, which reduces the species' ability to maintain a viable population overall and to recover from any short-term reductions. The current legal, social and political norm is that if a species is threatened, every individual of that species is equally protected from "take or harm" (McDonald and Buckley, 1993). Controversies, e.g., over the consequences of trophy hunting (Buckley, 2014), are about mechanisms, not aims.

Population triage approaches, however, signal that it is legally, socially, and politically acceptable for some of the remaining individuals of a threatened species to be destroyed, as long as others remain in existence. That provides an avenue for commercial interests to take or harm individuals, whether through fisheries bycatch, logging or agriculture, clearance for industrial, infrastructure, mineral or residential development, or any other human activity. Once population triage approaches are adopted, the number of remaining individuals can suffer continual attrition, until there is a viable wild breeding population with sufficient size, range and genetic diversity to resisting external shocks.

TRIAGE OF SITES

Site-based triage approaches abandon some conservation areas to focus resources on others. Many decision rules are possible, using different measures of biodiversity and land tenure. Information is commonly incomplete, especially when "rapid appraisal" is adopted. Prioritizing areas for future conservation is unavoidable (Bottrill et al., 2008), but that is very different from triage of existing conservation areas.

The key issue relates to the conservation value of land subject to anthropogenic modifications. Areas that are no longer pristine can make significant contributions to conservation: e.g., if they still support threatened species and ecosystems not well conserved elsewhere; or if they can be rehabilitated and restocked; or if they provide corridors linking other areas of high conservation value. For some species, the only remaining populations occur on modified landscapes. So, there are indeed cases where it is valuable to invest in conservation of modified as well as pristine ecosystems (Rappaport et al., 2015). Conservation trusts and NGOs can justifiably devote funds, on occasion, to purchasing private farmland. Conservation advocates can justifiably lobby to convert former farming and forestry lands, or waters used for fisheries, to future conservation reserves.

The risk to conservation occurs when this argument is used instead to lobby for social license to create conservation damage to areas that are still pristine. This lobbying approach is used frequently when economic interests want to use current conservation reserves for development, or infrastructure, or large-scale tourism. These interests argue that whilst their actions would indeed create impacts, the land would still be valuable for conservation, just like anthropogenically modified lands elsewhere. This is also the basis for biodiversity offset approaches. The relationship between physical modification to the natural environment and loss in biodiversity conservation value, however, is non-linear. Initial damage to pristine ecosystems is rapid and large, whereas recovery of modified ecosystems is slow and limited, a hysteresis effect (Buckley, 1982).

These relationships also differ greatly between ecosystems and types of anthropogenic modification. Grasslands used for low-intensity livestock grazing can be rehabilitated and restocked as conservation reserves for native herbivores and their predators (Varty and Buchanan, 2000; Lewa Wildlife Conservancy, 2015). Cutting roads or power lines through rainforest reserves, in contrast, causes fragmentation of the forest canopy, introduction of invasive species and pathogens, and access by high-impact human recreationists. Politicians, however, have wrongly attempted to argue from grassland to rainforest (Buckley, 2013b).

Landscapes differ by orders of magnitude in human modification. Where human modification is minimal, conservation aims to keep areas pristine. Park managers confine human modification to front-country areas so as to maintain pristine backcountry. Other factors equal, minimally modified lands have higher conservation value than heavily modified lands. The political signal from triage of conservation sites, however, is that if human-modified landscapes are valuable for conservation, there is no barrier to modifying pristine landscapes. If one conservation advocate argues that all landscapes are already modified, this gives conservation opponents a political license to modify wilderness: as attempted unsuccessfully by the Australian Government in the Tasmanian Wilderness World Heritage Area (International Union for Conservation of Nature (IUCN), 2014).

Similar objections apply to proposals that parks agencies could sell some of the lands under their control and buy larger areas elsewhere (Fuller et al., 2010; Venter et al., 2014). Parks agencies operate with annual recurrent funding from central government treasuries. If they sell land, the revenues earned are appropriated by central treasuries, not allocated to buy new parks. Areas proposed for sale and purchase are in different jurisdictions, with no mechanism to transfer funds between governments. If parks agencies buy and sell land, this changes land prices, reducing the total area purchasable. This effect occurs whenever news of proposed purchases reaches landowners. That is why land consolidators use secret intermediaries to purchase adjacent properties. It is also one reason why parks agencies find it so difficult to create corridors between parks by buying private land. Once they start negotiations, all landowners increase prices. Their lands are more valuable to parks agencies, which need parcels in specific sites, than in the open private market with greater substitutability.

DISCUSSION

The political-signal argument against triage is a pragmatist rather than a fundamentalist approach. There are parallel moral and ethical arguments against triage (Callicott and Grove-Fanning, 2009; Soulé, 2013; Cafaro and Primack, 2014), but those are different. My argument is that if any one well-regarded conservation organization or analyst endorses triage, that sends a political signal which changes the social norms regarding conservation, greatly increasing the barriers to effective action by other conservation advocates. This effect occurs at all scales of triage: species, populations, and sites.

TABLE 1 | Good intentions, adverse signals.

Triage scale	Triage advocates' intent	Inadvertent political signal
Species	Minimize total species extinctions	Species extinctions no longer a barrier to commercial development
Population	Prioritize effort to larger populations	Threatened species legislation no longer a barrier to commercial development
Site	Prioritize resources to sites with highest conservation values	Parks open for commercial development

These signals are inadvertent. Conservation analysts and advocates who endorse triage are no doubt well-intentioned, and believe that their proposals will contribute to conservation by allocating resources more efficiently. That is, they focus on choosing between different potential uses of limited funds provided to protected area agencies through annual government budget allocations.

In doing so, however, they create negative consequences for conservation by weakening the defenses of parks agencies, and non-government conservation advocates, against continual attacks by other interests. Such interests see conservation as an obstacle to commercial profit, and parks as resources available far more cheaply than corresponding private lands. Their actions are restricted by threatened species legislation and agencies, and they campaign continually to weaken both. Triage approaches provide large loopholes that are rapidly exploited by commercial interests, which are always in competition for new opportunities, and always engaged in political maneuvers to gain advantage.

The ways which triage approaches are perceived by their advocates are thus very different from the ways in which they are perceived by conservation opponents. These contrasts are summarized in **Table 1**.

Politics is ultimately a subset of animal behavior. It is a term to describe the ways in which humans gain and apply the power to change social structures in line with their own interests and desires. Many animal species form shifting social alliances; many also deceive each other and sometimes fight each other. I argue here that conservation is a political game, and that conservation efforts are unlikely to succeed unless conservation advocates recognize this, and design strategies accordingly. Games involve signals, either accurate or deceptive. I argue here that if any conservation analyst or advocate adopts triage approaches, that endorsement sends political signals that create damaging effects, and that damage far outweighs any gains which may be achieved through more efficient allocation of resources.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and approved it for publication.

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Conflict of Interest Statement: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

CORRECTION
published: 28 June 2016
doi: 10.3389/fevo.2016.00076

Corrigendum: Triage Approaches Send Adverse Political Signals for Conservation

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Keywords: conservation policy, corporation, landscape, rights, trade-off, economic

OPEN ACCESS

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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *26 April 2016*
Accepted: *08 June 2016*
Published: *28 June 2016*

Citation:
Buckley RC (2016) Corrigendum: Triage Approaches Send Adverse Political Signals for Conservation. Front. Ecol. Evol. 4:76. doi: 10.3389/fevo.2016.00076

A corrigendum on

Triage Approaches Send Adverse Political Signals for Conservation
by Buckley, R. C. (2016). Front. Ecol. Evol. 4:39. doi: 10.3389/fevo.2016.00039

Reason for Corrigendum:

Owing to an oversight, there was a mistake in the section "Triage of Populations," last sentence of the last paragraph. The phrase "…a viable wild breeding population..." should read "…no viable wild breeding population...". This correction does not change the scientific conclusions of the article.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and approved it for publication.

Conflict of Interest Statement: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Ecology and Evolution

PERSPECTIVE
published: 23 May 2017
doi: 10.3389/fevo.2017.00045

Conservation Triage Falls Short Because Conservation Is Not Like Emergency Medicine

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Conservation triage, as a concept, seems to have been born from analogizing circumstances that characterize conservation with triage, as the concept applies to emergency medicine. Careful consideration—facilitated through the aid of formal argumentation—demonstrates the critical limitations of the analogy. Those limitations reveal how the concept of conservation triage falls short. For example, medical triage presupposes that resources available for an emergency are limited and fixed. By contrast, the resources available for conservation are not fixed. Moreover, the ethics of prioritization in medical triage is characterized by there being universal agreement on the moral value of the patients. However, in conservation there is not universal agreement on the value of various objects of conservation concern. The looming importance of those features of conservation—disputed values and unfixed resources—make conservation triage a largely un-useful concept.

Keywords: conservation ethics, argument analysis, cost-benefit analysis, consequentialism, care ethics

OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *18 February 2017*
Accepted: *25 April 2017*
Published: *23 May 2017*

Citation:
Vucetich JA, Nelson MP and Bruskotter JT (2017) Conservation Triage Falls Short Because Conservation Is Not Like Emergency Medicine. Front. Ecol. Evol. 5:45. doi: 10.3389/fevo.2017.00045

INTRODUCTION

Conservation triage is usefully characterized as a strategic "process of prioritizing the allocation of limited resources to maximize conservation returns, relative to the conservation goals, under a constrained budget... achieved by explicitly accounting for the costs, benefits and likelihood of success of alternative conservation actions..." (Bottrill et al., 2008). Some argue that conservation triage is appropriate because of the "astronomical" shortfall in resources allocated to conservation (e.g., Balmford et al., 2003; Bottrill et al., 2008; McCarthy et al., 2012). As such, some goals of conservation will go unmet. Given that indisputable circumstance, the argument goes, we should strategically select which conservation goals should be denied. The rejection of conservation triage has been labeled "unconscious triage" and portrayed as "the worst of all possible choices" (Nijhuis, 2013, quoting Tim Male, Vice President at Defenders of Wildlife; see also Martin et al., 2012).

Views that are supportive of conservation triage are contested. A countervailing perspective is that conservation triage is inappropriate because it promotes a defeatist attitude; because it inappropriately presumes we can accurately predict which conservation goals are unattainable, given the available resources; and because it is simply wrong to forego any aspect of conservation given that the moral value of conservation is so great.

Importantly, much of the support for conservation triage seems associated with the idea that "rather than being an ethical position, conservation triage is simply an unavoidable step in the process of efficiently allocating resources when budgets are constrained" (Bottrill et al., 2008). There is value in acknowledging that academicians with expertise in the scholarly field of ethics consider their field to be about the formal analysis of ethical propositions, where an ethical proposition can be expressed, for example, as "We should (or should not)..." Moreover, ethical decisions are decisions about how one ought to behave when the behavior in question has consequences for other morally-relevant beings or entities. As such, we are unsure how one could conclude that conservation triage (opposed to unconscious triage) is not an ethical decision. For the same reason, we are unsure how one could conclude that decisions made within a conservation triage framework are not ethical decisions.

Some of the conflict might be resolved (at least clarified) by exposing conservation triage to formal argument analysis, which is a basic tool of scholarly ethics (Nelson and Vucetich, 2012). Argument analysis has been usefully applied to other concerns in conservation ethics, including advocacy by scientists (Nelson and Vucetich, 2009) and predator control (Vucetich and Nelson, 2014). The first step in argument analysis is to convert a rationale (for conservation triage) into a formal argument with premises and a conclusion. The second step is to evaluate whether (i) all the premises are true or appropriate, and (ii) the conclusion follows from the premises. By the rules of logic, a conclusion is supported by an argument if and only if both conditions hold. One of the benefits of argument analysis is to clarify points of disagreement. Here is a nascent argument for conservation triage which we can begin to analyze:

> *P1. Conservation is a multifaceted endeavor, the realization of which requires vast resources, financial, and otherwise. P2. The resources allocated to conservation are insufficient. C. Therefore, we should thoughtfully and strategically prioritize the allocation of those scarce resource; doing so entails the willful denial of many conservation goals.*

The conclusion of this argument, then, is to endorse conservation triage. One could add or revise premises to the argument, and doing so may be critical. However, arguments are like scientific models in the sense that they should be made as simple as possible (though no simpler than required). It is often better to consider a simpler argument; then, revise and add premises to the argument after some analysis shows the value of doing so.

AGENTS OF CONSERVATION

Consider the word "we" in the argument's conclusion. The referent of "we" is unspecified. Insight might arise from considering who "we" refers to.

Conservation is manifest in society through a variety of actors or agents that affect change. These agents include, for example, individual humans, certain non-governmental organizations (NGOs), government agencies whose purview is conservation, and entire societies (such as states, nations, or sets of nations). For the conclusion to be reliable, P2 (about scarce resources) must be true. The truth of P2 may depend on the agent of conservation of whom we are speaking.

First, consider an individual human whose resources are scant with respect to the resources required to affect all conservation. (Please bear with us for what may seem pedantic. This is an important starting place for more sophisticated ideas to follow.) The person with scant resources is unable to attend most conservation goals, necessarily and indisputably. So an individual person must decide the tiny portion of conservation to which they will direct their effort and resources. As such, it would be wise for an individual to consider that allocation thoughtfully.

Similarly, consider an NGO devoted to some aspect of conservation. Their circumstance is essentially like that of an individual: their resources are scant in comparison to the cost of conservation. The NGO has a choice—more properly, the leaders of the NGO have a choice—about what aspect(s) of conservation to allocate their resources; but they do not have a choice about whether to selectively allocate resources. As such, it would be wise for an NGO to strategically consider where to allocate its resources.

Now consider—as an agent of conservation—an entire citizenry, such as a nation. Recall, that the critical premise of conservation triage is the premise that resources are far too scarce. For a social entity as large and encompassing as an entire nation, the appropriateness of premise P2 is arguable. P2 is likely expressed too simply to be judged true or false, or too simply to support the conclusion.

In particular, if the agent of conservation is an entire citizenry, then P1 and P2 likely support a conclusion something like:

> *C. These citizens have a genuine interest in thoughtful and strategic allocation of scarce resource.*

However, if the agent is an entire nation, then the argument (P1 and P2) likely does not support the conclusion that many conservation goals should be willfully set aside. An important set of premises that had been missing from the argument is:

> *P3a. The resources that a nation allocates to conservation are not fixed. P3b. The allocation of additional resources toward conservation depends on persuading the citizenry that the goals of conservation should override other societal interests.*

The truth and relevance of P3 casts a deep shadow on the conclusion that "conservation goals should be willfully denied."

A related idea is that limited resources is a proximate cause of conservation failures and the ultimate cause is a citizenry that does not sufficiently value conservation. By this view, the inadequate allocation of limited resources is a consequence of undervaluing conservation.

The last agent that we consider is a government agency acting within a nation or state, whose purview is conservation. Because the funding allocated to such an agency is typically not determined by the leaders of the agency, funding is scant in relation to the cost of conservation. As such, selective allocation is inevitable and strategic allocation would be in the genuine interest of the agency's constituents.

Strategic allocation of resources is, however, only one responsibility of such an agency. A second responsibility is to advocate to its constituents the need to allocate enough resources for conservation. Given the severity of the shortfall, this second responsibility is arguably more critical than efficient allocation. To think otherwise may be analogous to arranging deck chairs on a sinking ship in the most efficient manner.

The key point is this—an agency using the language and rhetoric of conservation triage in service of its one responsibility, may be undermining its other responsibility—in spite all intentions to the contrary.

COMPARISON WITH EMERGENCY MEDICINE

Consider a hypothetical incident: Two paramedics with first aid supplies arrive at a scene with dozens of injured people. There is a relatively short, but critical period of time during which the paramedics and their supplies are the only resources available for treating the victims. For emphasis, the available resources are limited *and fixed*. Sufficient resources are being brought to bear as fast as humanly possible. In the meantime, some people are going to die, but the number of people who die depend on how the paramedics allocate their medical assistance. This scene represents salient elements of triage as the concept is applied in emergency medicine.

There has been an ongoing effort to explain and justify conservation triage by making—sometimes elaborate—comparisons to triage as the concept is applied in emergency medicine. For example, Wilson and Law (2016) write: "Our aim is to contrast the concept and practice of triage in emergency medicine and conservation in order to discern why it is more accepted in medicine yet polarized in conservation..."

The analogy fails to convince those opposed to conservation triage likely for several interrelated reasons. First, in the emergency medicine scenarios to which triage is applied there is no question that the resources available are insufficient *and fixed*. In conservation, by contrast, resources are not fixed. Unlike the paramedics who arrive at the scene of an medical emergency, we—as a society—can decide to allocate more resources to conservation. Also, the emergency medicine crisis we described will pass within minutes, while most conservation crises will play out over many years.

The analogy between conservation and triage as the concept is applied in emergency medicine fails short in another critical way. That is, in emergency medicine scenarios, there is essentially universal agreement about the moral value of what is at stake, i.e., human life and well-being. Again, by contrast, there is not universal agreement among citizens about how valuable conservation is or the reasons why it is valuable. Those differences make the comparisons to emergency medicine of limited value and undermine the appropriateness of conservation triage; the next section is devoted to explaining why.

THE ETHICS OF PRIORITIZATION

Supporters of conservation triage also seem to be in broad agreement that it "is achieved by explicitly accounting for the costs, benefits, and likelihood of success of alternative conservation actions" (Bottrill et al., 2008). That idea is formalized by the claim that resources should be allocated to one conservation project as opposed to another, according to the efficiency (E) of the project, where $E = (V \times B \times S)/C$ and C is the cost of the project, S is the probability of realizing the project's goal, given the expenditure of that cost, B is the benefit of the project to the particular object of conservation concern (say, an endangered species), and V is the overall value of this particular object of conservation concern (e.g., Kilham and Reinecke, 2015; see also Bottrill et al., 2008).

Some scholars have expressed concern for the tendency to overestimate the accuracy of cost-benefit analyses, in part, because we overestimate our confidence in predicting the future state of ecosystems (Holling and Meffe, 1996). That shortcoming would be inherited by any version of conservation triage that relied heavily on cost-benefit analysis. While that concern is important, its discussion is beyond the scope of this essay.

Public discourse on conservation reflects vigorous debate about the value different people assign to various elements of nature and its conservation. That debate includes, for example, whether non-human elements of nature possesses intrinsic value or if those elements are of value only to humans (Vucetich et al., 2015; Batavia and Nelson, 2017). That debate has critical implications for how much value (V in the efficiency equation) would be assigned to various elements of nature. Other important debates pertain to the conflicts that conservation creates with animal welfare (Paquet and Darimont, 2010), social justice (Brown, 2003), and economic growth (Czech et al., 2000). One's perspective on those debates would also greatly influence assignment given to value (V) for various conservation projects.

Those circumstances indicate, at least to us, that one's view on what to prioritize in conservation would be depend largely on the disparate assignments to V that various people would give to various aspects of nature and conservation. Also note that the above mentioned debates occur *within* the conservation community. The disparateness in assignments to V increase greatly when one takes account of citizens without a basic appreciation for nature or conservation.

The concern is that conservation triage—insomuch as it is represented by that efficiency equation, $E = (V \times B \times S)/C$—suggests that the greatest challenge to conservation is a problem for which conservation triage is not well suited to handle. That is, the challenge is undervaluing conservation. Or perhaps the challenge, more precisely is, heterogeneity among citizens concerning the value of various conservation goals. The rhetoric and concepts associated with triage are not well-tailored to advancing the discourse on debates so deeply steeped in unresolved values.

Supporters of conservation triage routinely highlight the importance of clearly articulated goals. They also *mention* the importance of stakeholder processes aimed at developing goals. However, the greatest challenge to conservation is, perhaps, the unmet need for robust justifications that persuade those who are not in agreement with various goals of conservation. That problem exists within the conservation community as well as between the conservation community and the rest of society. The concern is that the rhetoric and concepts of conservation triage are not especially well-suited for such handling of values—at best. At worst, it is a dangerous for deceptively undermining conservation.

CONSERVATION TRIAGE IN ACTION

To illustrate how these ideas can be manifest in the real world, consider red wolf (*Canis rufus*) conservation. In 2016, the United States Fish and Wildlife Service (USFWS) announced significant adjustments in its approach to conserving red wolves (USFWS, 2016). The changes include a significant shift of effort away from conserving the wild population. The underlying rationale for the adjustment is "maximizing efficient use of Services resources." While conservation triage calls for an explicit analysis of efficiencies of various possible conservation strategies, no such analysis pertaining to red wolves has been shared with the public. Moreover, a reasonable case can be made that the decision was the result of intense political opposition to wolves by local landowners and state governments (Fears, 2016). If so, the decision was not driven by a prioritizing of one conservation project over another on the grounds of efficiency. Rather the decision was driven by contempt for conservation. Then the USFWS covered that explanation with the language of conservation triage; all the while there is an implicit and unresolved disagreement over the value (V) of a wild population of red wolves.

The rhetoric of conservation triage has also been used in the context of conserving woodland caribou (*Rangifer tarandus*) in Alberta, Canada. In particular, Schneider et al. (2010) conclude that preventing habitat degradation by the petroleum and forestry industries would incur an "*opportunity* cost... in excess of 100 billion dollars" [italics added]. They also conclude that a wolf-control program (intended to reduce predation on caribou) would cost only on the order of "tens of millions of dollars." That analysis—steeped in the rhetoric of conservation triage and explicitly motivated by concerns that Albertans have "limited capacity" for manifesting conservation—has been cited as justification for decisions by the Canadian province to focus caribou conservation on wolf control (and maintaining a fenced population of caribou) and to forego the protection of habitat. Nevertheless, most familiar with the circumstance believe that caribou cannot be properly conserved without protecting habitat (e.g., Proulx and Powell, 2016). Our concern is that the language of conservation triage has been used to the effect of obfuscating whether the people of Alberta—as represented by their government—lack the capacity to protect habitat or whether they place insufficient value (V) on caribou habitat compared to the value they place on the petroleum and forestry industries.

Conservation triage also lurks beneath the USFWS's the legal-political process for determining whether a species should be listed (i.e., protected) or delisted by the U.S. Endangered Species Act (ESA). The listing of a species is supposed to be acknowledgment that a species meets the legal definition of threatened or endangered. Being listed obligates the USFWS (acting on behalf of U.S. citizens) to take several basic protective actions. One of the key protective actions is a prohibition on "take," a legal term meaning to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Take has also come to include activities that lead to the degradation of habitat. A second protective element is a legal obligation to develop and implement a plan for recovering each listed species.

The USFWS has a prioritization system allowing it to forego those obligations for a particular listed species if limited resources preclude the USFWS from fulfilling those obligations. That prioritization system—criticized for too often being implemented inappropriately (Evans et al., 2016)—is a codification of conservation triage allowing the USFWS to provisionally forego an obligation without dismissing the obligation.

In addition, (and this is where the troubling parts begin) the USFWS may determine that a species should be listed but decide not to do so because resources are too scarce to list the species and the protection of other species is of greater priority. These decisions are referred to in legal shorthand as "warranted but precluded." By 2011, the listing of 251 species was judged to be warranted, but precluded. Concerns about the abuse of warranted-but-precluded decisions have been widely noted (Greenwald et al., 2005; Smith, 2011; Puckett et al., 2016). In recent years, at least some resolution to those concerns has been realized, but only because of a legal settlement requiring the USFWS to make final listing decisions for all 251 species by 2017 (Bricketto, 2011; Puckett et al., 2016).

Since that settlement, the director of the USFWS has expressed views which raise similar concerns over the legal-political process of *delisting* species. A species is to be delisted only if it no longer fits the legal definition of threatened or endangered and if the threats which caused the species to have been threatened or endangered have been mitigated. In particular, the director indicated that delisting decisions should also take account of the fact that decisions not to delist take away from the resources that can be devoted to other species of higher priority because conservation resources are scarce (Nelson and Vucetich, 2014).

The concern with these circumstances surrounding the legal-political process of listing and delisting is this: Because the USFWS has a prioritization system for allocating resources to listed species, being listed is no assurance that resources will be devoted to the conservation of a particular species. However, being listed is absolutely critical as acknowledgment of a conservation failure and acknowledgment of our obligation to address that failure. If we fail to meet a particular obligation because of scarce resource—then fine (perhaps). But failing to meet an obligation is not the same as absolving an obligation. When a species is unjustly delisted (or unjustly denied of being listed) we are not merely failing to address a failure—we are denying that a failure even exists.

Moreover, "take" (as defined by the ESA) is illegal if a species is listed. Even if the prohibition on take cannot be enforced (e.g., prosecution of poaching), the act is still illegal. Being illegal is liable to have at least some positive conservation effect. For example—and we recognize that elements of what follows is controversial—if gray wolves in the northern Rocky mountain states had not been prematurely delisted, then state governments would not have implemented harvests that impede recovery of the species; the states would have refrained because harvesting would have been illegal for violating a prohibition on take (Bruskotter et al., 2014).

Finally, we would not decide to legalize instances of murder in the U.S. because the inability to allocate sufficient resources contributes to a third of murder cases going unsolved (Kaste, 2015). For the same reason, we should not legalize the take of a species that fits the legal definition of endangered simply because we do not have the resources to enforce the law.

Collectively, these examples raise concerns that rhetoric associated with conservation triage is used in the real world, not for the efficient allocation of scarce conservation resources, but to rationalize the abdication of obligations to conservation.

COMPARISON WITH SOCIAL JUSTICE

Conservation triage also implies moral judgment *against* those supporting aspects of conservation deemed by others to be low priority, e.g., the conservation of charismatic species that are otherwise less valuable. The judgment is that those people are misallocating scarce resources and contributing to "unconscious triage."

With that context, consider a comparison between two aspirations—conservation and social justice. Conservation is multifaceted, not fully realized, and broadly (though not universally) supported as a value in society. Social justice is usefully characterized in the same way—multifaceted, not fully realized, and broadly supported. Now consider two agents (they could be individuals or NGOs) who care about social justice. Neither has enough resources to fully manifest social justice. One decides—for whatever reason—to support causes aimed at reducing starvation. The other decides—for whatever reason—to support causes aimed against human trafficking. We are unaware of any rationale that would lead to admonishing either agent on grounds that their cause is less important than other causes and therefore represents a misallocation of the scant resources to social justice.

Those ideas applied to social justice can be generalized in a manner that would pertain to conservation. The claims to consider are: a person is culpable for the breadth and depth of their care for others (human and non-human), and culpable for being open to new knowledge and developing skills to better manifest (and direct) the care that motivates their actions. But to judge someone harshly for the idiosyncratic circumstances that brought a person to manifest their care for one cause rather than another—that seems unjust.

Along the same lines, there is a moral obligation for those so educated to teach others about the most neglected aspects of conservation, as a means of encouraging others to contribute to those aspects of conservation. Conservation triage does not seem especially valuable for promoting the moral obligations mentioned above—indeed, it could undermine them.

CONCLUSION

Others have raised different kinds of criticism against conservation triage (e.g., Pimm, 2000). While implicitly mindful of those criticisms, this short essay is *not* intended to serve as a comprehensive review of such criticisms, nor should this essay be taken as passing judgment on the robustness or relative merit of those prior criticisms. Our criticism of conservation triage is limited to the points raised herein.

Supporters of conservation triage emphasize two principles, i.e., clear articulation of goals and the strategic allocation of scant resources. Those principles are indisputably valuable to any organization, including conservation organizations. Those two principles underlie all strategic planning processes. They are not exclusive to scenarios to which triage is traditionally applied (emergency medicine or disaster relief).

Moreover, the rhetoric associated with conservation triage has some legitimate shortcomings. First, conservation triage may undermine a conservation agency's other mandate to advocate for the allocation of more resources to conservation. Second, conservation triage is not well-suited (or even designed) to better understand how and why we should value non-human nature and its conservation. Conservation triage's greatest contribution may be as a vehicle for demonstrating that scant resources is not the greatest threat to conservation. Rather, the greatest threats to conservation are values and policies that are antithetical to conservation. If so, then conservation triage may be akin to a famous metaphor in philosophy, i.e., Wittgenstein's ladder. That is, conservation triage is a ladder that may be useful for gaining a new perspective; but after ascending the ladder, it is best to throw it away.

While many aspirations of conservation will be lost in the near future, the great challenge of conservation is not deciding which ones to deny. The most important and possibly most urgent challenge is figuring out how to inspire a deeper and broader sense of care for others—humans and non-humans, alike.

AUTHOR CONTRIBUTIONS

All three co-authors contribute equally to the ideas of the manuscript. JV wrote the first draft of the manuscript. All three authors contributed equally to transforming the draft manuscript into the final manuscript.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Ecology and Evolution

PERSPECTIVE
published: 27 September 2016
doi: 10.3389/fevo.2016.00112

Ethics of Conservation Triage

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Conservation triage seems to be at a stalemate between those who accept triage based on utilitarian rationalization, and those that reject it based on a number of ethical principles. We argue that without considered attention to the ethics of conservation triage we risk further polarization in the field of conservation. We draw lessons from the medical sector, where triage is more intuitive and acceptable, and also from disaster planning, to help navigate the challenges that triage entails for conservation science, practice, and policy. We clarify the consequentialist, deontological, and virtue ethical stances that influence the level of acceptance of triage. We emphasize the ethical dimensions of conservation triage in principle and in practice, particularly in the context of stakeholder diversity, a wide range of possible objectives and actions, broader institutions, and significant uncertainties. A focus on a more diverse set of ethics, more considered choice of triage as a conservation tool, open communication of triage objectives, and protocols, greater consideration of risk preferences, and regular review and adaptation of triage protocols is required for conservation triage to become more acceptable among diverse conservation practitioners, institutions, and the general public. Accepting conservation triage as fundamentally an ethical problem would foster more open dialog and constructive debate about the role of conservation triage in a wider system of care.

Keywords: biodiversity, decision-making, equality, equity, optimization, prioritization, socially acceptable, utilitarianism

OPEN ACCESS

Edited by:
Matt W. Hayward, Bangor University, UK

Reviewed by:
Bilal Butt, University of Michigan, USA
Bilal Habib, Wildlife Institute of India, India

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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *19 April 2016*
Accepted: *12 September 2016*
Published: *27 September 2016*

Citation:
Wilson KA and Law EA (2016) Ethics of Conservation Triage. Front. Ecol. Evol. 4:112. doi: 10.3389/fevo.2016.00112

INTRODUCTION

Triage (derived from the French word, *trier*, to sort) is essentially the process of making difficult decisions regarding priority under severely constrained resources (financial, knowledge or time; Weinerman et al., 1966; Aacharya et al., 2011). This simplistic definition does not however capture the ethical challenges of triage. In resource-limited contexts, triage decisions "sacrifice" the needs of a few, resource-intensive, critical cases so that resources can be distributed to a greater number of less critical cases, i.e., for "the greater good". In the biodiversity conservation sector, triage has been interpreted as allowing some critically endangered species to go extinct in order to save others (Jachowski and Kesler, 2009). This interpretation has led conservation triage to be a poignantly controversial issue (Hagerman et al., 2010) with people either promoting triage, accepting the concept but being uncomfortable with its application, or resisting it (Colyvan and Steele, 2011; Hagerman and Satterfield, 2014).

Conservation triage is promoted by those that accept it typically through reference to the rationality of triage as a system for decision-making (Bottrill et al., 2008). The often-inadequate budgets for conservation (Balmford et al., 2003; McCarthy et al., 2012) and the predicted impacts of global change (Rudd, 2011; Hagerman and Satterfield, 2014) suggest that conditions that incite the need to prioritize conservation actions given resource constraints (referred to herein as the triage context) are often unavoidable. From this point of view, triage is seen as a rational (and even inevitable) approach to prioritization under resource scarcity (Bottrill et al., 2009), although taken often with moral discomfort (Hagerman and Satterfield, 2014). Interestingly, the need for prioritization more generally is typically not contested (Hagerman et al., 2010; Hagerman and Satterfield, 2014), unanimously seen as better than decision-making strategies of "no prioritization" or *ad hoc* prioritization that is not guided by an explicit decision-making system (Martin et al., 2012). Proponents of conservation triage typically cite a utilitarian reasoning for its justification: maximizing benefits given resource constraints, even if this means that some species may be sacrificed in order for resources to be more efficiently distributed.

The position against conservation triage is less singular. On one hand, conservation triage is berated as submission to a "defeatist" ethic, which fails to incentivize for or even recognize opportunities to increase budgets or develop innovative solutions to mitigate extinction (Noss, 1996; Pimm, 2000; Parr et al., 2009). The notion of sacrificing the most critically endangered species is also viewed as a slippery slope to accepting extinction (Pimm, 2000; Hagerman et al., 2010), for example as part of the opportunity costs of development (Noss, 1996; Jachowski and Kesler, 2009). Accepting triage is seen as a contradiction to conserving all biodiversity, which is inherently an ethical consideration for the conservation movement more broadly.

Here, we do not argue the relative merits of conservation triage; these have been discussed in the existing literature (Bottrill et al., 2008). Rather, we argue that the ethical basis of conservation triage have been treated superficially to date. This is epitomized by the suggestion that the inevitability of conservation triage contexts makes triage immune from ethical considerations (Bottrill et al., 2008). While conservation triage contexts may be largely inevitable, decision theory itself does not inform what objective ought to be maximized, for whom, or how (Wilson et al., 2009), and therefore whether prioritization will involve sacrifice of the most critical cases (i.e., triage). The criteria and process under which resources are allocated are clearly ethically laden, and current conservation triage often sits at odds with society preferences (Wilson et al., 2011) and moral ideals (Hagerman et al., 2010; Hagerman and Satterfield, 2014).

We argue that conservation science, practice, and policy requires a deeper understanding of ethical motivations for and implications of triage, as well as a greater appreciation of the differences between triage in principle and in practice. These advances are required in order to more fully appreciate the benefits and limitations of conservation triage and to effectively communicate these to stakeholders and the general public. To illustrate, we draw on the ethical principles that underpin triage in emergency medicine. The concept of triage is central to emergency medicine, including within hospitals and in field settings, and is rarely questioned by patients, practitioners, or institutions (FitzGerald et al., 2010; Aacharya et al., 2011; Pou, 2013), to the point of being intuitively implemented (FitzGerald et al., 2010). Our aim is to contrast the concept and practice of triage in emergency medicine and conservation in order to discern why it is more accepted in medicine yet polarized in conservation, and to identify areas in conservation triage that may benefit from further research attention.

SHIFTING CONSERVATION TRIAGE TO A PLURALIST ETHICAL STANDPOINT

Acceptance or resistance of triage as a normative concept can essentially be characterized as the realization of fundamentally different ethical principles. Broadly speaking, those in favor of conservation triage take a consequentialist ethical reasoning (the objective of maximizing benefit), and those that resist triage take a deontological or virtue ethical stance (**Figure 1**; the objective of not wanting to "sacrifice" species). However, it is also possible to oppose conservation triage on consequentialist grounds (e.g., disagreement that resources for conservation are limited), or to oppose the implementation of triage if the triage protocol is controversial (e.g., disagreement of the calculated "benefits" of particular actions). The important difference is in the reasoning behind the arguments, and what this might suggest as a solution to the impasse: for example, the triage protocol might be adjusted to placate stakeholders or the solution might need to address parameters of the problem at larger institutional scales.

Acceptable triage protocols likely consider multiplicit concepts of distributive justice. Distributive justice is the process of balancing the principles of equality, utility and need, in order to derive equitable distributions (see below), principles which may draw influence from consequentialist, deontological, or virtue ethics. Further, triage systems will differ according to traditions, cultures, social contexts, and religious beliefs (Bodansky, 2009). These varied contexts mean that the situation illustrated by **Figure 1**, which is predominantly based only on Western philosophical divisions, is in reality much more complex. No ethical reasoning or moral stance based on logical arguments and truths are necessarily "better" or "worse", or more "right" or "wrong" than others. Even within one triage protocol, *triers* (the individuals conducting triage) may differ substantially in their classifications (Fernandes et al., 1999; Göransson et al., 2006; FitzGerald et al., 2010). This emphasizes the need for triage systems to reflect and better accommodate possible diverse ethical perspectives.

CONSERVATION TRIAGE IN PRINCIPLE AND IN PRACTICE

Distributive Justice: Balancing Equality, Utility, and Need

The principle of equality derives from the deontological principle that each person's life is equal. A focus on equality in triage might be interpreted as allocation on a first-come first-serve basis. This is unlikely to deliver an optimal strategy for the efficient use of scarce resources (it may, for example, result in a greater burden for many). However, the principle of equality can also be interpreted as an equal opportunity to receive care. A central tenet of emergency medicine triage is that no patient is excluded or given preferential treatment, despite how difficult this may be in practice (Ten Have, 2014). In conservation, the principle

FIGURE 1 | Possible ethical stances in relation to conservation triage. Example principles are given, which may lead to different positions on the triage of critically endangered species, such as the black-footed ferret. Outcomes that may be drawn from these positions are contingent on the context and dependent on subjective interpretations.

of equality is contradicted by the fact that species are functional components of ecosystems, that we "use" species every day, and typically we value resources more when they are scarce (Balmford et al., 2011). In developing conservation triage protocols the relative emphasis on equality, utility, and need has to be decided.

The principle of utility confers that we should achieve the greatest good for the greatest number, though there may be many objectives with which to achieve this (for instance maximizing benefit, minimizing harm, or maximizing likelihood of success), and many metrics for which to measure "good". In medical practice, the benefit metric is somewhat limited as pertaining to human life and happiness, resting on the premise that all humans have an intrinsic value. In conservation the choice of benefit metric is less constrained. The benefit metric may include, for example, measures of extinction or persistence, species richness or phylogenetic diversity, the use or non-use values of species, the contribution of the species to ecosystem processes, functions, and health (Faith, 2009; Probert et al., 2011; Arponen, 2012; Bennett et al., 2015; Redding and Mooers, 2015), and the intrinsic values of nature that are held by some (Justus et al., 2009). The wide selection of available metrics has given rise to controversy, but critical use of metrics has the potential to moderate the ethical implications of triage.

The principle of need entails prioritizing the ones that are worst-off. Focussing on need reflects pity, or a desire for retribution (or guilt) for injury caused (i.e., reparation or restorative justice). In conservation, criteria to define "need" are poorly defined. Is it the most threatened, most urgent, most damaged by humans? Or is it the most "salvageable"? This relates to a general lack of data and knowledge about "symptoms" and what these mean for prognoses in treated and untreated systems. This challenge is different from emergency medicine, as while patients are typically similar and similar symptoms tend to similar prognoses and outcomes, species and ecosystems are more diverse. A population size of 10 may mean a very different prognosis regarding extinction for a long-lived bog turtle than a pygmy rabbit (Shoemaker et al., 2013). A distinction also must be made between the urgency and severity of conditions, as urgent conditions may not necessarily be severe and severe conditions may not necessarily be urgent (Hobbs and Kristjanson, 2003). These knowledge gaps suggest a need to deliberate and consider a wide variety of evidence when developing triage protocols in conservation.

Respecting Autonomy, and the Role of Communication and Stakeholder Engagement

In medicine, a respect for autonomy focuses on the democratic right of the patient to make choices regarding their own care, including informed consent for both evaluation and treatment (Aacharya et al., 2011). This principle is often not given priority, however, given the urgency of emergency situations and the likelihood that patients will lack the capacity to give prior consent. Without dismissing the need for respect for autonomy, emergency medical situations compensate for loss of autonomy though open communication, including information regarding wait times and treatment effects (Aacharya et al., 2011).

In conservation, the principle of respect for autonomy may be extended to considering who the stakeholders are (to ensure recognitional equity) and ensuring their right to participate in decision-making is respected (to achieve procedural equity). Considerations include deliberation on who is qualified to "speak for nature" (O'Neill et al., 2006) and what inherent rights different components of biodiversity ought to have (Sandler, 2014). While the need for recognitional and procedural equity is gaining traction in conservation prioritization (Bennett and Dearden, 2014), these concepts have not featured with respect to triage *per-se* (Rudd, 2011; Hagerman and Satterfield, 2014). Involving stakeholders to develop prioritization protocols and objectives may increase acceptance of decisions in conservation triage contexts, by forcing participants to recognize the benefits, costs, feasibility, and uncertainty of different actions (Conde et al., 2015).

Situating Triage in a Broader System of Care

The principle of non-maleficence ("do no harm") and beneficence ("do or promote good") focuses attention in emergency medicine triage on providing care, rather than only considering efficient use of resources (Aacharya et al., 2011). In the broader system of health care these principles also enact the need for preventative medicine to reduce the need for symptomatic care, and palliative care for cases with an imminent inevitability of death (Hobbs and Kristjanson, 2003; Pou, 2013). Here, it becomes evident of the small, but important role that triage systems play in a wider system of medical healthcare (**Figure 2**): triage systems themselves typically aim to facilitate the initiation of further assessment and treatment, but do not typically concern resources for that further care (FitzGerald et al., 2010).

Applications of conservation triage have typically been more ambitious. However, if the medical model is to be followed, triage should be seen as just one element in the conservation toolbox, to be enacted at specific times, within specific contexts, and with a carefully defined objective. This will require different types of care in conservation to be clarified, including what might constitute "preventative" and "palliative care", and when these different categories of care should be enacted (Hobbs and Kristjanson, 2003). For example, preventative care in conservation could relate to habitat improvements and controlling threatening processes, while palliative care could relate to taking remaining individuals from a species into captive breeding or storing seed or genetic material when species become functionally extinct (Sandler, 2014; Conde et al., 2015). Many species and ecosystems are now perceived to be reliant on conservation actions in perpetuity (Wiens et al., 2012). "Chronic" conditions such as these are typically are not dealt with in an emergency medicine triage situation; instead institutional strategies are aimed at reducing crowding in emergency rooms, and limiting the need for triage in the first case (Aacharya et al., 2011).

Situating conservation triage within a wider system of care would also necessitate greater coordination and collaboration among individuals and institutions working toward a "common vision" that encompasses a range of ethical stances (Sexton et al., 2010). We envisage that like in medicine, a coordinated system of care would help, for example, "top-down" policy makers and on-ground practitioners to understand the scope and role of their duties within a larger context of care. For instance, it may clarify urgent and resource-limited contexts where triage is a pragmatic process, from contexts where other systems of prioritization that need not involve the sacrifice of the most critical cases. The latter may include exploring how budgets or other resources may be expanded, or enacting novel interventions (Pimm, 2000; Parr et al., 2009; Cundill et al., 2012).

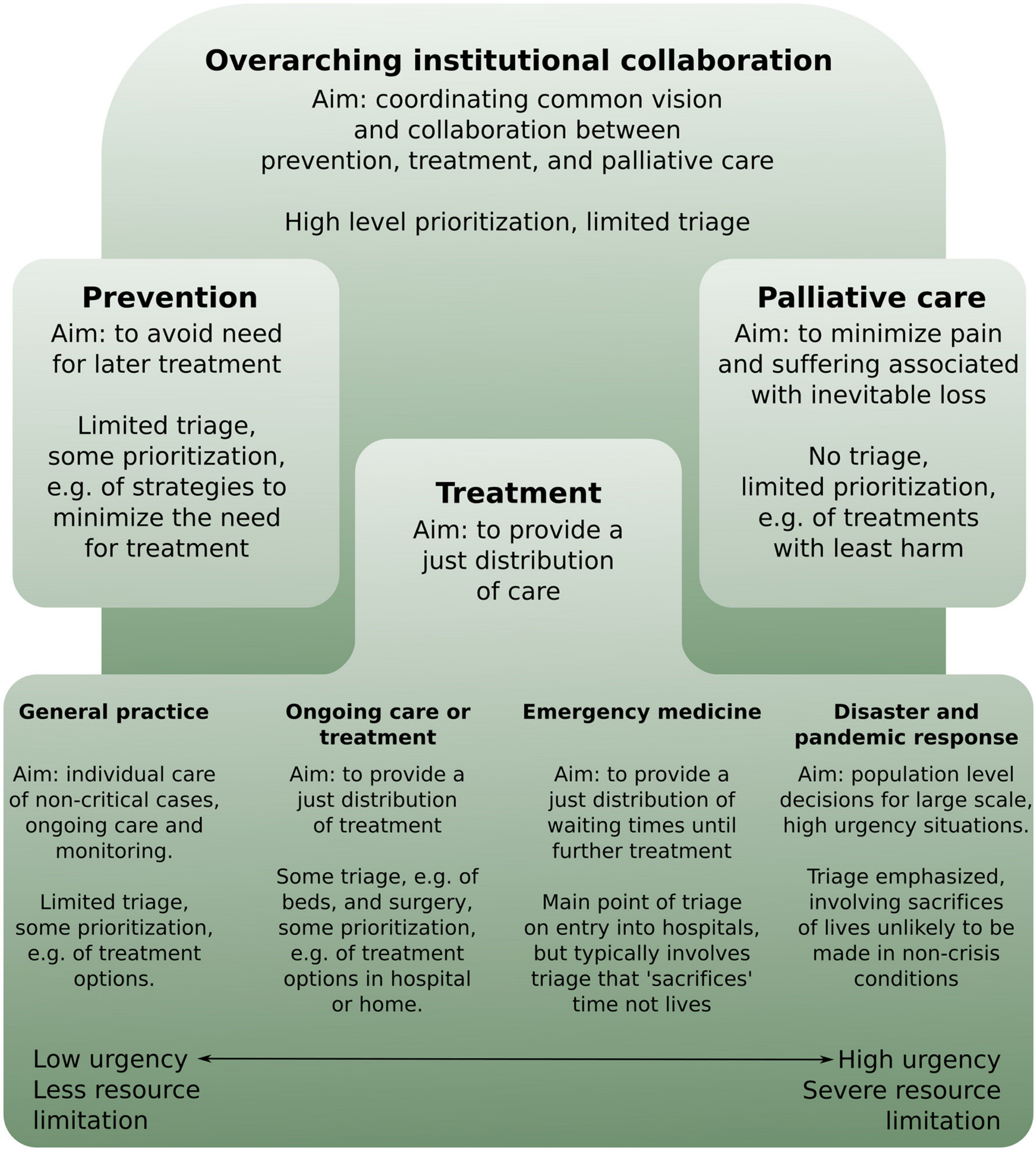

FIGURE 2 | Triage decisions (here defined as prioritization that may involve sacrifice of some critical but resource intensive cases so these resources can be allocated to "the greater good") can be understood as just one element in a wider system of care. Here we illustrate how triage decisions in medicine are typically concentrated in disaster and pandemic responses, and, albeit with different aims, in emergency medicine, but play a much less emphasized role in other sectors of the wider system of care.

Uncertainty Necessitates Consideration of Risk Preferences, Innovation, and Adaptive Improvement

Triage in practice needs to account for uncertainty and the limits of knowledge, of both the trier and the triage protocol (Parr et al., 2009). Medicine has a greater history of being evidence-based (Ahmad et al., 2014), and as human patients are more alike than differing species, such evidence is more readily transferred between patients. This means there is a higher level of certainty in regard to what different "symptoms" may mean for both diagnosis and prognosis in medicine, compared to conservation. This higher level of uncertainty means risk profiles ought to be more emphasized in conservation prioritization (Auerbach et al., 2015). Large uncertainties may indicate a greater role for deontological, rule-based ethical systems, rather than relying solely on a consequentialism perspective. Triage assessment protocols also need to be updated regularly as conditions change, values shift and new knowledge and technology arises (Aacharya et al., 2011).

To achieve optimal delivery of care and to maximize patient safety, triage processes in emergency medicine seek to minimize under-triage (to reduce preventable morbidity and mortality) while keeping over-triage low (to enhance efficiency; Uleberg et al., 2007; Lehmann et al., 2009; Xiang et al., 2014; Shawhan et al., 2015). The temptation to over-triage is often exaggerated when long wait times may result in increased harm (Aacharya et al., 2011), if there is emotional involvement or high possibility of litigation (Pou, 2013), or if there is institutional or financial incentive to do so (FitzGerald et al., 2010). The conservation sector must also be cognizant about such conditions that may lead to incorrect or undesirable triage decisions. This necessitates being critical of the data and information available, seeking baseline information and supporting the evaluation of actions that are implemented (Miteva et al., 2012).

Challenging Triage Conditions Result in Harder Decisions

The basic premise of triage in emergency medicine is that we should preserve and protect as many human lives as possible by assigning priority to patients with an immediate need for life-sustaining treatment. The scale of the conservation problem could however be more accurately reflected by triage decisions faced in disaster or pandemic contexts. Pandemic and disaster triage are characterized by sudden onset and overwhelming resource scarcity, and with larger scales and longer timeframes than in emergency medicine contexts. A feature that conservation shares with disaster triage is a shift in focus from management of individuals to populations (Aacharya et al., 2011; O'Mathúna et al., 2014; Ten Have, 2014).

Disaster triage conditions typically require more "hard" decisions to be made, that is, decisions that demand consideration of sacrifice of human life for "the greater good". Sacrifices that could be avoidable, and would, under normal circumstances, not be made (O'Mathúna et al., 2014). In reality, these challenging triage decisions mean that efforts in disaster contexts are often far from being optimally or equitably distributed (Ten Have, 2014). The field of disaster ethics is in its infancy (Thompson et al., 2006; O'Mathúna et al., 2014, but early efforts have looked toward preparedness, including special protocols, for example, stating that the decision not to treat cases considered "beyond emergency care" cannot be considered a failure to come to aid (World Medical Association, 2006), giving legitimacy to the utilitarian aspects of triage. Such protocols need to be set, agreed on, and clearly communicated prior to a disaster context in order to be effective, and even still they can be challenging to implement on an individual level (Pou, 2013; O'Mathúna et al., 2014). Biodiversity conservation has often been compared to a "crisis", although some individual cases are clearly more urgent and severe than others. Clearly recognizing instances of high magnitude, urgency and severity as "special" cases may increase acceptability of triage as a prioritization option, provided triage is not over-emphasized in other sectors of care or other less critical conservation contexts.

TRIAGE IN A CONSERVATION CONTEXT RECONSIDERED

Emergency medicine triage and triage in the biodiversity conservation sector are notionally similar in that they relate to prioritization, but differ in terms of aims (e.g., allocation of wait times, vs. treatment), entities (e.g., individuals vs. groups), resource availability, including knowledge of prognoses with and without treatment, and institutional contexts. Medical and conservation triage are however unified by a wide variation in cultural and social contexts, and because the burden in both systems are increasing, as are the expectations of society.

We suggest conservation can learn much from emergency medicine triage. Emergency medicine triage has a much stronger emphasis on a wider variety of ethical principles than do common examples of conservation triage. Systems for conservation triage need to reflect more diverse ethical considerations to ensure it is more critically and effectively utilized. Conservation triage has to date been based on the principle of maximum utility, but needs to widen the scope of its ethical principles to include consideration of other concepts of distributional justice such as need. Importantly, triage contexts in conservation need not force the sacrifice of the most critically endangered species or ecosystems, as the outcome of any prioritization will depend on the proximal and distal objectives of the prioritization itself and the trade-offs that are acceptable (Conde et al., 2015).

Clear identification and communication of triage protocols and objectives, and situating triage within a broader system of care are key components of effective and ethical triage systems. While triage in emergency medicine is commonly evoked to justify/promote acceptance of conservation triage, for conservation there are likely better analogies from pandemic or disaster triage, where more "hard" decisions that involve sacrifice for the "greater good" are typically made—but still with unease and controversy. However, all conservation contexts need not be characterized as crises: a single conservation triage process would be better characterized as an important, but small component of a larger system of care and be driven by a wider and more diverse ethical perspective than has been previously been referred to.

We do not argue for or against triage as a concept, but rather conclude that to cast triage systems as "just" decision-making is simplistic. To expect one triage protocol will satisfy all stakeholders is naïve. Triage, like any prioritization or environmental decision, is associated with poignant environmental, economic, social, and ethical trade-offs. Triage systems may ultimately seek to deliver more good than harm from each triage decision that is made, but the premise of triage in medicine is to give ethical, rather than merely efficient, care. There is thus a need to reframe the notion of conservation triage from being predominantly about "rational" and "efficient" use of resources to considering the ethics of triage decisions when they are enacted.

AUTHOR CONTRIBUTIONS

KW and EL designed the paper, drafted and revised the paper, and approved the final version of the manuscript before submission.

ACKNOWLEDGMENTS

We appreciate the comments received on earlier versions of this manuscript from E. Meijaard, D. Biggs, G. FitzGerald, S. Hagerman, B. Traill, H. Possingham and I. Lunt. KW and EL acknowledge funding from the Australian Research Council (http://www.arc.gov.au/), Future Fellowship (FT100100413), Centre of Excellence (CE110001014), and Discovery (DP150101300) programs.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Ecology and Evolution

ORIGINAL RESEARCH
published: 17 August 2016
doi: 10.3389/fevo.2016.00098

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Repeatability and Reproducibility of Population Viability Analysis (PVA) and the Implications for Threatened Species Management

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Conservation triage focuses on prioritizing species, populations or habitats based on urgency, biodiversity benefits, recovery potential as well as cost. Population Viability Analysis (PVA) is frequently used in population focused conservation prioritizations. The critical nature of many of these management decisions requires that PVA models are repeatable and reproducible to reliably rank species and/or populations quantitatively. This paper assessed the repeatability and reproducibility of a subset of previously published PVA models. We attempted to rerun baseline models from 90 publicly available PVA studies published between 2000 and 2012 using the two most common PVA modeling software programs, VORTEX and RAMAS-GIS. Forty percent ($n = 36$) failed, 50% (45) were both repeatable and reproducible, and 10% (9) had missing baseline models. Repeatability was not linked to taxa, IUCN category, PVA program version used, year published or the quality of publication outlet, suggesting that the problem is systemic within the discipline. Complete and systematic presentation of PVA parameters and results are needed to ensure that the scientific input into conservation planning is both robust and reliable, thereby increasing the chances of making decisions that are both beneficial and defensible. The implications for conservation triage may be far reaching if population viability models cannot be reproduced with confidence, thus undermining their intended value.

Keywords: conservation triage, VORTEX, RAMAS-GIS, essential data

Edited by:
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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *11 May 2016*
Accepted: *02 August 2016*
Published: *17 August 2016*

Citation:
Morrison C, Wardle C and Castley JG (2016) Repeatability and Reproducibility of Population Viability Analysis (PVA) and the Implications for Threatened Species Management. Front. Ecol. Evol. 4:98. doi: 10.3389/fevo.2016.00098

INTRODUCTION

Despite concerted efforts by conservation practitioners worldwide, species extinction rates continue to increase (Butchart et al., 2010; Pimm et al., 2014). Current conservation spending remains well below that required to return rates of extinction to natural levels (Balmford et al., 2003; McCarthy et al., 2012). The persistent and often escalating threats to biodiversity, coupled with inadequate funding, make it inevitable that conservation managers apply triage in decision making (Bottrill et al., 2008, 2009; Arponen, 2012).

Conservation triage focuses on prioritizing species, populations or habitats based on urgency, biodiversity benefits, recovery potential (i.e., chance of success), and costs to achieve a desired goal (Bottrill et al., 2008). Urgency is frequently a function of extinction risk but also values associated with particular species (Farrier et al., 2007). Some argue that it is futile to spend time and scarce resources on hopeless cases or on species/populations that are likely to persist without conservation intervention (Arponen, 2012). Essentially, projects should be prioritized on species uniqueness (e.g., evolutionary distinctiveness, Jetz et al., 2014), probabilities of extinction and cost of conservation actions (McDonald-Madden et al., 2008; Reece and Noss, 2014). However, the uncertainty associated with some or all of these parameters will ultimately influence our ability to make robust conservation decisions (Beissinger and Westphal, 1998; Nicholson and Possingham, 2007). In many cases trade-offs become critical in directing limited resources optimally amongst a suite of species, whether these are a few high priority species or a greater number of lower priority species (McCarthy et al., 2008; Joseph et al., 2009; Arponen, 2012).

Population Viability Analysis (PVA) is used to support conservation decision making by providing empirical evaluations of different management actions for the species or population in question (Burgman and Possingham, 2000; Dreschler and Burgman, 2004; IUCN, 2008). PVA modeling of the effects of demographic, environmental and genetic stochasticity, natural catastrophes, environmental spatial structure, landscape heterogeneity, and the influence of management strategies permits estimation of the extinction risk of populations (Reed et al., 2002). By predicting population persistence in the short (a few years) to medium (10s–100s years) term, PVA allows quantitative ranking of alternative management strategies that benefit populations or metapopulations (Burgman and Possingham, 2000; Reed et al., 2002; Traill et al., 2010).

The use of PVA as a decision support tool to guide threatened species management interventions is not without limitations. The decisions made by users are heavily reliant on PVAs using comprehensive, reliable, accurate, and up-to-date information (Beissinger and Westphal, 1998; Traill et al., 2010; Flather et al., 2011). The reliability and predictive capacity of PVA has been tested previously (Taylor, 1995; Brook et al., 2000) and is influenced by the availability of known historical population level data (Reed et al., 2002). While the underlying data quality (robustness) is fundamentally important in supporting conservation triage decision making, an often overlooked aspect relates to how reliable or repeatable the PVAs are themselves. This has recently been emphasized by Pe'er et al. (2013) when advocating for a standard protocol for PVA that included detailed communication criteria.

This has important implications for dynamic conservation management considering that if original PVAs cannot be repeated and reproduced, how can we reliably evaluate the effectiveness of different management strategies or prioritize species? Repeatability is important for the development of any field of research (Cassey and Blackburn, 2006; Ellison, 2010) and is a basic requirement for the assessment of management strategies. Reproducibility is desirable when extending or attempting to evaluate the results of previous research and goes someway to protecting against deliberate fraud (Cassey and Blackburn, 2006) or accidental errors.

Faced with the need to adopt a more strategic and defensible approach to threatened species management and prioritization, it can be expected that practitioners will want to reassess the extinction risk of species at some time in the future building on initial PVA predictions. These may be required for various reasons including that better data may have become available, management interventions may have changed in response to ongoing or novel threatening processes or financial and/or other resources may have changed. A first step in such revisions will be the comparison of previous predictions and models using new data. This paper explores this aspect by asking to what extent previously published PVAs are repeatable and reproducible. This is critically important in determining their effectiveness in providing accurate and reliable information for conservation management decisions.

METHODS

Our evaluation of previous PVAs comprised three successive steps (**Figure 1**). First, we created a database of accessible PVA models published since 2000. We confined our analysis to more recent studies, i.e., post 2000, given recent advances in the computational capacities of simulation software commonly used in undertaking these analyses and the presence of older reviews of PVAs (e.g., Menges, 2000). For our purposes "PVA models" referred to those where a PVA or Population and Habitat Viability Analysis (PHVA) had been completed for primarily terrestrial fauna and flora. The quality of data used in PVA models can vary widely depending on the species or populations involved (Brook et al., 2000). We wanted to test PVA models with the best data so we focused our data collection on species that included well-known keystone species (e.g., wolves), species involved in tourism (e.g., whale sharks), or species involved in subsistence or commercial hunting (e.g., dugongs)($n = 148$), to maximize the potential for repeating these models. The demographic data on these species tends to be more extensive and as a result, PVA models and the subsequent population predictions are more robust (Brook et al., 2000; Coulson et al., 2001; Gordon et al., 2004).

Secondly, we eliminated PVAs that were either user-defined PVAs with unusual structures ($n = 43$) or PVAs incorporating both spatial and demographic data where the data were inextricably linked and the spatial data were not available ($n = 15$). We focused our data collection on studies that were published using two of the most common PVA modeling software tools, i.e., VORTEX or RAMAS-GIS. These two programs are repeatedly used, subject to wide scrutiny, and are frequently revised and updated (Brook et al., 2000). They have both been used in the management and conservation of endangered species. We also chose PVA studies using these programs as many PVA models are not necessarily run or constructed by modeling experts. VORTEX and RAMAS-GIS have many default values for standard analyses and can be easily run if the required data are available. Therefore, while authors of these individual studies were likely familiar with their focal species, they would not be expected to (i) be able to construct their own models, or (ii) calculate some demographic criteria from other data.

Thirdly, we compiled the necessary model parameters as reported by the final selected studies ($n = 90$) and tried to rerun the baseline models of each to determine repeatability. We then

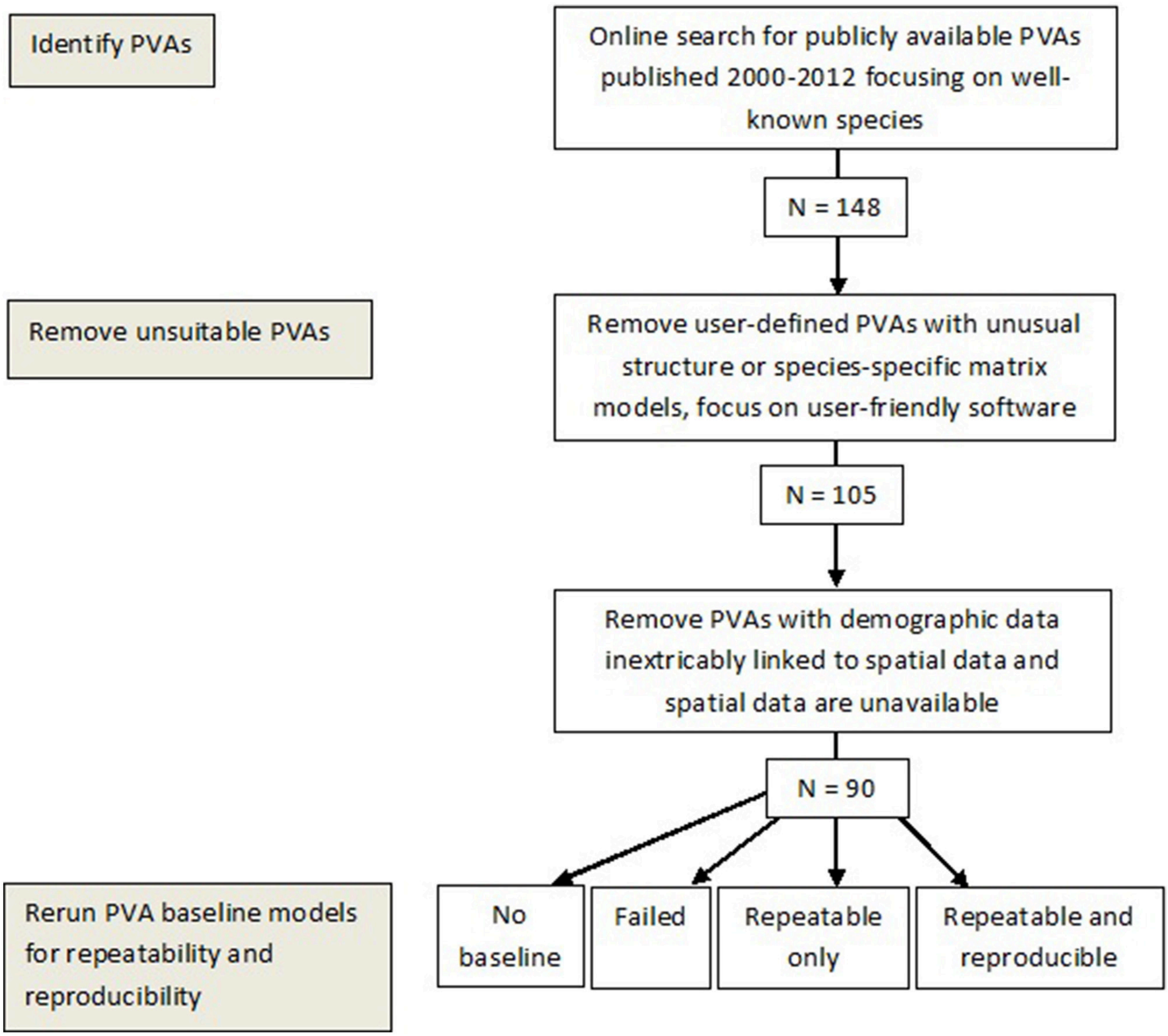

FIGURE 1 | Summary of methodology used to select Population Viability Analysis (PVA) models and determine repeatability and reproducibility of PVAs.

determined the reproducibility of repeatable models. Models deemed to be reproducible were those where the confidence limits of data from our models overlapped with confidence limits of the data from the original model predictions.

Data Collection

We obtained publicly available, peer-reviewed species PVAs through extensive internet searches using Google Scholar, Science Direct and from websites including the IUCN Conservation Breeding Specialist Group (CBSG, http://www.cbsg.org/cbsg/). Searches were conducted between September 20 and October 23, 2012.

We found 148 species-specific PVAs on “popular” species (described earlier) published in peer-reviewed journal articles, PVA/PVHA workshop reports, and accepted post-graduate theses. The majority of PVAs were run using VORTEX (87 PVAs for 81 species) and RAMAS-GIS (18). The remaining PVAs were completed using a variety of self-built models.

Population Viability Analysis

We extracted baseline model input values from 81 of the 90 PVAs from the published sources and entered the data into VORTEX (version 9.99) or RAMAS-GIS (version 4.0) to run the baseline models. No baseline models were provided for the other 9 PVAs. For some PVAs the parameters were clearly defined in tables or lists; for some they were unclear and/or buried within the text; some stated that the input values could be found in supplementary data, which were not always accessible; and for several PVAs they were simply not available. For each PVA where applicable, we noted parameters with missing data and/or for which the data were ambiguous or had multiple options. These measures provided an indication of the robustness of these model data parameters.

In some instances, assumptions could be made about missing parameters for models rerun using VORTEX where these were not explicitly articulated in the respective studies. We assumed Environmental Variation (EV) concordance, catastrophes, dispersal, density dependent reproduction, future change in carrying capacity, harvesting, and supplementation were all excluded from the original baseline model if not explicitly mentioned. We left lethal equivalents, per cent due to recessive lethals, and age distribution at default values of 3.14, 50, and stable, respectively, if not specified. We left EV correlation among populations at 0.5 if a value was not provided, unless the baseline consisted of only one population. We were still able to run baseline models without some of these data.

If information was not available for parameters that were required to run the model (see **Table 1** for required data for VORTEX), or for which assumptions could not be made, we recorded the PVA as missing required data and these studies were deemed ***non-repeatable***. We assumed that the authors of the studies would not be able to calculate missing parameters based on other demographic data, e.g., "% adult females breeding" is not required if fecundity is estimated from a regression of juveniles (t) on adults (t-1).

We compared the baseline model outputs for our successfully run PVAs (repeatable) to the output values of the original models. This included a combination of commonly used viability measures such as growth rates, probability of extinction, extant population size, remaining genetic diversity, lambda and time to extinction in addition to the confidence limits for these data. If our baseline models did not match the original models (no overlapping confidence limits) we rechecked the input data and any parameters for which assumptions had been made (based on missing or ambiguous data), and these parameters were re-estimated. We then reran models and if these still did not match the original models we recorded the PVA as being ***non-reproducible***. If baseline models were not provided in the original study, we recorded the PVA as ***missing baseline***. As we wanted our analyses to be consistent and rigorous, we did not attempt to run alternative models for those studies missing baseline models.

All 90 PVAs were independently analyzed by two of the authors (CW, CM). For each original PVA, we recorded the version of VORTEX or RAMAS used the year the study was conducted, and the threat status of the species based on the IUCN Red List criteria (http://www.redlist.org). At the end of the analyses, we classified each PVA into one of four categories, (i) repeatable + reproducible = PVA ran and matched original (overlapping confidence limits), (ii) repeatable only = PVA ran but did not match original (non-overlapping confidence limits), (iii) failed = PVA could not be run due to missing data, or (iv) missing baseline models.

TABLE 1 | Criteria required for running the VORTEX Population Viability Analyses (PVAs) reviewed in this study including the number and frequency of examined PVAs missing these criteria.

Criteria	# of all PVAs missing this criterion ($N = 90$)	# of non-repeatable PVAs missing this (criterion $N = 36$)
% adult females breeding	5	5
Age of first offspring (F)	2	2
Age of first offspring (M)	4	4
Carrying capacity	7	7
EV in % breeding	19	18
Initial population size	2	2
Mate monopolization	10	10
Maximum age of reproduction	3	3
Mortality rates (M/F)	8	8
SD in mortality rates	17	16
Type of reproductive system	8	8

Statistical Analysis

We used χ^2 tests to compare the repeatability and reproducibility of PVA models in (i) different taxonomic groups (birds, mammals, reptiles), (ii) IUCN threatened species categories (Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern), (iii) version of software (VORTEX or RAMAS) used in the original study, and (iv) publication quality (based on current journal impact factors and/or gray literature). We also used χ^2 analysis to compare missing data in species from different threat categories. A correlation analysis was used to determine if there was a relationship between year of publication and our ability to replicate/reproduce the study. Kruskall-Wallis tests were used to compare the average number of missing criteria in the different taxonomic groups and threatened species categories. Statistical analysis was completed using SPSS Ver. 22 with alpha set at 0.05.

RESULTS

General Summary

The vast majority of the 90 PVAs modeled mammal (62 species) and bird (19) populations. The remaining PVAs assessed amphibians (1), fish (1), insects (1), and reptiles (6). No plant PVAs met all the selection criteria. Eleven species are currently listed as Critically Endangered, 27 Endangered, 18 Vulnerable, 11 Near Threatened, and 23 Least Concern. The geographic spread of species was wide ranging covering the Neotropical (25 species), Nearctic (16), Afrotropical (16), Palearctic (15), Indomalayan (12), and Australasian (6) regions. Forty-one PVAs were published in peer-reviewed journals, 48 were published in CBSG reports and one was a post-graduate thesis.

PVA Repeatability and Reproducibility

Half of the 90 PVAs ($n = 45$) were both repeatable and reproducible, none were repeatable only, 36 failed, and nine had no baseline model (Table S1 for details).

Bird PVAs appeared more repeatable and reproducible than those for mammals or reptiles (71% vs. 43% and 33%, respectively) but not significantly so ($\chi^2 = 4.659$, df = 2,

$p = 0.097$). There was also no relationship between the threat status of the species and PVA repeatability ($\chi^2 = 1.304$, df = 4, $p = 0.86$).

There was no correlation between the year the original model was run and our ability to replicate it ($r = 0.108$, $p = 0.29$), nor was there a relationship between the version of VORTEX or RAMAS used in the original PVA and our ability to replicate the model ($\chi^2 = 27.336$, df = 27, $p = 0.49$). Publication quality (assessed by using current journal impact factors) had no effect on PVA repeatability ($\chi^2 = 3.524$, df = 4, $p = 0.47$).

Missing and/or Incorrect Input Data

VORTEX 9.99 has 65 input data criteria, 11 of which are required data (**Table 1**). Most of the failed PVAs were missing these data ($n = 32$) and/or provided a range of data values ($n = 12$). The required data most frequently absent from PVAs included mortality rates for males and females (missing from 9% of all reviewed PVAs), standard deviation in mortality rates (20%), mate monopolization (11%), and EV (Environmental Variation) in % breeding (22%).

Required data were missing from 12% of bird PVAs, 50% of reptile PVAs, and 36% of mammal PVAs. There was no relationship between the threat status of the species and missing data (CR = 36%, EN = 24%, VU = 33%, NT = 45%, LC = 27%; $\chi^2 = 1.983$, df = 4, $p = 0.74$).

The total number of input data missing from PVAs (out of 65) ranged from 0 to 43 (average = 8.67 ± 9.42). There was no difference in the average number of input data missing in bird (6.0 ± 7.80), mammal (9.26 ± 10.09), and reptile (10.17 ± 8.57) PVAs (Kruskal Wallis test: $p = 0.187$). There was also no difference in the average number of input data missing in CR (8.1 ± 6.67), EN (6.68 ± 7.15), VU (10.61 ± 16.54), NT (11.55 ± 7.03), and LC (8.18 ± 5.12) PVAs (Kruskal Wallis test: $p = 0.197$).

Of the PVAs run using RAMAS-GIS, two were both repeatable and reproducible while the third did not provide a baseline model for comparison.

DISCUSSION

Our analysis has revealed that a substantial number of current PVAs for "popular" species are not repeatable due largely to the fact that the model parameters required to repeat these analyses were poorly communicated in papers or reports. The importance of communicating all inputs and outputs of PVA models in a systematic manner to ensure that studies can be repeated was recently highlighted by Pe'er et al. (2013). Here we provide an empirical demonstration of the consequences should these model parameters not be reported. Of course this has immediate effects on whether conservation practitioners can repeat the models. More broadly, however, this also diminishes the ability of practitioners to reliably make decisions on conservation actions.

Importantly, there was no pattern among studies to suggest that some were worse than others in terms of reporting baseline parameters. Consequently, repeatability was not linked to taxa, IUCN category, PVA software version used, year published or the quality of publication outlet. Plant-focused PVAs were not represented in our analysis as these were either completed using self-constructed models, or RAMAS-GIS where there were no associated spatial data. A detailed assessment of these models was therefore beyond the scope of the current paper. This does, however, highlight the need for a more detailed review of these aspects within plant-focused PVAs, building on the previous review by Menges (2000).

While the quality and quantity of data is one primary source of uncertainty affecting the reliability of PVA predictions (Beissinger and Westphal, 1998), the implications of not being able to repeat studies has not yet been empirically evaluated. While the reliability of predictions could result in scarce resources being directed inefficiently, where predictions cannot be repeated or reproduced practitioners may be unable to evaluate whether any conservation action or spending has achieved the desired conservation objective. Our results suggest that the latter problem is systemic within the discipline, despite the fact that numerous guidelines for undertaking PVAs exist (e.g., Beissinger and Westphal, 1998; Burgman and Possingham, 2000; Ralls et al., 2002; IUCN, 2008). Given that our sample of PVAs also concentrated on species with a higher profile, we may have expected that data for these species would be more comprehensive. Nevertheless, the number of PVAs that could not be replicated was still relatively high suggesting that our assessment of repeatability and reproducibility in PVAs could be an overestimate. We therefore, echo the sentiments of Pe'er et al. (2013) who have called for the complete and systematic presentation of PVA parameters and results to ensure repeatability of these studies.

Previous reviews of the utility of PVAs consider the importance of reducing uncertainty through careful selection of model structures based on known available data (Burgman and Possingham, 2000). Pe'er et al. (2013) provide the most recent evaluation of model parameters commonly included in the application of PVAs. However, they do not suggest which of these are fundamental to being able to compile and run a simple baseline model, despite suggesting that the inclusion of density-dependent processes remains poor. From our analyses we were able to identify those parameters that should be seen as minimum requirements (in our case for studies completed using VORTEX) to enable others to repeat the models at a later stage. These parameters are similar to those listed by Ralls et al. (2002) and included aspects of mortality rates and changes in carrying capacity. Of course the suggestions provided by Pe'er et al. (2013) are still valid in that any data used in these baseline models should be accompanied by all the necessary metadata. As such, all baseline PVA models should be checked for repeatability and reproducibility during the peer review process to make sure that all necessary data is provided prior to publication. The current transition to academic publication models that require authors to submit their raw data together with manuscripts may successfully address this issue in the future.

The repeatability of PVAs is critical to improving conservation efficiencies for a number of reasons. Firstly, those that are not repeatable may bring into question the validity and predictions of the original model. This is important as there are numerous authors who have highlighted the shortcomings for conservation practice should PVA predictions not be sufficiently robust (Taylor, 1995; Burgman and Possingham, 2000; Ralls et al., 2002). Furthermore, given that improvement of PVA models is an ongoing process (Lindenmayer et al., 2000; Ralls et al., 2002), non-repeatable PVAs limit the ability of conservation practitioners to compare revised models using updated parameters to previous models. This will be the case regardless of the simulation program used, i.e., VORTEX, RAMAS, etc.

With finite resources to develop and implement conservation strategies for threatened populations, conservation managers need to prioritize strategies and options to the species and/or habitats where they produce the greatest benefit (McDonald-Madden et al., 2008; Arponen, 2012). Robust and reliable PVAs based on biology and management resources that examine the costs and benefits of different management options can aid in decision making in an objective and transparent way. In practice though, conservation prioritization is often a subjective and value-driven process (Farrier et al., 2007; Arponen, 2012) that is heavily influenced by sociopolitical factors. Given the influence of so many other factors on the conservation planning process, it is critical that the scientific input is robust, reliable, and reproducible thereby increasing the chances of making decisions that are both beneficial and justifiable.

AUTHOR CONTRIBUTIONS

Study design CM, JC; data collection and analysis CM, CW; manuscript preparation CM, JC, CW.

ACKNOWLEDGMENTS

We thank Mark Burgman for feedback on an earlier version of this manuscript and Ralf Buckley for discussions on the topic. We also thank Daniel Brito and the reviewers for their useful comments and suggestions that improved the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fevo.2016.00098

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers
in Ecology and Evolution

ORIGINAL RESEARCH
published: 15 November 2016
doi: 10.3389/fevo.2016.00128

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Stakeholder Perspectives on Triage in Wildlife Monitoring in a Rapidly Changing Arctic

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OPEN ACCESS

Edited by:
Ricardo Baldi,
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Reviewed by:
Viorel Dan Popescu,
Simon Fraser University, Canada
Orly Razgour,
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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *22 April 2016*
Accepted: *28 October 2016*
Published: *15 November 2016*

Citation:
Wheeler HC, Berteaux D, Furgal C, Parlee B, Yoccoz NG and Grémillet D (2016) Stakeholder Perspectives on Triage in Wildlife Monitoring in a Rapidly Changing Arctic. Front. Ecol. Evol. 4:128. doi: 10.3389/fevo.2016.00128

Monitoring activities provide a core contribution to wildlife conservation in the Arctic. Effective monitoring which allows changes in population status to be detected early provides opportunities to mitigate pressures driving declines. Monitoring triage involves decisions about how and where to prioritize activities in species and ecosystem based monitoring. In particular, monitoring triage examines whether to divert resources away from species where there is high likelihood of extinction in the near-future in favor of species where monitoring activities may produce greater conservation benefits. As a place facing both rapid change with a high likelihood of population extinctions, and serious logistic and financial challenges for field data acquisition, the Arctic provides a good context in which to examine attitudes toward triage in monitoring. For effective decision-making to emerge from monitoring, multiple stakeholders must be involved in defining aims and priorities. We conducted semi-structured interviews with stakeholders in arctic wildlife monitoring (either contributing to observation and recording of wildlife, using information from wildlife observation and recording, or using wildlife as a resource) to elicit their perspectives on triage in wildlife monitoring in the Arctic. The majority (56%) of our 23 participants were predominantly in opposition to triage, 26% were in support of triage and 17% were undecided. Representatives of Indigenous organizations were more likely to be opposed to triage than scientists, and those involved in decision-making showed greatest support for triage amongst the scientist participants. Responses to the concept of triage included that: (1) The species-focussed approach associated with triage did not match their more systems-based view (5 participants), (2) Important information is generated through monitoring threatened species, which advances understanding of the drivers of change, responses and ecosystem consequences (5 participants), (3) There is an obligation to try to monitor and conserve threatened species (4 participants), and (4) Monitoring needs to address local people's needs, which may be overlooked under triage (3 participants).

The complexity of decision-making to create monitoring programmes that maximize benefits to biodiversity and people makes prioritization with simple models difficult. Using scenarios to identify desirable trajectories of Arctic stewardship may be an effective means of identifying monitoring needs.

Keywords: arctic monitoring, decision-making, polar observation, prioritization, recording, wildlife conservation

INTRODUCTION

The Arctic faces multiple pressures, which have substantial potential to affect arctic wildlife and the ecosystems that support these species (Post et al., 2009, 2013; Gilg et al., 2012; CAFF, 2013). A rapid rate of change is observed and projected in the Arctic, given warming is considerably higher than the global average (Hartmann et al., 2013). In addition to climate change, the dramatic rate of increases in mining and petroleum exploration and development, commercial wildlife uses, subsistence harvesting and long-range pollution are all potential drivers of change in the population, distribution, and health of many species in the Arctic (Johnson et al., 2005; Huntington et al., 2007; CAFF, 2013). Consequently, the monitoring of wildlife plays an important role in identifying change in populations and habitat such that actions can be taken to mitigate or minimize pressures. Accordingly, it is essential to identify the motivations for monitoring in the Arctic, what should be monitored and how monitoring should be undertaken (Yoccoz et al., 2001).

The Arctic represents a system in which it is necessary and timely to examine triage in wildlife monitoring. Understanding the speed of changes in the Arctic, governments are increasingly recognizing the need to address what science needs to be done and how it should be implemented (Tesar et al., 2016). Due to remoteness and difficulties with access, the costs of monitoring in the Arctic can be very high, creating a strong need for prioritization of activities.

Triage involves the prioritization of how to distribute limited resources. Multiple definitions of conservation triage exist, varying in breadth. The traditional definition of conservation triage concerns selecting between species (McIntyre et al., 1992), populations or subpopulations (McDonald-Madden et al., 2008) based on their probability of survival, given a level of investment. This has been broadened to other situations related to prioritization of actions to maximize conservation benefit (Bottrill et al., 2008). The latter, broadened definition can encompass a wide range of decision-making processes and algorithms. Under this broad definition, triage effectively encompasses any strategic decision making concerning conservation. As argued by Bottrill et al. (2008), triage under this broadened definition, may simply be smart decision-making and is already implicit in the planning of many conservation activities. Under the broad definition, any failure can be attributed to mis-specification of the problem rather than a fundamental issue with the approach. Here, we focus on the traditional (narrower) definition of triage in reference to monitoring of arctic wildlife. In particular, we focus on whether the likelihood of survival of a population or species should influence the amount of effort devoted to monitoring.

To evaluate the appropriateness of triage in monitoring, we need to define the desirable outcomes from monitoring, the extent to which triage can achieve desired outcomes and whether triage provides an acceptable route to achieving these objectives. Lindenmayer and Likens (2010) define three types of monitoring: identifying change in populations, often in response to political directives and government mandates; testing predictions to understand processes and mechanisms underlying changes; and curiosity-driven monitoring, which has less direct goals and rationale. Perhaps the most direct outcome of monitoring is management decisions. Monitoring has an important role in adaptive management and adaptive co-management in complex socio-ecological systems, such as found in the Arctic (Armitage et al., 2009). In these systems, monitoring contributes to decision-making based on ecosystem state by informing evaluation of effectiveness of management actions and facilitating learning about the system (Lyons et al., 2008). More indirect outcomes from monitoring are increased awareness of the public and politicians, increased support, leverage, and effort toward reaching desired outcomes through local, public, and political engagement (via publicity from monitoring or active engagement in monitoring), and discovery of new and useful information (Possingham et al., 2012). These more indirect outcomes of monitoring can have substantial benefits to society (Possingham et al., 2012) but are more often overlooked when evaluating the benefits of monitoring. Many of the indirect benefits of monitoring relate to facilitating different stakeholders in learning about socio-ecological systems, with the goal of driving action, however often the link between monitoring, management at learning is poorly defined (Armitage et al., 2008, 2009), as is the link between learning and action. This high degree of complexity creates challenges in determining the applicability of strategies such as triage to meeting often diverse and diffuse outcomes from monitoring.

Spatial scale is a key consideration regarding the needs and motives for monitoring and conservation (Pearson, 2016). Stressors acting on the Arctic range from global drivers such as climate change, which are primarily generated outside the Arctic, to regional pressures associated with increased opportunities for development under warming, to local pressures such as harvesting (CAFF, 2013; Andrew, 2014). The spatial scale at which action is required to address these pressures varies widely as does the ability and mechanisms to exert control over stressors. While climate change and contaminants in wildlife may require concerted global action, resource use may be manageable more locally.

A range of methods for observing and recording changes in wildlife populations exist in the Arctic, in particular scientific monitoring, community based monitoring, and traditional knowledge (Moller et al., 2004). These methods include a range of stakeholders including scientists, local resource users, government agencies, and industry (Kouril et al., 2015). It is important to consider the needs of multiple stakeholders when examining the concept of triage in wildlife monitoring in the Arctic. A range of stakeholders are either involved in monitoring, use information from monitoring or are affected by decisions arising from monitoring. In particular, the potential for monitoring and conservation plans to be co-produced with local communities is being recognized (Johnson et al., 2005), however the extent to which Indigenous peoples have land rights and the degree of self-determination varies very substantially across the Arctic, particularly between countries. In North America, local participation of Indigenous peoples is greatest, primarily occurring in local and regional decision-making through wildlife management boards and this is also observed in greater levels of community based monitoring (Kouril et al., 2015). Further, little is currently known about the perspectives of different actors in arctic wildlife monitoring and conservation regarding the application of triage.

Using interviews with multiple stakeholders, we explore views on triage in monitoring with a focus on arctic terrestrial vertebrate and seabird systems. We explore perspectives among those involved in, directing the collection of, or who are recipients of the data generated by monitoring programs. We examine attitudes toward triage, opinions on the validity of the assumptions underlying triage (e.g., transferability of resources between species and sites) and how characteristics of the Arctic might influence the applicability of triage. In particular, we address the following questions:

1. Are stakeholders broadly in support or opposition to triage in wildlife monitoring in the Arctic?
2. What are the core justifications given by stakeholders in support of triage?
3. What are the core justifications given by stakeholders in opposition to triage?
4. What factors modify whether triage in wildlife monitoring in the Arctic might be appropriate?
5. What other issues might affect prioritization of monitoring in the Arctic?

TABLE 1 | Summary of all participants interviewed on triage, with their affiliations (unless otherwise requested), and countries.

Name	Affiliation	Country
Jason Akearok	Nunavut Wildlife Management Board	Canada
Tycho Anker-Nilssen	Norwegian Institute for Nature Research	Norway
Robert Barrett	University of Tromsø	Norway
Christine Cuyler	Greenland Institute of Natural Resources	Norway
Knud Falk	Independent	Denmark/ Greenland
Maria Gavrilo	Russian Arctic Nature Reserve	Russia
Grant Gilchrist	Environment Canada	Canada
Olivier Gilg	University of Bourgogne	France
Ann Harding	Pribilof Island Seabird Youth Network	U.S.A.
Henry Huntington	Huntington Consulting/NGO	U.S.A.
Gabriela Ibarguchi	Arctic Institute of North America	Canada
David Irons	US Fish and Wildlife Service	U.S.A.
Sarah Kalhok Bourque	Indigenous and Northern Affairs	Canada
Gary Kofinas	University of Alaska, Fairbanks	U.S.A.
Eva Krümmel	Inuit Circumpolar Council	Canada
Flemming Merkel	Aarhus University	Denmark
Don Reid	Wildlife Conservation Society	Canada
Manon Simard	Makivik Corporation	Canada
Martin Sommerkorn	WWF	Norway
Michael Stickman	Arctic Athabascan Council	U.S.A.
Hallvard Strøm	Norwegian Polar Institute	Norway
Ole-Anders Turi	Saami Council	Norway
Bob van Dijken		Canada

MATERIALS AND METHODS

We conducted one-on-one semi-directed interviews (Gubrium et al., 2012) with 23 individuals who were involved in the production or use of observations and recordings, were associated with arctic wildlife use, or were designated representatives of those groups. Interviewees were selected from attendees at Arctic Council working group and expert group meetings, international conferences and via snowball or referral sampling among interviewed participants (**Table 1**). Across stakeholder groups, we aimed to achieve representation of circumpolar countries and arctic Indigenous groups. Within the group of scientists interviewed, we attempted to achieve representation of those who work solely on scientific monitoring and those who incorporate community-based monitoring and traditional knowledge. We also tried to incorporate both scientists heavily focussed on decision-making and applied science, and those primarily engaged in fundamental science. Some participants filled more than one of these roles.

At the time of interviews, individuals followed an informed consent process after which each participant was asked questions to elicit their perspectives on using triage in the allocation of monitoring effort. A process of thematic content analysis (Saldaña, 2015) was applied to transcribed qualitative data from interviews. All questions were posed in a semi-structured form to allow participants to discuss the premise of the questions, generate new ideas and explore nuances in their answers. To maintain consistency across interviews, interviewees were given a definition of the traditional view of triage prior to being asked questions. Interviews were conducted either in person at arctic conferences and working group meetings or remotely via skype and telephone. In each case, interviews were audio recorded and then transcribed and reviewed to identify key themes in responses (Gubrium et al., 2012). Applicable portions of transcripts of responses were then associated or coded to commonly identified themes. All participants were given the options of having their names associated with quotes or quotes being used anonymously.

In analysis, responses were categorized as being largely supportive, largely opposed, or discussing both advantages and disadvantages such that they neither showed strong support nor strong opposition, or they were undecided. Interviews were conducted as part of a larger project on monitoring needs for the Arctic, which included additional participants. The study was carried out under the approval of Trent University Research Ethics Board. All subjects gave written informed consent in accordance with the Declaration of Helsinki.

In order to compare views on the traditional triage with views on other forms of prioritization aimed at maximizing conservation benefit (the broadest definition of triage), a subset of 11 participants were asked their perspectives on prioritizing resources toward monitoring that would generate the greatest conservation benefit. Five of these individuals were representatives of Indigenous organizations and five were scientists, of which one was involved in decision making, and two participants were from NGOs (one was a scientist, one was not). To examine perspectives on some of the key assumptions of triage, we then asked participants the extent to which they thought resources for monitoring were transferable between species and locations. This subset of individuals represented the last individuals interviewed, reflecting the development of the interview structure as we identified the need to examine the triage theme in greater detail.

Although, our primary goal was to explore stakeholder perspectives across all groups, we also assessed differences in responses between groups to indicate where key differences in perspectives may occur. We compared proportions of participants in each of the categories described below giving each response type (e.g., support or opposition for traditional triage and for monitoring for maximization of conservation benefits, context dependence in attitude toward traditional triage); we did not use inferential statistics, as our sample should be considered non-random. Given the distribution of participants among designated groups (representatives of Indigenous organizations, scientists, people involved in decision-making, and NGOs), all but one individual was either attributed to an Indigenous organization or was a scientist and there was no overlap between categories, we therefore focused our quantitative analysis on comparing responses by representatives of Indigenous organizations with those by scientists. This excluded the single individual who was a representative of an NGO and neither a scientist of representative of an Indigenous organization. We then focused on variation in response between those strongly involved in decision-making and those who were not. We did not compare representatives of NGOs with other categories due to low sample size within this group.

RESULTS

General Attitudes to Triage

Of the 23 participants interviewed concerning triage, six participant's primary role was to communicate Indigenous needs, nine were strongly linked to decision-making or policy-related organizations, and 16 were actively working in arctic science. Three participants worked for NGOs. Of our 23 participants, 13 (57%) gave responses predominantly opposing triage, six (26%) gave responses predominantly in favor, and four (17%) were either unsure or had views showing equal support and opposition to triage.

Participant type appeared to influence the degree of support for triage, in particular representatives of Indigenous organizations showed a strong opposition to triage (**Figure 1A**, left panel). In contrast, within scientists the response was more divided between support and opposition (**Figure 1A**, right panel). Within the scientists, a greater proportion of decision-makers were supportive of triage than non-decision-makers, although this difference was weaker than that observed between representatives of Indigenous organizations and scientists (**Figure 1A**). Fifty percent of those participants predominantly in favor of triage proposed some level of context specificity in the relevance of its application as opposed to 38% of participants in opposition to triage (**Figure 1B**), suggesting most respondents were only supportive of triage in limited contexts if at all.

Participants showed greater support for prioritizing monitoring according to maximization of conservation benefits than for the traditional definition of triage (where conservation was defined as benefits for wildlife and people, **Figure 1C**). Of a subset of 11 participants asked, 64% were in favor of monitoring being prioritized toward activities with clear conservation benefits, while only 18% of that subset were in favor of triage as a means of prioritization. This suggests that while most participants were not opposed to all monitoring prioritization efforts, many of those participants were not in favor of triage.

Responses to Triage As a Means of Prioritization of Monitoring

Interviews generated seven main types of response (**Tables 2–4**). Those addressing the conceptual framework of triage included criticism of the species-focussed worldview that underlies triage ($n = 5$) and the wildlife focussed view that may not take into account human needs ($n = 3$). Some participants also addressed the ecological validity of triage. These opinions on ecological validity were proposed both in support and in opposition to triage. Views included highlighting (in opposition to triage) the low functional redundancy in high latitude systems and perhaps greater need to preserve all species, or conversely (in support of triage) the prevalence of abundant species in the Arctic and the need to focus on common species.

The relevance of monitoring triage to information needs was also discussed. The need to learn about how species respond to rapidly changing arctic processes was highlighted. The lack of current ability to predict species responses to change was also cited as a reason not to apply triage approaches, as it may not be possible to accurately predict which species are least likely to persist and thereby accurately select species for triage. Practical issues were identified, such as whether threatened species generate their own funding in opposition to triage or whether it is more cost-efficient to monitor abundant species in support of triage. Political and ethical issues were also identified. More specifically, participants raised the need to monitor threatened species in order to highlight species declines

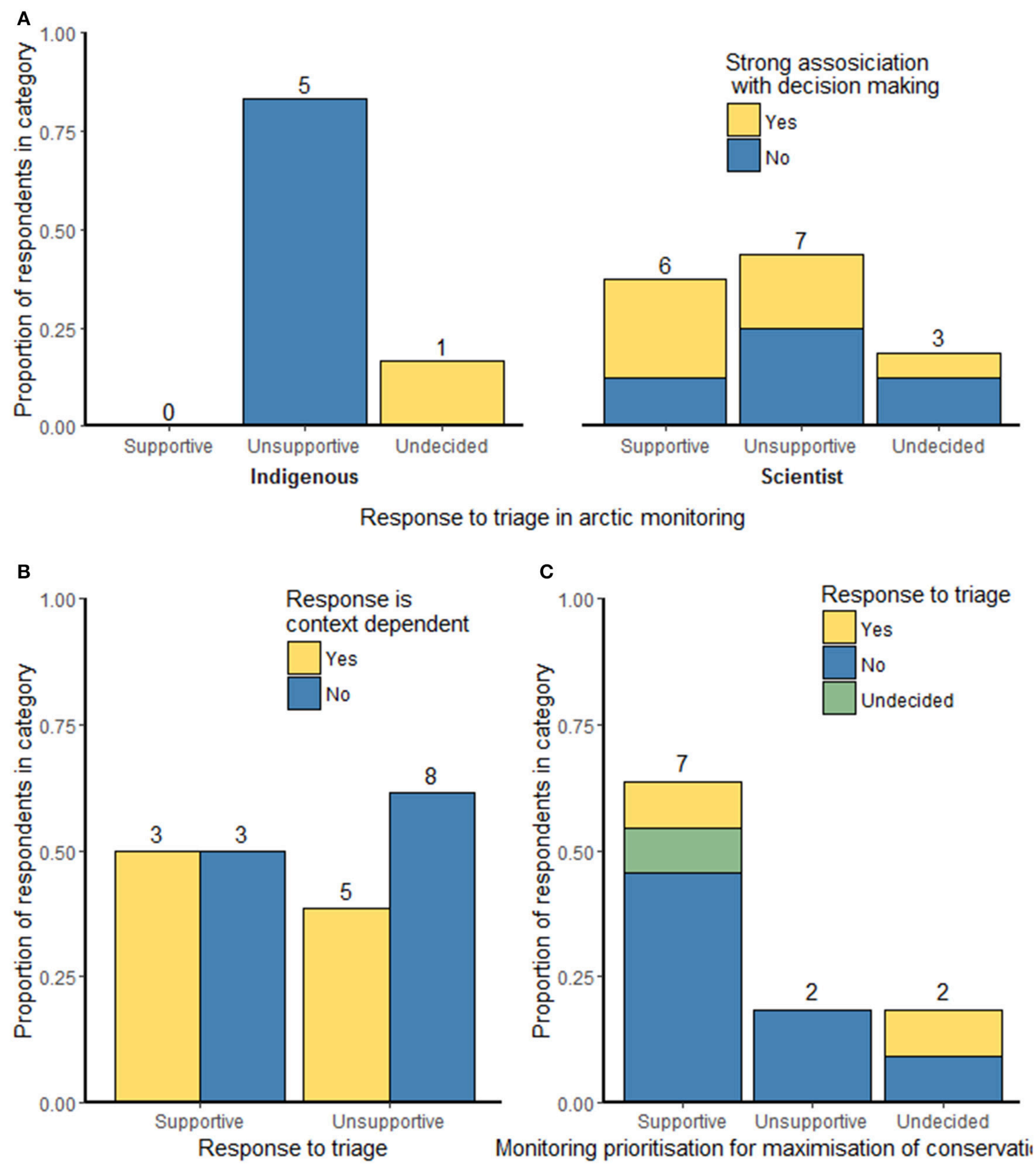


FIGURE 1 | Summary of stakeholder responses to triage and related issues (A) shows differences between representatives of Indigenous groups, scientists and individuals strongly related to decision-making in responses to triage, **(B)** shows the whether respondents supportive and unsupportive to triage showed a degree of context dependence in whether application of triage might be justified, **(C)** shows the responses of a subset of individuals asked whether monitoring should be prioritized for maximization of benefit for conservation and whether individuals were supportive of triage. Numbers of participants responding in a given way are indicated above bars.

and generate attention toward issues of arctic change, as well as the ethical stance that species should not be abandoned.

In addition, a number of modifying factors were acknowledged which might affect the applicability of triage. It was suggested that the applicability of triage might depend on spatial scale, and that species that are threatened locally (e.g., the Arctic fox in Norway, **Table 2**, quote 4.7.1) but not at a pan-arctic scale might be less important foci than those threatened across the entire Arctic. Whether there were means of addressing declines was also an important consideration in whether triage might be appropriate. Finally a consideration of who decides was an important modifying factor, with particular reference given to the need to involve Indigenous people and local communities in setting monitoring agendas. Several participants gave responses

TABLE 2 | Summary of stakeholder conceptual and ecological issues in monitoring triage for arctic wildlife.

Ref.	±	Theme	Participant quotes
4.1 CONCEPTUAL ISSUES			
4.1.1	−	Species focussed approach is antithetic to world views	"In monitoring of the environment, I'm thinking of broader issues..... I'm driven by environmental marine issues" Grant Gilchrist (Environment Canada, Canada)
			"I think it is better to have a wider approach, so you focus on a set of species and you do not focus on the very rare species who are likely to go extinct whatever you do" Hallvard Strøm (Norwegian Polar Institute, Norway)
			"Because the First Nations are very ecosystem [focussed] and holistic, I think it would probably be a tough argument to say now we'll just cut one loose, concentrate on the others [species]" Bob van Dijken (Canada)
			"That's a tough one because we pretty much depend on everything out there, so everything is important" Michael Stickman (Arctic Athabascan Council, U.S.A.)
			"Things that prioritise one population above the other could have an effect on the whole ecosystem in those areas but also people; because the whole population are dependent on other populations of species and [triage should be an] absolute last resort" Ole-Anders Turi (Saami Council, Norway)
4.1.2	−	Monitoring for the needs of local people	"If you want to look at it in terms of a human perspective, in terms of diversity to secure options (such as options for future human choices or ecological response options) and food security for example, I don't think it is a very good idea" Martin Sommerkorn (WWF, Norway)
			"Caribou seems to be important here, focussing conservation efforts for instance on caribou, again it is very important culturally to people, it's very important for people's diet and I think it is also important spiritually, I guess you are on the land and connecting with the land again for caribou, so I think that would be a fair approach" Jason Akearok (Nunavut Wildlife Management Board, Canada)
			"When you prioritise funds for one species above the other...their extinction has such an effect on the species you are trying to maintain, the communities of those species and the community of people, especially in the Arctic areas....Some [people] are so dependent on animals..." Ole-Anders Turi (Saami Council, Norway)
4.2 ECOLOGICAL ISSUES			
4.2.1	+	The conservation of abundance	"We are trying to keep the common species common, and if we put all out resources into trying to just help threatened species, the resources are all skewed towards...emergencies, many of which we can't help" Grant Gilchrist (Environment Canada, Canada)
			"One of the great things we have going in Alaska in the conservation world is we are in the position to conserve abundance..... We talk about the decline of the western caribou herd, that is has gone from 500 000 to something over 200 000, this is not an extinction problem, we are facing right now, we are trying to conserve that abundance" Henry Huntington (NGO and Huntington Consulting, U.S.A.)
4.2.2	−	Lack of functional redundancy	"The little functional redundancy we have in the Arctic, we just don't know which ones we can let go and still have a functioning ecosystem. In the Arctic...species are often irreplaceable" Martin Sommerkorn (WWF, Norway)

Where a perspective is compatible with triage is denoted + and incompatible −.

both in support and opposition to triage, therefore quotes in support or opposition to triage do not necessarily represent that a given participant gave an overall response of the same nature.

Finally, our interviews also identified how existing structures within arctic monitoring might impact the ability to prioritize monitoring across the Arctic and perspectives on current foci in arctic monitoring. In particular, the large number of agencies involved and the variety of their mandates may limit flexibility in monitoring across the Arctic. Participants identified the current focus on harvested species and economically relevant species as a potential concern within the current monitoring agenda.

DISCUSSION

General Attitudes to Triage

Our study demonstrates an overall lack of support for triage in monitoring within our participant group. Opposition was particularly pronounced for representatives of Indigenous organizations. This opposition may reflect a more holistic view of socio-ecological systems (and thus a lesser tendency to reduce them to their individual components) or a stronger cultural and spiritual value placed on arctic species (Cochran et al., 2013). Scientists were more split in their support; those strongly associated with decision-making had greatest support for triage. This may reflect a willingness of and necessity for those closer to the decision making process to make compromises concerning certain values to deal with trade-offs within decision-making.

Reconciling perspectives between different actors is an important part of decision-making regarding monitoring, to promote effective arctic stewardship under continuing rapid socio-ecological change. In the Arctic, meaningful involvement of Indigenous peoples in decision-making processes regarding monitoring priorities may be one way of managing the variation in perspectives toward monitoring, to obtain mutually acceptable monitoring agendas. This includes decisions regarding scientific monitoring and use of Indigenous knowledge, local ecological knowledge, and community based monitoring. Although, there are increasing efforts for Indigenous and local community involvement in setting monitoring agendas (Russell et al.,

TABLE 3 | Summary of stakeholder perspectives relating to information needs and cost efficiency in relation to triage in wildlife monitoring in the arctic.

Ref.	±	Theme	Participant quotes
4.3 INFORMATION NEEDS			
4.3.1	–	Important knowledge generated through monitoring	"I think [threatened species] are important because they can still tell us things about the marine environment, so we are studying Ivory Gulls not just because they are a rare or endangered species but because they are a really arctic species.....if that population is declining or its range is shrinking and we can relate that to sea ice conditions..that's a very big issue" Grant Gilchrist (Environment Canada, Canada) "The Ivory Gull......could be one of the first to disappear from climate change because it is so strictly linked to sea ice......we know that in in 20, 30, 50 years the sea ice will disappear in summer...it will likely die or adapt...it is extremely interesting knowledge for us because we can eventually infer how other species will react in the longer future..potentially all these species are facing a decline or extinctions in the longer term, so the sooner we understand part of how it works, the sooner we will be able to have alternative conservation policy and strategy" Olivier Gilg (University Bourgogne, France) "We must still learn about some management opportunities, just closing your eyes doesn't help" Knud Falk (Independent, Denmark/Greenland) "If there is a species which we think is doomed, what does that represent to the ecosystem?" Robert Barrett (University of Tromsø, Norway) "We want to keep an eye out for the local disappearance, extirpation or sudden die off of key species, and then pin point the cause(s) why.... we have got to find out why because the cause(s) could negatively impact populations elsewhere, possibly involving the entire arctic." Christine Cuyler (Greenland Institute of Natural Resources, Greenland)
4.3.2	–	Uncertainty in species responses	"Our projections can be wrong" Participant B "We don't know the impact of the environmental change to come and so there actually is only one strategy that makes sense in such a situation and that is conserve diversity" Martin Sommerkorn (WWF, Norway)
4.4 COST EFFICIENCY			
4.4.1	+	Greater efficiency in conserving and monitoring more abundant species	"The common species are easier to monitor, you get more bang for your buck" David Irons (US Fish and Wildlife Service, U.S.A.) "One of the problems I see with things like the endangered species focus is that is just sucks up so much time and attention to a handful of species or cases and this is to the detriment of the ones that are abundant or are doing well.....What do we lose by devoting all our resources to one animal to say it is still there, when we are neglecting what could be major shifts in populations of other animals" Henry Huntington (NGO and Huntington Consulting, U.S.A.)
4.4.2	–	Threatened species generate research funds	"when you know it is collapsing the money is often there" Robert Barrett (University of Tromsø, Norway)

Where a perspective is compatible with triage is denoted + and incompatible −.

2015), and the need has been long-highlighted, in many cases involvement remains limited. Notable exceptions are the strong participation of Indigenous and local communities in monitoring of contaminants to better understand impacts on traditional foods (Berkes et al., 2001) and co-production of knowledge in co-management of narwhal and beluga entrapments and Dolly Varden char (Armitage et al., 2011).

Greater understanding of how to involve Indigenous people in monitoring decisions may be gained from applying the successful approaches adopted in management. There is substantial geographic variation in the degree of Indigenous rights across the Arctic (Nuttall, 2000). Across arctic states, co-management is most advanced in North America, where land claims agreements define ownership of land, rights to resource use and processes of co-management involving Indigenous and government organizations (Kocho-Schellenberg and Berkes, 2014; Boudreau and Fanning, 2016). Effectiveness of decision-making within arctic co-management structures has been linked to key individuals acting as focal nodes for communication networks, involvement of bridging organizations in facilitating communication and bringing together different sources of knowledge (Kocho-Schellenberg and Berkes, 2014) and frequent and high quality interactions between stakeholders over extended time periods (Brooks and Bartley, 2016). Limitations to co-management include overreliance on individuals and small advisory councils to speak for multiple tribes and communities (Brooks and Bartley, 2016) and excessive burden on a limited number of individuals (Gallagher, 1988).

Our data suggest that evaluating triage in isolation from other strategies for prioritizing monitoring activities gives an incomplete picture of attitudes toward prioritization of monitoring activities. The lower acceptance of triage relative to monitoring for maximization of conservation benefit, suggests that triage is not perceived to be the most effective or acceptable way of maximizing conservation benefits from monitoring. Most of those who were supportive of triage expressed context dependence in this belief. This also suggests that few individuals believed that triage could be a single strategy for prioritization of monitoring efforts. A wider set of trade-offs need to be evaluated to understand how to maximize the multiple desirable benefits that may be attained from monitoring. Examining attitudes to triage may elucidate some of alternate underlying trade-offs of importance to stakeholders, which should determine broader monitoring agendas.

TABLE 4 | Summary of perspectives on political and ethical issues and factors that modify the applicability of triage in arctic wildlife monitoring.

Ref.	±	Theme	Participant quotes
4.5 POLITICAL AND ETHICAL ISSUES			
4.5.1	–	Political risks in the absence of monitoring of a species	"I mean you can have a policy where you say that if you don't know enough about something ... then we perhaps lower the quota, or we reduce the hunting season because we don't know enough to know whether this utilisation is sustainable or not. If that is the practise, well then it is easier not to know a lot. But if the other way round is that when we don't know a lot and as far as we know there is not a problem, so we just go ahead and shoot the birds or fish the fish stocks then it is more dangerous in terms of conserving the resources for the next generation." Flemming Merkel (Aarhus University, Denmark) "Without a monitoring program, gathering information, you have nothing to talk about. You have nothing to present and then the assumption is that everything's stable, so that's where monitoring is so key." Grant Gilchrist (Environment Canada, Canada)
4.5.2	–	Obligation to try	"If they are so threatened and we have a chance to save them, then we need to invest" Participant A "As long as there are two mating animals out there; there is an opportunity." Michael Stickman (Arctic Athabascan Council, U.S.A.) "If you stop monitoring a species that is being threatened..., you are giving up on it; and I don't agree with that approach at all" Participant B "I just try to be hopeful that...we don't have to sacrifice one because of limited resources, but that would be my view, that we try to get resources to be able to prevent extinction of any type of species and hopefully will not be faced with that choice." Jason Akearok (Nunavut Wildlife Management Board, Canada)
4.6 MODIFIERS			
4.6.1		Spatial scale	"When we introduced national Red Lists, those were really biased toward the small population component within our borders ....for borderline species that might do very well elsewhere, you should expect that they do worse when they are at the limit of their range, so you should be more reluctant to address those populations...........Management at the national level should be addressed with an international perspective and that is not always the case" Tycho Anker-Nilssen (Norwegian Institute for Nature Research, Norway)
4.6.2		Are drivers of change addressable?	"If we cause [the decline] then there is a way to reverse it, that's different, but if they are at the end of their range and they are disappearing... This is an example, the Kittlitz's [Murrelets] are dependent on glaciers......the glaciers are gone, the Kittlitz's Murrelets and going to go away. So if you want more Kittlitz's Murrelets, it might be best to spend money on enhancing their habitat rather than on the birds themselves" David Irons (US Fish and Wildlife Service, U.S.A)
4.6.3		Who decides?	"I would hope that would be hopefully partly a community decision rather than a regional or national conversation or a wildlife management conservation in isolation" Bob van Dijken (Canada) "I am very uncomfortable with getting ourselves to a point of allowing ourselves to have anything go extinct but I understand that you might have to make some very difficult decisions, but they should be very well supported decisions from various points of view." Gabriella Ibaguchi (University of Calgary, Canada)

Where a perspective is compatible with triage is denoted + and incompatible –.

Conceptual Issues in Triage

The species-centered focus of triage and the lack of integration of needs of local people were two core conceptual issues where triage did not conform to the world view on how monitoring effort should be allocated (**Table 2**). Both scientific and Indigenous perspectives highlight the need to move beyond species approaches to more complex monitoring and management (Mace, 2014). The scientific viewpoint often points toward the need for incorporation of more components of the ecological system, for example a more dynamic ecosystem and landscape-focussed approach to arctic conservation has been proposed (Elmqvist et al., 2004). Indigenous systems of thought also highlight the need for more systems-based and holistic approaches, but have greater emphasis on the inclusion of culture and spiritual aspects (Cochran et al., 2013).

In the Arctic, some agencies are transitioning from more species-focussed to more location-focussed monitoring and management, for example:

> "the Yukon government used to use that model of a wolf biologist, a bear biologist, a sheep biologist and a caribou biologist and a moose biologist, so everyone was siloed, had their specialties, would compete for budgets every year.... About 10 years ago, the Yukon government moved to another model with regional biologists who.. had specific areas of the Yukon, and they worked with the First Nations and Renewable Resources Canada and populations and looked at the region rather than the species." B. van Dijken (Canada).

However, a mixture of species-focussed and more ecosystem-based monitoring approaches exist within arctic ecosystem monitoring (Ims R. et al., 2013), with only a few addressing both human-ecosystem interactions and ecosystems in an integrated programme. When networks of monitoring sites are used to monitor ecological change at pan-arctic scale, the need for an ecosystem-based approach has been highlighted (Christensen et al., 2013); however the complexities of synthesizing information at large scales often result in single species assessments. Therefore, while the concept of triage at a species level may be compatible with some existing mechanisms of monitoring and conservation in the Arctic, it may be less compatible with aspirations for more systems-based monitoring and Indigenous perspectives.

The second conceptual misalignment that triage does not explicitly incorporate the needs of local people (**Table 2**) also emerges from an increased focus on more socio-ecological systems in conservation and management. As many arctic Indigenous people use wildlife through harvest, the persistence of certain species directly affects food security (Power, 2008). Prioritizing monitoring decisions based on likelihood of persistence of species or population does not take into account the cultural, social and physical value of species to local people. For example, the Ivory Gull is both near threatened and a species that has generated local concern over declines; it has traditionally been hunted and although not a principle food source, it is highly valued by local people (Gilchrist and Mallory, 2005). A triage approach based on probability of species survival alone might consider Ivory Gulls a candidate for monitoring triage. Long term persistence of the Ivory Gull may be limited by rapid increases in heavy methyl mercury burden from anthropogenic mercury, increases in other contaminants (Braune et al., 2007; Bond et al., 2015), and also by the species' strong association with sea ice and changes in wintering conditions (Gilchrist and Mallory, 2005; Spencer et al., 2015). However, the value of Ivory Gulls to local people may render such a triage approach inappropriate.

Arctic Ecological Characteristics and Triage

Two apparently contrasting views in response to triage were that a key goal in the Arctic was to conserve abundance to maintain species functions in ecosystems, and that the low species richness in the Arctic leads to low functional redundancy, meaning it was critical to not allow extinction of rare species. The need to conserve abundance could support the concept of triage, where focus should be given to dominant rather than rare species. The potential for conservation of abundance also partly reflects the current situation in the Arctic, where more large-scale ecological and social processes remain from ancestral times and therefore there is still the opportunity to conserve abundance (Chapin et al., 2006, **Table 2**). Changes in abundance of widely distributed dominant species in the Arctic might have substantial or even disproportionate ecological and social consequences relative to lower abundance species (Chapin et al., 2006; Díaz et al., 2006). A lack of functional redundancy in the Arctic was proposed in opposition to triage by one participant (**Table 2**). The Arctic is characterized by low species diversity and relatively simple food webs, which might lead to lower resilience to loss of species. This lack of functional redundancy has been used to suggest that allowing certain species to go extinct may have greater ecological consequences than in lower latitudes (Post et al., 2009) and highlights a potential need not to limit monitoring to abundant and widespread species. Relevant to both arguments is the existence of ecological (Power et al., 1996) or cultural keystone species (Garibaldi and Turner, 2004), which could be problematic to an abundance-driven monitoring agenda. Identifying keystones and ecosystem engineers (where species have a large role but this can be driven by abundance) with respect to arctic ecosystems and cultures should be core to developing monitoring agendas.

Information Needs and Triage

The need to learn from the trajectories of threatened species was stated by four participants in opposition to triage (**Table 3**). Participants highlighted the need for a greater mechanistic understanding of species responses to changing climate and habitat in order to plan more effective preparations and responses. The ability for species to adapt to rapidly changing conditions is indeed uncertain and a complex area of research (Sih, 2013; Merilä and Hendry, 2014). Excluding species from monitoring based on projections of high risk of extinction may thus be misguided if there is insufficient certainty in the predictions that these species will go extinct or that populations will be extirpated (Morrison et al., 2016). Rapidly changing ice and snow conditions are expected to pose a substantial challenge for arctic vertebrates and rates of cryospheric change may exceed the limits of phenotypic plasticity and rates of adaptation (Gilg et al., 2012). Monitoring responses of species at high risk of extinction may provide information that is unreplicable in higher abundance populations.

Cost Efficiency Issues in Triage

The ability to achieve greater efficiency in monitoring of abundant species was highlighted by two participants and in particular the cost of excessive focus on endangered species was discussed (**Table 3**) in support of triage. This may be particularly true when monitoring is focussed on single species. However, integrated ecosystem-based monitoring programs (Meltofte and Berg, 2004; Gauthier and Berteaux, 2011; Ims R. A. et al., 2013) and community based monitoring and greater use of traditional knowledge may reduce the inefficiencies of monitoring low density or difficult to observe species:

> "So we're trying to ....develop an integrated ecosystem-based monitoring design,... the idea is to capture,.. as many things as possible.. you are still using the same number of people in the field and the same number of days in the field. For just a little bit of extra effort you can capture a whole new level of information" G. Ibarguchi (Arctic Institute of North America, Canada).

Ecosystem-based monitoring may capture rare species without the explicit monitoring for rare species, although this is dependent on the co-occurrence of species with monitoring sites. However, many funding mechanisms are not currently structured in ways that facilitate these approaches.

In contrast, another participant highlighted that the decline or collapse of a species tended to generate money for monitoring (**Table 3**). These resources may not be transferable to other species. It may not be appropriate therefore to incorporate monitoring of certain species (particularly charismatic or rapidly changing species likely to gain attention) in to a cost benefit analysis of species rarity or abundance and economic efficiency of investment unless these contributions are fully quantified.

Political and Ethical Issues in Triage

One of the most common responses to the idea of triage was primarily ethical. The idea that people should not give up on a species even if it is severely threatened was common amongst scientists and Indigenous representatives (**Table 4**). The application of triage might also increase acceptability of species extinctions (Buckley, 2016). Two participants highlighted that there may be political implications to reducing the amount of attention to threatened species (**Table 4**), as they may highlight undesirable drivers of change. Two participants highlighted that in the absence of information, it may be assumed that an ecosystem is in good condition or a species is being exploited at a sustainable level. Without a precautionary approach to development and management across the Arctic, highly threatened species may be an important component of highlighting threats to ecosystem, the application of triage could be detrimental to these initiatives.

One consideration in the Arctic, mentioned in our interviews is whether it is possible to address drivers of decline, and whether this should determine monitoring focus. In the Arctic, drivers of ecological change range from locally generated pressures such as local harvesting to broader spatial extent pressures such as resource extraction, commercial fishing, and land conversion to impacts generated at the global scale such as climate change, and long distance pollutants. Often it is easier to translate monitoring activities into desirable outcomes at the local scale than address global drivers of change. Focussing monitoring on maximizing benefits may create inequalities in the expectations of behavioral change from different stakeholders and institutions, while not holding to account other actors contributing to change.

Existing Structures and Monitoring

The realities of both organizational structures and monitoring needs may limit the ability to prioritize monitoring at large scales across the Arctic. The responsibility for monitoring of species and decision making regarding management and conservation rests with a large number of agencies across the Arctic with different mandates, operating at different spatial scales.

> "...caribou is very important to people here and the principle enforcement organization is the Nunavut government... the migratory birds, that's managed by the federal government so there's two legislative authorities managing different species so it is not always easy to be able to ... take one pocket of money over to another organization when there's different mandates for different organizations." J. Akearok (Nunavut Wildlife Management Board, Canada).

One participant mentioned that academic scientific research may provide greater opportunities for switching between species than governmental organizations with specific mandates, when asked the extent to which resources for monitoring were transferable between species, they replied:

> "... you need to apply for funds, so it depends on the argument you have, you cannot suddenly switch all the monitoring from one species that is sexy and makes the front line news to a more boring species, because you cannot argue with the same arguments for the need for monitoring. So, I'd say, for a science grant certainly you could, but when it comes to management kind of funding pool, I think you would have quite a challenge in just switching." K. Falk (Independent, Denmark/Greenland).

Although, explicit coordination of prioritization across all organizations may be unlikely, organizations may inform their internal prioritizations according to where effort is already allocated, for example one participant in a wider analysis of monitoring needs commented:

> "WWF is not really very much working on birds as species because of different reasons. One reason is that there are many other organizations working on birds, so that's why we decided to prioritize our limited resources...somewhere where probably there are less efforts." A. Shestakov (WWF, Canada).

While there has been extensive effort to coordinate monitoring and research efforts across the Arctic via a number of organizations (e.g., the Circumpolar Biodiversity Monitoring Program and Arctic Monitoring and Assessment Program), it is unlikely that any system of prioritization can provide sufficient flexibility to incorporate the needs of stakeholders and biodiversity objectives across the vast range of relevant scales and these will most likely need to be tailored to different agency needs.

Does Triage Currently Occur in Arctic Monitoring?

Prioritization is implicit in the current status of monitoring across the Arctic. This does not necessarily reflect a species triage approach, but does reflect priorities advanced by a set of stakeholders and decision-makers who have varying levels of influence on these processes. A number of species were perceived as current foci, such as commercially important species and harvested species. For example:

> ".. we don't have enough resources to deal with everything. It doesn't matter what we do, we necessarily leave certain species or certain locations out of the equation and they become second cousins by default. So high political and governmental interest in harvested species necessarily means that a whole bunch of other species will not get attention." D. Reid (Wildlife Conservation Society, Canada).

These were not always perceived to reflect the needs of all stakeholders. For example when asked about the biggest weaknesses in current arctic monitoring in interviews for a larger project on arctic monitoring C. Behe (Inuit Circumpolar Council, U.S.A.) responded:

> "Economic driven questions. I think for me personally, that's the largest weakness, because it's often laden with intentions. I mean we always have intentions but it's laden with the intention of extracting from the environment that you're monitoring and that's really concerning. I'm not saying there shouldn't be development of extraction from the environment, obviously, I drive a car. But, for that to be the only intention and reason that we're gathering information makes it impossible for us to make management decisions, whether its long term or short term."

In order to rectify these problems, greater attention should be put toward identifying a full set of arctic stakeholders, discussing and defining the legitimacy of different stakeholder groups and defining monitoring needs of a broad set of arctic stakeholders and compare the support for proposed strategies relative to that for existing monitoring priorities.

Emerging Opportunities and Triage

The need for triage in monitoring might be altered by greater inclusion of different types of information concerning wildlife. Community-based monitoring has been gaining increasing attention in the Arctic as a means of co-production of knowledge between Indigenous people and scientists. This may allow more extensive and integrated monitoring without some of the substantial costs associated with externally driven monitoring (Pulsifer et al., 2014):

> "Over the long-term I think strategic investment in community based monitoring may get you the same results and a smaller price tag and more chance of keeping continuity in programs" B. van Dijken.

Involvement of local people in monitoring may also have other benefits, such as accelerating decision-making processes at local scales (Danielsen et al., 2010) and a high potential for local participation in data gathering and analysis has been identified for arctic monitoring at an international scale (Danielsen et al., 2014). Within such locally driven programs there will be greater need to engage local people in prioritization of monitoring needs.

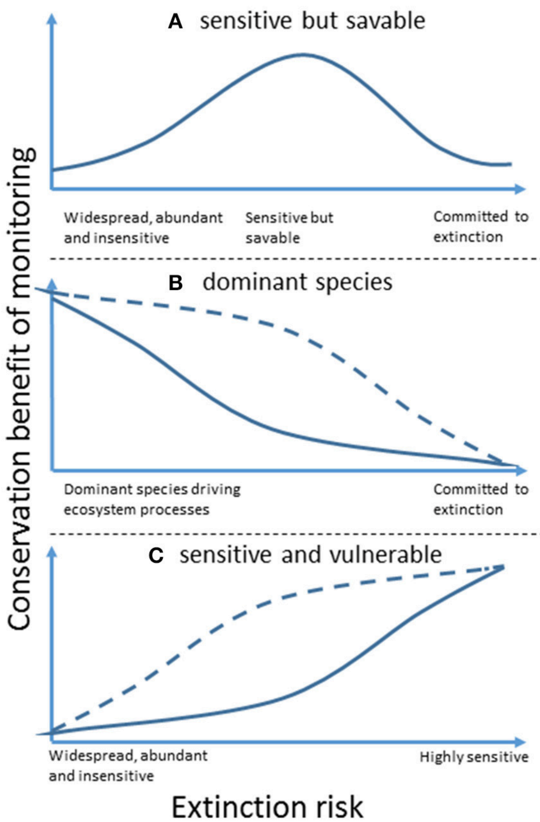
Conclusions

Ecological monitoring fulfills a number of roles which can benefit conservation, from identifying drivers to ecosystem change, to generating understanding of how ecosystems respond to change, to simply documenting observed changes (Lindenmayer and Likens, 2010; Possingham et al., 2012). Each of these can help generate outcomes that contribute to conservation benefits. Outcomes include identifying actions that can mitigate undesirable changes, predicting how ecosystems will respond to change to facilitate adaptation and evaluate potential outcomes of different decisions. Monitoring can also produce information that generates public and political will to take effective action to alter trajectories of change where it will lead to desirable outcomes. In most circumstances, the routes between monitoring and these outcomes are indirect and the extent to which individual monitoring decisions contribute to these outcomes are impossible to fully quantify. Within monitoring of these complex systems, benefits and outcomes are derived at multiple scales and can differ between stakeholders (Cash and Moser, 2000).

Increasingly the need for a stewardship is being proposed and a need to address future arctic scenarios in a more systems-based approach (Chapin et al., 2015), which highlights the need to identify desirable outcomes as a prerequisite to identifying monitoring strategies to achieve them (such as monitoring triage). Better understanding of desirable outcomes is required to inform improved arctic monitoring agendas. The use of scenarios may be one way of addressing the substantial complexity in decision-making. Defining desirable arctic futures may provide one route to fostering stakeholder involvement and understanding what the most effective priorities for arctic monitoring will be (Chapin et al., 2010). Structured decision-making, whereby a set of objectives, alternative actions, and projected consequences are defined and information is fed back to improve monitoring may also be an effective mechanism of making decisions about what to monitor with respect to more direct use of information such as in monitoring for management (Lyons et al., 2008), particularly where these three characteristics are more easily defined. The related field of biocultural conservation places greater emphasis on governance structures and multiple knowledge systems (Gavin et al., 2015) and is equally relevant to arctic monitoring. Here, the role of multiple objectives and stakeholders are incorporated to making (in this case monitoring) decisions based on the socio-ecological context.

Traditional triage might be considered decision-making based on an assumed relationship between likelihood of persistence and conservation benefit to be derived from monitoring. This could take a number of forms (**Figure 2**) and models could be applied at a number of levels of organization, including ecosystems, species, and populations or other ecosystem components. Our participants were primarily unsupportive of triage approaches but showed a greater level of support for monitoring that would maximize benefits for biodiversity and people, suggesting greater support for a broadened view of triage (described in Bottrill et al., 2008).

Perhaps a prerequisite to deciding on any given set of appropriate monitoring strategies (including triage) is identifying the essential characteristics of strategies for monitoring prioritization for stakeholders. In evaluating their reasons for support or opposition to triage, our participants identified a number of factors that might affect the validity of triage approaches and could give a broader indication to necessary characteristics of monitoring strategies. These include whether approaches monitor the trajectories of functionally and culturally important components of the system, whether they take a systems-based approach considering linkages within and between ecosystems and society and are compatible with stakeholders perspectives, whether they are a cost-efficient means of achieving monitoring objectives, whether they are appropriate to the scale at which monitoring is conducted and take in to account relevant information at other scales and whether they are ethically acceptable to all stakeholders. We also identified that the outcomes of strategies should not increase injustices in the burden of responsibility for ecological change or create undesirable outcomes such as caused by the assumption that no reported change equates to healthy ecosystems. Linking between these requirements and desirable outcomes is a key challenge for those creating monitoring programs for conservation purposes. Our analysis suggests that stakeholders differ in their perspectives on the validity of approaches according to their worldview and we suggest that greater meaningful integration of multiple stakeholder in decision-making regarding monitoring might help develop strategies, which reconcile these differences.



Arguments	Ecological questions	Socio-political questions
Species with intermediate extinction risk have specific habitat needs and are sensitive to change. Unlike highly at risk species, for which there may be few options for remediation of declines, there are opportunities to effectively protect these species.	To what extent are certain species committed to extinction, is there enough information to identify such species? To what extent are dominant species insensitive to arctic drivers of change?	What is the cultural significance of rare species in the arctic? What would be the effects of loss of these species?
Dominant species can have a key role in ecosystem processes. Changes in their abundance may have the most substantial ecosystem effects	To what extent do dominant species drive ecosystem processes compared to less common species? Are rare species somewhat functionally redundant in arctic ecosystems, if so to what extent?	Are dominant species more frequently important resources or of cultural importance of species? Are the public and political bodies as likely to respond to changes in abundance as risk of extinction?
Species at high extinction risk are likely to be highly sensitive to drivers of change and in most urgent need of action for conservation.	To what extent are highly endangered species able to recover or adapt to novel environments?	To what extent does evidence of declines in rare species drive public understanding of ecosystem change and conservation action? To what extent do rare species generate independent funding for monitoring?

FIGURE 2 | Three possible scenarios for the relationship between extinction risk and conservation benefit of monitoring: (A) where monitoring both high and low extinction risk species provides fewer conservation benefits, **(B)** where greatest benefits derive from monitoring dominant species, and **(C)** where greatest benefits are generated from high extinction risk species. Both **(A,B)** involve the concept of triage. Explanations for each approach are given under arguments in the associated table and ecological and socioecological questions pertinent to each model are given. Solid and dashed lines represent alternative function forms within the same broad concept. Note that questions can also have overlapping applicability between multiple models.

AUTHOR CONTRIBUTIONS

All authors were involved in the conception or design of the project. HW conducted, analyzed and interpreted the interviews and wrote the manuscript. DG, CF, DB, NY, and BP revised the manuscript and provided important intellectual content.

ACKNOWLEDGMENTS

We are grateful to J; Akearok, T. Anker-Nilssen, R. Barrett, C. Behe; C. Cuyler, K. Falk, M. Gavrillo, G. Gilchrist, O. Gilg, A. Harding, H. Huntington, G. Ibarguchi, D. Irons, S. Kalhok-Bourque, G. Kofinas, E. Krümmel, F. Merkel, D. Reid, A. Shestakov, M. Simard, M. Sommerkorn, M. Stickman, H; Strøm, O.-A. Turi, and B. van Dijken for their participation in interviews. We also thank other members of the CAFF CBird expert group for interesting discussions. Funding was provided by a Belmont Forum Small Cooperation Grant (TAMANI project), supported by the National Sciences and Engineering Research Council of Canada, Agence Nationale de la Recherche, France and The Research Council of Norway. We are also grateful to the National Science Foundation (USA) and the French Polar Institute Paul-Emile Victor (ADACLIM programme No. 388) for support.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Ecology and Evolution

OPINION
published: 28 September 2016
doi: 10.3389/fevo.2016.00113

Moving the Goalposts: Possible Effects of Changes in Opportunity Costs on Conservation Triage

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Keywords: triage, prioritization, conservation planning, extinction, uncertainty, strategic foresight

The resources required to halt biodiversity declines are estimated to be many times more than current investment, underpinning calls to increase financial support for conservation, and to develop methods for allocating funds more efficiently (McCarthy et al., 2012; McDonald et al., 2015). Conservation triage is an important part of the latter strategy, with proponents arguing that by explicitly prioritizing resources toward targets (e.g., particular species or populations) identified as generating the greatest benefits for a given investment, triage avoids using resources on cases in which conservation effort is unlikely to make a difference (i.e., improvement is unlikely or is near-certain irrespective of investment; Bottrill et al., 2008; Schneider et al., 2010; Gerber, 2016). However, triage has been criticized on several grounds, such as potentially signaling to decision-makers that some extinctions or population losses are acceptable, and the scientific, ethical, and practical arguments have been debated without reaching clear consensus (Bottrill et al., 2008; Jachowski and Kesler, 2008; Parr et al., 2008). Our primary aim here is not to revisit these arguments, but to highlight an additional issue—the potential for substantial, unforeseen changes in the future costs of conservation—and investigate how this issue might affect triage and non-triage approaches.

OPEN ACCESS

Edited by:
James Guy Castley, Griffith University, Australia

Reviewed by:
Carly Cook, Monash University, Australia

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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *22 April 2016*
Accepted: *13 September 2016*
Published: *28 September 2016*

Citation:
Woodcock P and Hayward MW (2016) Moving the Goalposts: Possible Effects of Changes in Opportunity Costs on Conservation Triage. Front. Ecol. Evol. 4:113. doi: 10.3389/fevo.2016.00113

CHANGES IN OPPORTUNITY COSTS

Species conservation ultimately requires habitat to be protected within which threatened populations can persist. Protecting this habitat for conservation therefore often involves forgoing activities that would yield economic benefits (in the short-medium term at least), e.g., mining, conversion to agriculture etc. The need to consider these forgone revenues—or opportunity costs—is recognized in the broader land-use planning literature (Cameron et al., 2008; Wilson et al., 2010; Mazor et al., 2014), and triage assessments can include opportunity costs for conserving particular sites (Schneider et al., 2010). Although this research can consider several alternative levels of opportunity cost, future costs can be both difficult to predict and variable. For example, short-term spikes in demand for oil, minerals, cash crops etc. can result from changes in economic pressures or shifting political priorities that may be difficult to foresee at the time triage plans are formulated. More permanent increases in opportunity costs can also occur as new resources are discovered and existing resources are used in novel ways (e.g., increasing demand for rare earth metals for new technologies; Service, 2010; Sutherland et al., 2012; Campbell, 2014). Large increases in the potential financial returns from resource exploitation raise the costs of protecting habitats and create pressure to use land or sea for purposes that are detrimental to conservation. Indeed, the tripling of gold prices during the global financial crisis is argued to have been an important driver of Amazonian deforestation from 2007–2013 (Alvarez-Berrios and Aide, 2015), whilst economic pressures such as oil and gas exploitation have led to the downgrading, downsizing, and degazettement of protected areas across the globe (Symes et al., 2016).

IMPLICATIONS OF CHANGING OPPORTUNITY COSTS FOR TRIAGE

Effective triage-based prioritization requires knowledge of both the resources available to conservation and the likely costs. Whilst the extent to which conservation funding can be accurately predicted over time has been highlighted as a potential weakness in triage (Parr et al., 2008), there has been less consideration of the importance of accurate information on conservation costs, and particularly the future opportunity costs associated with protecting the habitats in which populations and species conserved under triage can persist. Uncertainty in future opportunity costs can be incorporated into triage assessments by determining the most efficient approach to protecting particular populations or species under a range of scenarios. However, the most effective triage strategy can be influenced by which cost scenario is ultimately used, and individual scenarios may not consider the potential for marked fluctuations in costs. Unanticipated increases in opportunity costs (even if transient) are a particular problem if funding no longer offsets the revenues forgone by conserving the habitats required by the populations/species protected under the original plan. Importantly, the initial acceptance of triage could undermine justifications for additional resources. The logical continuation of triage seems to then imply a re-prioritization, in which the loss of further populations/species is accepted as inevitable because rising opportunity costs can no longer be offset with the available funding. This would not only erode the conservation benefits from triage, it could also generate a revised protection plan that is less efficient than would have been achieved if future opportunity costs had been established more accurately initially.

IMPLICATIONS OF CHANGING OPPORTUNITY COSTS FOR NON-TRIAGE APPROACHES

Approaches to species conservation without a formal triage-type prioritization do not expressly accept that some populations or species cannot be conserved. As such, if rising opportunity costs exceed existing funding, these approaches do not necessarily imply the type of re-prioritization suggested by triage, and instead may perhaps be better able to justify arguing for additional funding. Equally however, the success of philosophies that reject triage arguments will still be affected if the funding needed to conserve particular populations increases due to rising opportunity costs. In these circumstances, sufficient public and political support to continue protection despite rising opportunity costs would be needed: contemporary impacts on protected areas (Symes et al., 2016) illustrate the difficulties of maintaining such support in the face of increasing economic pressures.

PLANNING FOR UNCERTAINTY IN FUTURE OPPORTUNITY COSTS

Irrespective of whether triage or non-triage approaches are used, one response to the risk posed by unexpected increases in opportunity costs may be to place greater emphasis on anticipating and planning for uncertainty through strategic foresight. This could involve methods such as horizon scanning (e.g., to identify possible novel uses of resources; Sutherland and Woodroof, 2009), understanding drivers of current and future trends in opportunity costs, and building a range of scenarios including low probability-high impact events (see Cook et al., 2014a,b for detailed discussion of the range of techniques used within strategic foresight approaches). Based on this information, contingency plans can be developed that include strategies to pre-empt or respond to unexpected future increases in opportunity costs. For example, triage might also consider the risk from spikes in land use values and whether or not long-term guarantees can be provided in such situations for populations/species protected under the initial plan. Updating contingency plans periodically would also be pivotal to ensuring that new potential risks are identified, evaluated, and mitigated.

CONCLUSIONS

In general, we support the view that triage is compatible with other approaches to conservation (McCarthy, 2014). However, we feel that triage-based approaches may risk unwanted conservation outcomes if opportunity costs rise unexpectedly in the future, particularly given the impacts such economic drivers continue to have across the world. Moreover, because long-term habitat protection is vital, we suggest strategic foresight approaches that identify risks from potential future increases in opportunity costs and include contingency plans should be more widely incorporated into triage prioritization.

AUTHOR CONTRIBUTIONS

MH and PW jointly discussed and designed the manuscript. PW wrote the initial draft. PW and MH both contributed to subsequent revisions.

FUNDING

MH was supported by the Centre for African Conservation Ecology, Nelson Mandela University.

ACKNOWLEDGMENTS

We are very grateful to Carly Cook for the helpful and constructive comments provided during the review of this manuscript.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling Editor declared a collaboration with one of the authors MH and states that the process nevertheless met the standards of a fair and objective review.

frontiers in Ecology and Evolution

PERSPECTIVE
published: 05 January 2017
doi: 10.3389/fevo.2016.00144

Triage of Conservation Needs: The Juxtaposition of Conflict Mitigation and Connectivity Considerations in Heterogeneous, Human-Dominated Landscapes

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OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: 07 June 2016
Accepted: 15 December 2016
Published: 05 January 2017

Citation:
Goswami VR and Vasudev D (2017) Triage of Conservation Needs: The Juxtaposition of Conflict Mitigation and Connectivity Considerations in Heterogeneous, Human-Dominated Landscapes. Front. Ecol. Evol. 4:144. doi: 10.3389/fevo.2016.00144

Conservation of wide-ranging endangered species is increasingly focused on large heterogeneous landscapes. At such scales, particularly when conservation landscapes are human dominated, it is imperative that prioritization techniques be used to allocate limited resources wisely. Moreover, spatial aspects of conservation planning warrant key consideration within these landscapes, such that certain sites that are key to either mitigating threats to species or to maintaining ecological processes, are prioritized. However, there are often multiple conservation needs, and multiple associated constraints, for species conservation in such landscapes. While there are tools to prioritize sites based on single or few conservation requirements and constraints, there is less knowledge on how these conservation needs, or corresponding management interventions, relate to each other in a scenario where conservation focus on one issue potentially detracts from another. We take the specific example of two conservation needs that are central to landscape-scale conservation of the endangered Asian elephant *Elephas maximus*, namely the maintenance of connectivity, and the mitigation of human–elephant conflict. We show that conservation decision making, in addition to considering which species and sites to focus on, should also prioritize conservation needs. We review documentation of conflict mitigation and examine if the maintenance of connectivity was simultaneously addressed, and if so, whether optimal conservation solutions differed when connectivity considerations were included. We conclude with a discussion on the triage of conservation needs, and future prospects and challenges in ensuring that landscape-scale conservation strategies account for multiple interacting conservation needs for endangered species in heterogeneous human-dominated landscapes.

Keywords: conservation planning, elephants, human–wildlife conflict, movement, spatial conservation prioritization

LANDSCAPE-SCALE CONSERVATION INVOLVES MULTIPLE CONSIDERATIONS

Species that tend to range widely and have a low reproductive potential require very large amounts of habitat for persistence (Fahrig, 2001). Large-bodied mammals fit this description perfectly as they have extensive home ranges (Karanth and Sunquist, 2000; Crooks, 2002; Fernando et al., 2008b), and are intrinsically rare and extinction prone (Madhusudan and Mishra, 2003). To meet the habitat requirements of such species, many of which are endangered, conservation programs are increasingly expanding their scale of focus from individual protected areas to heterogeneous landscapes (Sanderson et al., 2002; Wikramanayake et al., 2004). Such a landscape-scale conservation strategy hinges on the use of human land-uses by wildlife (Athreya et al., 2013; Goswami et al., 2014a), but the co-occurrence of large mammal species and people can often lead to negative interactions and conflict between them (Naughton-Treves, 1998; Woodroffe et al., 2005; Goswami et al., 2014b).

Elephants are among the most severely impacted species when it comes to human–wildlife conflict. For example, India—a country that houses nearly 60% of the extant Asian elephant population (Sukumar, 2003)—is estimated to experience an annual mortality of approximately 100 elephants and 400 people because of human–elephant conflict (Rangarajan et al., 2010). Crop depredation by elephants is the primary form of human–elephant conflict (HEC), and one that imposes substantial costs on the lives and livelihoods of local people (e.g., Naughton-Treves, 1998; Madhusudan, 2003). Recurrent conflicts can not only encumber local support for conservation (Naughton-Treves et al., 2003), they can also lead to levels of retributive killing of elephants that can seriously undermine long-term persistence of elephant populations (Goswami et al., 2014b). Effective mitigation and management of HEC is thus a critical conservation requirement.

Conflicts between elephants and people are inevitable in a scenario where nearly half of the Asian elephant's range lies in habitats that are both fragmented, and heavily impacted by humans (Leimgruber et al., 2003). India is no exception, with human-impacted landscapes comprising as much as two-thirds of existing elephant habitat (Leimgruber et al., 2003). A leading strategy to mitigate HEC in India and elsewhere has therefore been to minimize the interface between elephants and people, typically implemented in two broad forms: (a) strategies designed to keep elephants within forested habitats through the use of barriers at the forest edge; (b) strategies focused on keeping elephants out of cultivated areas and human habitation (see Fernando et al., 2008a, for a review). The former includes the implementation of various forms of barriers including elephant-proof trenches, solar-powered electric fences, and metal fences of different shapes and designs. The second strategy typically involves community-based guarding where elephants are deterred from entering agricultural areas using noise, light and different chili-based tools, or through the use of barriers such as solar fences around cultivated areas and human habitation (Hedges and Gunaryadi, 2009; Davies et al., 2011). Other strategies to mitigate HEC and other forms of human–wildlife conflict, that do not rely on the physical separation of wildlife and people include early warning systems to reduce threat to human safety through accidental encounters with elephants (Fernando et al., 2008a); farming of crops that are unpalatable for elephants (Fernando et al., 2008a); economic incentive schemes (Zabel and Holm-Müller, 2008); government-sponsored compensation (Karanth et al., 2013) and insurance schemes (Mishra et al., 2003) to offset economic losses due to wildlife.

Conserving species in heterogeneous landscapes, however, often entails addressing multiple conservation needs, and multiple associated constraints. Securing long-term species viability in large landscapes, for instance, hinges on establishing (or maintaining) connectivity, or the movement of individuals and genes, among habitat patches (Doerr et al., 2011). Connectivity enhances species viability through demographic rescue effects (Brown and Kodric-Brown, 1977), inbreeding avoidance (Frankham et al., 2010), colonization of unoccupied habitat (Hanski, 1998) and ameliorating negative impacts of climate change (Doerr et al., 2011). As a result, connectivity is increasingly included into species conservation programs worldwide (Sanderson et al., 2002; Wikramanayake et al., 2004; Worboys et al., 2010). Connectivity is an inherently spatial process arising out of an interaction of dispersing individuals with landscape features (Taylor et al., 1993; Vasudev et al., 2015). Similarly, HEC shows spatial patterns such that there exist "hotspots" that are prone to conflict; these patterns are typically driven by spatial covariates, such as distance to forests, rainfall, or terrain (Goswami et al., 2015). Consequently, spatial aspects of conservation planning warrant key consideration within heterogeneous landscapes, such that conservation efforts focus on sites that are key to either mitigating threats to species or to maintaining ecological processes (Moilanen et al., 2009).

There are a number of tools to prioritize sites (Moilanen et al., 2009), but in practice these often focus on single conservation requirements or constraints (e.g., Vasudev and Fletcher, 2015). There is less clarity on how conservationists should integrate multiple and potentially conflicting conservation needs that show spatial patterns across heterogeneous landscapes, into a single holistic conservation program (**Figure 1**). Here, we take the specific example of the Asian elephant to examine how HEC mitigation and the maintenance of landscape connectivity can potentially detract from each other. We pull from recent developments in the theory of connectivity conservation to demonstrate that the simultaneous consideration of the two issues could change recommendations for optimal landscape-scale conservation strategies. We then review the current literature on HEC in India, and Asia, to examine the current state of practice with regards to simultaneous consideration of the two conservation requirements, namely HEC mitigation and maintenance of landscape connectivity. We conclude by drawing inferences and making recommendations for future conservation programs to acknowledge and account for multiple conservation constraints that play out in heterogeneous, human-dominated landscapes.

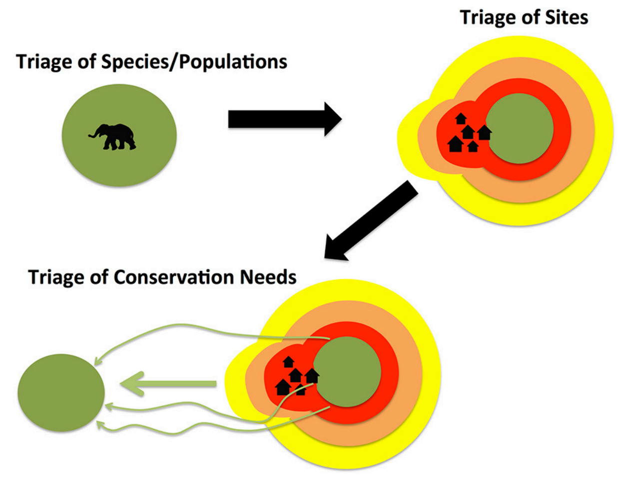

FIGURE 1 | A hypothetical scenario depicting the multi-dimensionality of conservation decision-making. Conservationists may first prioritize species or populations—triage of species/populations—in this hypothetical example, the Asian elephant in a habitat fragment (depicted as a green circle). Conservation investments may then be focused on high-conflict zones (depicted in red), over medium (orange) or low (yellow) conflict zones—triage of sites. We consider a simple scenario here where HEC decreases as one moves further away from the habitat fragment, and is high around human settlements (depicted as a cluster of huts). We highlight an added dimension in conservation contexts where strategies that address one conservation need may detract from others. Here, high-intensity HEC zones are also important for elephant connectivity, and hence, spatially informed landscape-scale HEC mitigation strategies are optimal—triage of conservation needs—such that implemented strategies additively address multiple conservation needs. Elephant silhouette (licensed public domain) was sourced from publicdomainpictures.net, Karen Arnold.

CONFLICT MITIGATION STRATEGIES AS BARRIERS TO CONNECTIVITY

Connectivity is forged through interactions between species and landscape elements (Taylor et al., 1993). A number of factors can limit connectivity; Vasudev et al. (2015) classify these as (a) spatial constraints, which limit connectivity by virtue of their spatial location, (b) environmental constraints, which include biotic (e.g., predators, competitors) and abiotic (e.g., wind, terrain) factors, and (c) intrinsic constraints, which include species-, population-, sub-population-, or individual-level traits that impact a disperser's ability or motivation to traverse the landscape. Vasudev et al. (2015) point out that these factors can limit connectivity through either (a) an alteration of demographic parameters (e.g., mortality), or (b) through a modification of movement behavior. In the latter case, barriers to connectivity need not be imposed through physiological constraints of dispersers, but rather through individual behavioral restraints (behavioral barriers to dispersal; sensu Harris and Reed, 2002). For example, factors that (a) heighten perception of risk (Laundré et al., 2001; Ciuti et al., 2012), (b) modify the ability of animals to navigate landscapes (Pijanowski et al., 2011), or (c) impact identification of high-quality habitat (Robertson and Hutto, 2006; Gilroy and Sutherland, 2007), may serve as behavioral barriers to connectivity.

Several HEC mitigation strategies are adopted to suppress elephant use of, and presence within, human land-uses, and in serving this function, they may strongly impact elephant landscape connectivity (**Figure 1**). Physical barriers, particularly those implemented at large spatial scales along the forest edge, are designed to restrict elephants to forested habitats and as such directly impede elephant movement between habitats. Veterinary fences in Botswana, for instance, have been shown as a barrier for elephant landscape connectivity (Cushman et al., 2010). Community-based guarding or antagonistic responses of local people to elephant presence in their lands can result in an increased perception of risk for elephants traversing human land-uses, thereby limiting their use of these areas (Goswami et al., 2014a). Thus, such strategies or responses can impose a behavioral barrier to connectivity. Finally, HEC-induced mortality, which may be viewed as an extreme barrier-type conflict mitigation strategy, can depress survival rates of dispersing individuals, thereby hindering connectivity and exacerbating threats to elephant population viability (Goswami et al., 2014b).

A REVIEW OF CURRENT HEC MITIGATION PRACTICE: ARE CONNECTIVITY ISSUES CONSIDERED?

We conducted a literature review to assess the level of integration of the two specific conservation needs for the wide-ranging Asian elephant—HEC mitigation and connectivity considerations. We conducted the review at two spatial scales: one at the scale of the entire geographical range of elephants in Asia, and second, at the scale of India. We chose India specifically as (a) India is believed to house 60% of the global Asian elephant population despite accounting for 17% of its geographic range (Leimgruber et al., 2003); (b) a large proportion of studies from Asia originated in India; and (c) India presents an ideal context for the problem outlined in our study as many of the landscapes that house elephants in India are fragmented—typically comprising protected areas surrounded by densely populated settlement and/or agricultural lands—where issues of connectivity and conflict are very relevant. We searched for all studies with the term "human elephant conflict" and "India" or "Asia," through the search engine Google Scholar, to obtain papers that have researched Asian elephant conflict in India, or throughout Asia, respectively. We conducted the literature survey in March 2016, and consider the papers thus obtained as a representative sample of papers on HEC.

We first made an assessment of all mitigation strategies recorded in the studies reviewed, based on the impact they may potentially have on connectivity. To assess the level of integration of connectivity aspects into HEC mitigation in practice, we simply examined (a) whether the papers included the spatial context of either a source population for elephants, or a larger elephant conservation landscape, (b) the proportion of papers that mentioned connectivity in some form, and (c) what aspect of connectivity was described. We note that no study simultaneously aimed at assessing both conflict and connectivity; the studies we found were primarily focused on HEC, and we assessed the proportion of these studies that placed their study within the larger context relevant to connectivity. We further assessed if simultaneous consideration of HEC mitigation and connectivity modified optimal conservation solutions by evaluating if suggested mitigation measures varied when connectivity was considered. We then focused on assessments of the efficacy of strategies in mitigating HEC, in relation to whether the mitigation strategies impeded elephant movement or not.

In total, we obtained 48 papers on HEC in India, spanning the years 2001–2016, and 93 papers in Asia, from 1978 to 2016. The 93 papers we obtained for Asia were inclusive of the 48 papers we shortlisted as those involving HEC in India. These articles included studies of HEC that focused on ecology (24% in India, and 30% in Asia), socio-ecology/anthropology (35% in India, 33% in Asia) or both (41% in India, 37% in Asia). As expected the majority of studies either recommended or studied HEC mitigation measures (90% in India, 82% in Asia).

We classified mitigation measures described in these papers under the following categories. The HEC mitigation strategies that potentially act as behavioral or other forms of barriers to connectivity (henceforth, "barrier strategies") included: (a) fences or physical barriers to elephant movement such as electrified or non-electrified fences or elephant-proof trenches, (b) chemical deterrents, (c) bio-deterrents, such as bees, and (d) use of light and sound to chase elephants. (e) Monetary or other forms of compensation for loss incurred due to HEC, and (f) education and awareness programs fall under a broader category of strategies aimed at enhancing human–elephant interactions, or encouraging human–elephant coexistence (henceforth, "coexistence strategies"). Planning strategies included those related to (g) law, national or regional policy, or the implementation of the same, as well as (h) research, which through increased accrual of knowledge, can lead to more informed policy in the future. Lastly, landscape-scale strategies included (i) protection of source elephant populations in the larger elephant conservation landscape, (j) land-use planning, and (k) connectivity conservation.

The project location for 67% of the papers from both India and Asia were adjacent to a protected area or some other habitat fragment, while 48 and 39% of the papers in India and Asia, respectively, included context regarding the larger elephant conservation landscape. Thirty three percent of papers in India, and 45% of those in Asia explicitly identified the purported source population of elephants in the study area. Forty two percent of papers in India and 49% in Asia included some mention of connectivity considerations. These largely referred to the project area being located along elephant corridors, or movement routes (84% in India, 82% in Asia), while some studies mentioned colonization of elephants into the project location from nearby forests or refuges (28% in India, 33% in Asia). Note that these percentages do not add up to 100% as some papers included mention of more than one aspect of connectivity. Our review showed that nearly half (43%) of all HEC studies in India recorded their study location as also being important for connectivity. Similarly, 34% of all studies across Asia recorded the same. We consider this an underestimate of HEC locations that also have a bearing on connectivity, as many of these studies did not take the larger elephant landscape into consideration (c. 52–61% of studies).

We found that landscape-scale HEC mitigation strategies were often recommended, and this was particularly so when connectivity was an explicit consideration in the study (**Figure 2**). Barrier strategies were also recommended, and though these were mostly recommended when connectivity was not an explicit consideration, we found that this did not hold for fences (i.e., the proportion of studies recommending fences remained unchanged when connectivity was considered; **Figure 2**). We delved deeper into land-use planning, as this is a truly landscape-scale strategy that has potential for being an effective long-term conservation solution. Land-use was recommended almost twice as often in papers that considered connectivity issues, as compared to those that did not. Land-use planning sometimes included suggestions for habitat consolidation (in 38% of studies) or connectivity (in 15% of studies), but most often suggested a change in crops planted or in cropping pattern (71% of studies). Interestingly, 70% of studies included engagement of local communities with suggestions for land-use planning, when connectivity issues were also considered, in comparison to 50% when connectivity was not considered; we highlight this aspect as stakeholder engagement is a critical component of successful landscape-scale land-use planning programs.

We further evaluated 27 assessments of the impact of various mitigation measures. 74% (20) of these were of a barrier strategy, while 15% (4) were not. We note that 19 of the assessments recorded a positive impact of reducing HEC—by this we mean either reduced the incidence of crop loss or the entry of elephants into agricultural fields, or caused increased tolerance of elephants—but we do not place much importance on this high proportion as: (a) negative results are less likely to be reported unless when compared with mitigation measures that did show a positive impact, (b) an ideal study would be a comparison of multiple measures within a single landscape over a period of time, but such studies are rare, and (c) >50% of assessments did not involve a quantification of HEC reduction. We also note that barrier methods being more localized are probably more amenable to study, while coexistence methods that aim to modify people's perspectives toward elephants, or planning methods that work at a much larger landscape scale, are not. Nonetheless, we found that 50% of the times assessed, non-barrier methods showed a positive effect in reducing HEC ($n = 4$), while a much higher 85% of barrier methods reported a positive effect ($n = 20$).

TRIAGE OF CONSERVATION NEEDS

Making smart and informed decisions on where to allocate limited resources is required for increased efficiency, efficacy, and transparency in the practice of conservation (Margules and Pressey, 2000; Bottrill et al., 2008). We note here that we use the term triage throughout to depict smart and informed decision-making (Bottrill et al., 2008). Decisions, traditionally, have

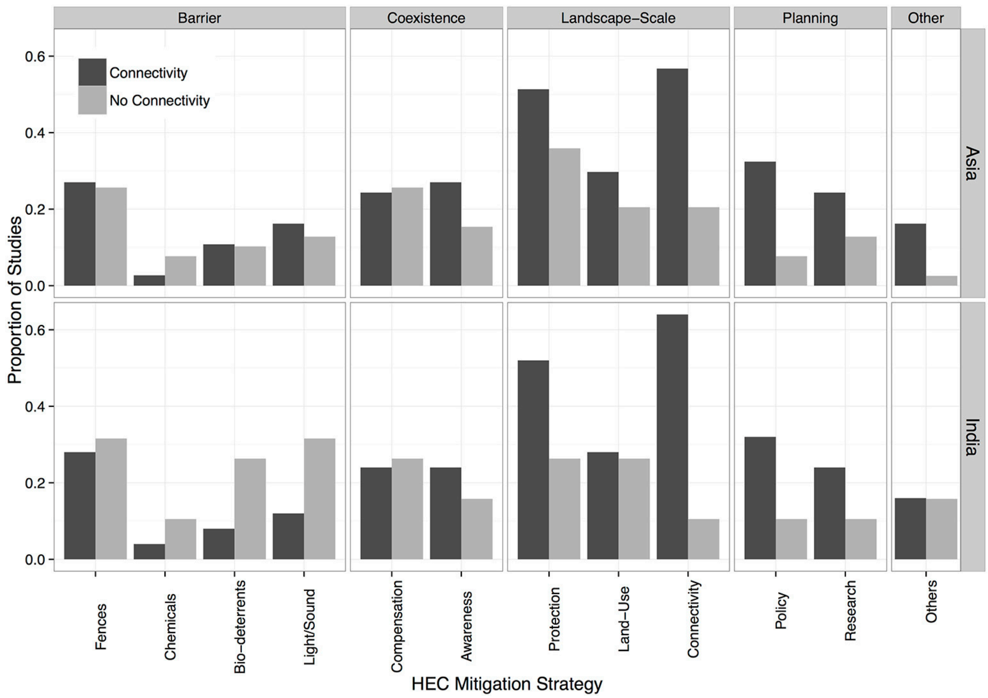

FIGURE 2 | The proportion of studies that either recommended, described or studied various HEC mitigation measures, when connectivity was explicitly considered (dark gray bars), and when connectivity was not considered (light gray bars). Measures include barrier strategies (*fences*–physical barriers, *chemicals*–chemical deterrents, *bio-deterrents*, *light/sound*–use of light and sound to chase elephants), coexistence strategies (*compensation*–financial or monetary compensation for HEC-incurred losses, and *awareness*–education and awareness programs) which are aimed at enhancing human–elephant positive interactions, landscape-scale strategies (*protection*–protecting source populations, *land-use*–land-use-planning, and *connectivity*–connectivity conservation) which are geared toward conserving the larger elephant conservation landscape, planning strategies (*policy*–law, national or regional policy measures, and *research*), and other strategies that do not fall under any of the above categories.

centered on prioritizing species of conservation focus (Jachowski and Kesler, 2009) and more often on deciding locations of conservation importance (Wilson et al., 2006; Moilanen et al., 2009). In heterogeneous landscapes, where species' resources and threats show spatial patterns, the question of *where* to allocate limited conservation resources is of particular importance. We highlight another dimension to this decision-making process, applicable in contexts of multiple conservation needs, the strategies and solutions for which may detract from each other.

While landscape-scale HEC mitigation strategies were by far the most recommended in the literature we reviewed, barrier strategies, which can restrict elephant movement (e.g., Cushman et al., 2010), are frequently and widely implemented (see Fernando et al., 2008a; Davies et al., 2011). Clearly, the spatial placement of these barriers needs to be carefully considered such that we do not unknowingly sacrifice one conservation priority—landscape connectivity—for another—HEC mitigation. Our review clearly shows that half or more sites experiencing HEC are also important for elephant connectivity. In such sites, employing barrier HEC mitigation strategies can severely undermine the overall conservation goal of ensuring long-term persistence of elephants, even when they successfully decrease elephant use of human-use lands and consequently reduce HEC. Moreover, given that the implementation of certain types of physical barriers involves substantial monetary and manpower investment (Fernando et al., 2008a), their unwise placement could be financially wasteful in addition to being ecologically damaging. There is need, therefore, for landscape-scale conservation programs to adopt strategies that facilitate conflict mitigation with the simultaneous maintenance of connectivity, and by extension, strategies that additively serve multiple conservation needs.

We make the following four recommendations for future HEC mitigation studies that emerge from our review. (1) We emphasize that at the minimum, a mention of the relevance of the project area for connectivity should be mentioned in all HEC studies or reports. (2) Despite their potential efficacy, the use of barrier strategies for HEC mitigation in areas that are potentially important for connectivity would be counterproductive for elephant (or wildlife) conservation, and hence should be used with great caution. (3) We noted that the use of local barriers (fences around individual agricultural field) was not clearly distinguished from large-scale fencing off of forests; we stress on the importance of distinguishing between these two forms of fences as their implication for connectivity is likely to be very different, even if their impact on reducing HEC at the local context is similar. (4) Assessments of the effectiveness of HEC mitigation measures should be comparative in nature and should ideally cover a landscape scale, rather than be focused on a small, localized scale. (5) Research on the impact of barrier methods for connectivity is crucial, especially on the potential for HEC mitigation strategies to act as behavioral barriers to connectivity. Goswami et al. (2014b) demonstrate how matrix population models can be used to assess the importance of HEC on elephant viability; an extension of similar population models to include impacts of the loss of connectivity can further shed light on the interplay between these two conservation considerations.

CONCLUSION

Species are faced with a multitude of threats and challenges that increasingly threaten their persistence in a rapidly changing world. In such a context, conservationists, wildlife managers and policy makers are faced with the responsibility of making smart decisions about which species to focus on, and where to invest limited resources. Whilst there exist sophisticated tools to aid conservation decisions, these tools are often focused on addressing, or used in practice to address, a single conservation requirement, particularly when it comes to conservation prioritization at the scale of landscapes. The juxtaposition of HEC mitigation and connectivity conservation highlights by way of an example, how landscape-scale conservation may involve multiple, and often-divergent conservation requirements. If we address and acknowledge this reality, and thereby identify optimal strategies based on a holistic view of multiple conservation needs, we stand to achieve greater efficacy and success at conserving threatened species in heterogeneous, human-dominated landscapes.

AUTHOR CONTRIBUTIONS

VG and DV conceived and designed the study. DV analyzed the data with assistance from VG in data interpretation. VG and DV wrote the manuscript and approved it for publication.

FUNDING

We thank the U. S. Fish and Wildlife Service—Asian Elephant Conservation Fund; the Department of Science and Technology, Government of India; Wildlife Conservation Society, New York; and Liz Clairborne–Art Ortenberg Foundation, New York, for financial support during the preparation of this manuscript.

ACKNOWLEDGMENTS

We record our gratitude to P. Hait, B. Joshi, and P. Sharma for their assistance with compiling studies on human–elephant conflict in India and other parts of Asia.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Ecology and Evolution

PERSPECTIVE
published: 22 November 2016
doi: 10.3389/fevo.2016.00132

Corridors at Crossroads: Linear Development-Induced Ecological Triage As a Conservation Opportunity

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The transportation infrastructure of a nation forms the backbone of its economic growth and social development, and, as a developing country, India is no exception. However, with imperatives to improve connectivity for economic and social growth, ecological costs are often at stake. Roads, old and new, cut through protected forests and connecting habitats, resulting in a plethora of ecological effects. These may include the severing of natural corridors thereby compromising the role of landscapes as conservation units especially for landscape-dependent wild animal species. Consequent loss of biodiversity and ecosystems and decline in innumerable ecosystem services emanating from these natural reserves are other serious impacts. As India aspires for better, modern roads, the ecological concerns regarding many road upgradation projects have recently been the cause of disputes between the transportation sector and the conservation community. Delayed consideration of ecological concerns into linear development project planning leads to inadequate appropriation of funds needed for mitigating impacts of such developments. It is in these circumstances that the question of prioritizing areas and strategies for mitigation given limited mitigation funds arises. We examine the different facets to the debate of triage vis-à-vis conservation, development and mitigation planning in the transportation sector in a developing country context. We suggest that it is important and possible to secure investment toward conservation in areas outside the purview of legal protection through project mitigation costs and other mechanisms. We also make suggestions to avoid the "laissez-faire" approach to linear development projects that is prevalent in India.

Keywords: roads, corridors, conservation, triage, sustainable development, mitigation

OPEN ACCESS

Edited by:
James Guy Castley, Griffith University, Australia

Reviewed by:
Nakul Chettri, International Centre for Integrated Mountain Development, Nepal
Gopalasamy Reuben Clements, Universiti Malaysia Terengganu, Malaysia

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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *30 May 2016*
Accepted: *03 November 2016*
Published: *22 November 2016*

Citation:
Habib B, Rajvanshi A, Mathur VB and Saxena A (2016) Corridors at Crossroads: Linear Development-Induced Ecological Triage As a Conservation Opportunity. Front. Ecol. Evol. 4:132. doi: 10.3389/fevo.2016.00132

INTRODUCTION

Much of India's economic growth in the past two decades has been driven by infrastructure development, prominent among them being development in the transportation sector. This can be attributed to reorientation of government spending toward public infrastructure (Ministry of Finance, 2016), including road-based transportation infrastructure. India today has the second largest road network in the world (ca. 5.2 million km), after the United States of America[1]. For a developing country like India, the importance of an efficient transportation system cannot be

[1]National Highways Authority of India (http://www.nhai.org)

understated: roads facilitate social well-being and economic development (Elisseeff, 1998). The manufacturing centers, commercial and cultural centers, that are the nuclei of development, are already connected via a well-built network of over 24,000 km of roads[1]. Many rural areas in India are now being connected to better civic amenities and economic opportunities via roads networks. With an annual economic growth pegged at 7–7.5 percent for the fiscal year 2016–17 (Ministry of Finance, 2016), the scale of infrastructure development is also set to increase.

Concurrent with India's high-paced development is the country's unique global position in terms of its biodiversity. Being one of the 17 megadiverse countries of the world (with 7–8% of the world's species, of which 12.6% of mammals, 4.5% of birds, 45.8% of reptiles, 55.8% of amphibians and 33% of Indian plants[2] are endemic), four of the world's biodiversity hotspots (Myers et al., 2000) are also located in India- Western Ghats and Sri Lanka (Western Ghats), Himalaya (Indian Himalaya), Indo-Burma (parts of North east India) and Sundaland (Nicobar Islands) (Pande and Arora, 2014). The vast biological wealth is comparable to the diversity of geographical features (plateaus, mountains, plains) and habitats and ecosystems (forests, grasslands, wetlands, deserts).

India is also home to 57% of the world's tiger population (Jhala et al., 2015; WWF, 2016). The tiger, being a keystone species, regulates prey populations thus reducing trophic cascades. In India, the protection and management of forested ecosystems has thus been envisaged through its conservation as a flagship species (Leader-Williams and Dublin, 2000) through a network of tiger reserves in landscapes across the country. The populations in these tiger reserves act as meta-populations, across which genetic exchange is vital for long-term persistence of the national animal. Securing the habitats and movement pathways of the tiger by extension equates to conserving all other species that share these forests (Roberge and Angelstam, 2004) and the invaluable ecosystem services provisioned by these forests. Habitat connectivity for tigers in Indian landscapes has been evaluated and mapped through GIS-based landscape permeability models (Qureshi et al., 2014; Mondal et al., 2016), and genetic analysis in combination with landscape permeability models (Joshi et al., 2013; Yumnam et al., 2014), generating structural corridors. These corridor maps are used to identify corridors that may be threatened by road construction/expansion. Securing these corridors is vital for maintaining landscape-level gene flow (Yumnam et al., 2014) and is an essential, and critical component of conservation of such species (Bennet, 1990). Similar corridors have been identified for connecting and conserving elephant populations (Menon et al., 2005).

However, a great part of these corridors lies outside the protected area (PA) network and under different land ownership tenures. It is in such areas that the challenge of building roads and nature conservation become most daunting. Many high-traffic highways crisscross the few remaining forested landscapes of the country and cause an array of short- and long-term ecological impacts. Intrusion of roads in natural areas and activities associated with road building and operation adversely impact native biodiversity through multiple pathways (Jalkotzy et al., 1997; Kumara et al., 2000; Forman et al., 2003; Donaldson and Bennett, 2004). Road-related disturbances create a filter to animal movement across their habitats on either side of the roads and, in the long-run, can cause populations of animals to disappear from habitats that have become isolated and fragmented by roads (Riley et al., 2006). In India, roads have affected daily and seasonal movement pathways of elephants, hoolock gibbons, one-horned rhinoceros and other mammals (Choudhury, 1987; Joshi and Singh, 2007; Gubbi et al., 2012; Krishna et al., 2013; Wildlife Institute of India, 2014). In the Central Indian Landscape alone, an important tiger conservation landscape (TCL), tiger corridors are bisected by at least 4302 km of national and state highways, upgradation of many of which are currently underway.

The objectives of road infrastructure development often conflict with efforts to maintain undisturbed and well-connected swathes of forested areas across landscapes. Development agencies see the merit of promoting upgradation of highway infrastructure in keeping with development aspirations of the country. However conservation groups advocate avoiding further development in sensitive habitats/wildlife corridors, opting for alternative alignments, adopting best possible mitigation measures for maintaining habitat connectivity and reducing animal mortality (where development cannot be avoided), and better and early integration of conservation issues into project inception, planning and design. In reality, however, development priorities take center-stage and several issues confound or hinder any cooperation between conservation and development proponents.

The lack of strategic/landscape-level planning in India (Saxena et al., 2016) to enable consideration of conservation objectives in transportation development policies, plans and programs results in a lack of or delayed participation of conservation proponents in the decision-making process. Such projects are therefore constrained in terms of allocation of resources for exploring options of avoidance, minimization, rehabilitation and offsetting. Considering these constraints, delayed intervention through litigation from conservation proponents after necessary permissions have been obtained by the developers leaves few options for mitigation planning and ensuing mitigation planning has to be prioritized considering limitations in the form of funding and political will to formulate and implement such plans.

This paper explores different facets to the debate on the "triage-like" situation that arises as a result of competing development and conservation objectives in the context of road upgradation projects in India using a prominent recent example. The case exemplifies the present status of delayed mainstreaming of conservation concerns into infrastructure development projects in the country. This delay in assessment of the anticipated threats to a vital wildlife corridor from the soon-to-be upgraded road translated into limited options to mitigate these threats. The ensuing prioritization exercise regarding choice of alignment, locations and specifications of mitigation measures made in light of the conservation

[2] http://thewesternghats.indiabiodiversity.org/biodiversity_in_india

importance of corridors, severity of threats, cost and possibility of positive conservation outcomes through mitigation, based on ecologically-informed alignment and mitigation alternatives have also been discussed. It concludes that implementation of mitigation measures in road upgradation projects in India can offer better avenues for promoting conservation in areas outside the purview of legal protection than *status quo*. To avoid future stand-offs resulting from the prevalent piece-meal approach to development, we suggest strategic environmental assessments and landscape-scale inter-sectoral planning for the road development sector to better include conservation concerns into development plans. We also suggest science-based prioritization exercises to delineate “no-go” zones by weighing costs and benefits of developing some lands and conserving others, and at the same time identifying areas where development is inevitable but conservation action can be mainstreamed into development projects.

USING TRIAGE TO ENABLE CONJUNCTION OF HUMAN AND WILDLIFE PASSAGE

Ecological triage is an informed prioritization of species to conserve, given their ecological role and chances of averting extinction through investment in conservation actions, after which funds for conserving these species are allocated accordingly (Hobbs and Kristjanson, 2003). However, triage of species must now move toward triage of habitats (Hudson, 2011), since pouring money to save a single species when its habitat is not preserved is moot (Shepard, 2011). Saving tigers and their habitats in India follows the same approach. However, given different threats to corridors outside the purview of protection, and limited funds for mitigation and conservation sourced from developers, it becomes imminent to prioritize areas where these funds would give the most positive conservation outcomes. Given duly established criteria for prioritizing landscapes for conservation are in place, the criteria to be given the highest weighting should be the magnitude of threats to the habitat.

Although development in the road sector in India is imminent and undeniably essential, it is the upgradation of arterial high-traffic highways passing through ecologically rich and sensitive areas that has to be dealt in light of factors justifying the need for expansion, increasing trends in traffic volume and the conservation importance commanded by the areas being traversed by roads. This was best exemplified in the case of upgradation of the National Highway (NH) 7, an arterial highway that connects major cities in Central India to the northern and southern parts of India. Upgradation work on the highway was initiated under Phase III of the National Highways Development Plan (NHDP). After upgradation work was completed in the non-forested sections of the road stretches, upgradation work was halted in a forested stretch that cut across the Pench-Kanha corridor, a critical tiger corridor in Central India for which clearances were required as conservation and forest authorities were not included in the project planning stages. The 2-lane configuration of NH 7 had not incorporated animal passageways as part of its original design, barring the natural drainage structures, which were used by wildlife in the absence of other suitable structures (Rajvanshi et al., 2013). Sandwiched between the upgraded segments (**Figure 1**), the forested 2-laned segment received greater number of vehicles per unit time than the 4-laned segments, thereby posing a threat of creating a barrier for animal movement across the corridor.

An alternative route via Chhindwara, Maharashtra, involving an additional length of 70 km (55% increase in distance) was suggested by a conservation organization. This alignment posed a threat to the connectivity of the Pench-Satpura-Melghat corridor which is vital for connecting six tiger reserves in the landscape. Opting for this alignment would also require re-alignment of 122 km of an existing highway (17% of which was in the hills), diversion of 163 ha of forest land and felling of 81,500 trees (Wildlife Institute of India, 2012).

The imminent threat to the Pench-Kanha corridor because of increase in and funneling of traffic on NH 7 was greater given its high use (daily traffic volume on NH 7 increased from 3048 to 6151 in three years Wildlife Institute of India, 2012; Habib et al., 2015). This meant that abandoning upgradation plans on this stretch would hinder movement in the corridor further. So long as mitigation measures conducive to animal movement were incorporated in the initial alignment, the possibility of recovery of this corridor was thought to be greater. Considering implications for wildlife conservation and future projections of road development and traffic growth, it was thus considered prudent to allow upgradation of the existing alignment (Habib et al., 2015).

PRIORITIZING MITIGATION ACTIONS, STRUCTURES AND TARGETS

Choosing the target species/group for mitigation planning requires prioritization of the goals of mitigation that could be aimed at maintaining viable populations of select species across the landscape, reducing the risk to human lives due to animal-vehicle collisions (van der Grift et al., 2013), or at reducing road-related animal mortality, and vice-versa. This would however depend on local conditions, development objectives and conservation priorities that need to be set out clearly at project inception stages.

In case of NH 7, it was considered best to focus on the entire suite of locally available species (30 mammals-22 of which belong to Schedule I and II of the Wildlife (Protection) Act, 1972) to achieve the desired goals. Moreover, since it is not always feasible to address the concerns of each species in a landscape, measures that would address the concerns of most animals in the landscape were considered. The predominant criteria was, however, to provide connectivity for the flagship species, for which we relied on corridor maps created for tigers in the landscape. Thus, it was proposed to build flyovers across all forested corridors by an appraisal of the initial project plan (Wildlife Institute of India, 2012). The objective was to provide structures large enough to offer natural

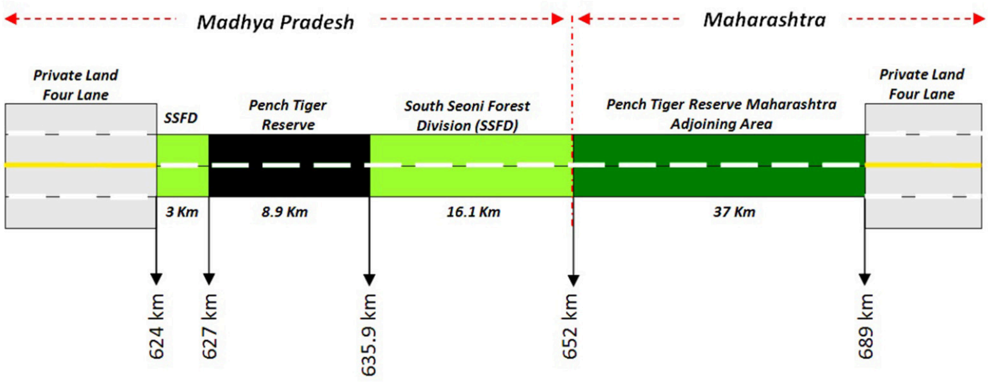

FIGURE 1 | Location of 2-laned segment of NH 7 between upgraded 4-laned segments causing a funneling of traffic.

passage to animals in the soon-to-be upgraded sections of the highway.

We achieved this by demarcating animal crossing zones based on sign surveys and then prioritizing locations of crossing structures based on the intensity of use by animals, and presence of villages and other ancillary development along the road stretch. In places where animal signs were found adjacent to villages and farmlands with weak connectivity to adjacent habitat patches, crossing structures were not suggested considering the possibility of conflict with humans. Some crossing zones were found to overlap natural drainage and in these places it was suggested to enhance existing drainage structures to facilitate use by animals, resulting in a multi-use structure.

USING TRIAGE TO CONNECT PEOPLE AND HABITATS: CONCLUSIONS AND WAY FORWARD

The average size of PAs in India is ca 220 sq. km[3], and is not enough to sustain long-term viable wildlife populations, particularly of landscape-dependent species such as elephant and tiger (Woodroffe and Ginsberg, 1998; Yumnam et al., 2014). These areas thus need to remain connected through a network of forested tracts outside the PA network, which often fall under different land ownership tenures. Existing and new roads in these lands inevitably lead to conflict with the objectives of maintaining connectivity among protected areas. Such roads, when upgraded, also present us with an opportunity to implement mitigation measures that offset the development impacts and those of the existing infrastructure. The internalization of mitigation costs incurred by developers into India's economic development can prove to be minimal in the long-term (Hudson, 2011).

Given the lack of strategic land-use planning in India and late consideration of conservation concerns into project planning, mitigation funds are not always adequate. Therefore science-based prioritization exercises of areas that are threatened by development and have a positive chance of recovery via investments in mitigation need to be outlined. Landscape conservation plans could also be used to guide the application of mitigation planning of development plans by overlapping development plans (present and future) with conservation objectives and align development and mitigation plans accordingly. Such exercises would also help delineate "no-go" zones for linear developments (Kiesecker et al., 2009). Hobbs and Kristjanson (2003) outlined a grid-like prioritization system that has been modified from emergency health-care for the "treatment" of landscapes. This approach helps assign appropriate levels and types of care to the landscapes considering relative level of threat and probability of recovery, factors critical for setting priority (Joseph et al., 2009). Prioritizing which corridors or habitats to save in no way means abandoning areas that are difficult to save or those with development interests; it merely allocates limited mitigation funding strategically to achieve conservation goals through effective mitigation planning (Bottrill et al., 2009).

New mechanisms for funneling development funds for conservation outside the PA system are currently being formulated in India. For example, under a new program, the MoEFCC is working on new guidelines to incentivize proponents to carry out afforestation and purchase and transfer land within recognized corridors as part of the compensatory afforestation program.

Strategic or landscape-level inter-sectoral assessments and land-use planning exercises could also help avoid issues that ensue as a consequence of a piece-meal approach to development, the prevalent practice in India today. This would also ensure that instead of keeping conservationists at the periphery in dealing with large development interests (Klages, 2010), they are engaged early in planning stages to evolve scientifically sound approaches in favor of the protection of ecosystems and ecosystem services within the mitigation hierarchy of such development plans. This strategy would both influence and be influenced by the allocation of

[3] http://www.wiienvis.nic.in/Database/Protected_Area_854.aspx

funds dedicated to avoiding and ameliorating development impacts to natural landscapes, and the business and political willingness to do so. There is also a need to initiate dialogue on science-based prioritization criteria suited to the conservation and development needs of India among conservation scientists which would then translate into prioritization in planning.

As conservationists, we cannot stop progress but we can shape it (Rosner, 2013). Identifying opportunities for positive conservation action through unavoidable development imperatives can help bridge the gap between our desire to conserve and our ability to conserve.

AUTHOR CONTRIBUTIONS

BH, AS, AR, and VM: Designed the paper, drafted and revised the paper, and approved the final version of the manuscript before submission. All authors contributed equally to this paper.

ACKNOWLEDGMENTS

We are thankful to the National Tiger Conservation Authority (NTCA), India, for funding our research. We are also thankful to the Maharashtra and Madhya Pradesh State Forest Departments for logistic support during field work.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Ecology and Evolution

PERSPECTIVE
published: 22 November 2016
doi: 10.3389/fevo.2016.00133

Triage of Means: Options for Conserving Tiger Corridors beyond Designated Protected Lands in India

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The latest tiger census conducted in India during the year 2014 shows that it harbors 57% of the global tiger population in 7% of their historic global range. At the same time, India has 1.25 billion people growing at a rate of 1.7% per year. Protected tiger habitats in India are geographically isolated and collectively holds this tiger population under tremendous anthropogenic pressure. These protected lands are in itself not enough to sustain the growing tiger population, intensifying human-tiger conflict as dispersing individuals enter human occupied areas. These factors—isolation and inadequate size of the protected lands harboring tiger meta-populations, highlight the need to connect tiger habitats and the importance of corridors beyond protected lands. It is imperative to conserve such corridors passing through private lands to safeguard the long-term survival of the tigers in India. The goal of long-term tiger conservation in India lies in smartly integrating tiger conservation concerns in various sectors where tiger conservation is not the priority. To effectively tap into all these resources, we propose a "Triage of Means" strategy. Here we do not prioritize species, populations or sites due to the non-availability of conservation resources. Instead, we aim to channel from available resources (means to achieve conservation) from other sectors where tiger conservation is not the focus. We outline how to prioritize resources available from various sectors into conservation by prioritizing issues hampering tiger conservation beyond protected habitats.

Keywords: triage of means, corridors, conservation, tiger, Central Indian landscape, India

Edited by:
James Guy Castley, Griffith University, Australia

Reviewed by:
Francesco Ferretti, University of Siena, Italy
Samuel A. Cushman, United States Forest Service Rocky Mountain Research Station, USA

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Specialty section:
This article was submitted to Conservation, a section of the journal Frontiers in Ecology and Evolution

Received: *30 May 2016*
Accepted: *08 November 2016*
Published: *22 November 2016*

Citation:
Mondal I, Habib B, Talukdar G and Nigam P (2016) Triage of Means: Options for Conserving Tiger Corridors beyond Designated Protected Lands in India. Front. Ecol. Evol. 4:133. doi: 10.3389/fevo.2016.00133

INTRODUCTION

India harbors over half the global tiger (*Panthera tigris tigris)* population within just 7% of their historic range (Jhala et al., 2015). These tigers are distributed in geographically isolated populations (Qureshi et al., 2014), being separated by landscapes of intensive human occupation, such as expanding agriculture, urbanization and an aggressive infrastructural development fuelled by a national aspiration to achieve 8% economic growth (Ministry of Finance, 2016). However, India does not have a comprehensive landuse policy (Department of Land Resources, 2013), which may lead to unchecked land conversion near forest fringes. Moreover, most of the reserves that contain these isolated tiger populations are not large enough to sustain the steadily growing tiger population (Chundawat et al., 2016). This leads to an intensification of conflict between the growing tiger population and a human population of 1.25 billion increasing at a rate of 1.7% annually (Chandramouli, 2011). Dispersing tigers from protected reserves are prone to confrontations with humans, resulting in human-tiger conflict (Dhanwatey et al., 2013). Isolation and inadequate reserve size (average size is 486 km^2, Karanth and Defries, 2011) amongst sites that harbors the fragmented tiger populations highlight the need of connecting these forest patches and the importance of corridors in doing so.

CORRIDORS: CONNECTING LINKS FOR LONG TERM CONSERVATION

The last decade in conservation research has illustrated that habitat corridors are an important conservation intervention to offset negative impacts of habitat fragmentation and to maintain meta-population dynamics (Hilty et al., 2012). The Central Indian Landscape which roughly covers an area of 76,913 km^2 (Yumnam et al., 2014), sets a perfect example of the importance of connecting fragmented tiger populations by corridors (Dutta et al., 2016). Deforestation, road widening, mining, aggressive urbanization and unchecked human activity in corridors are major concerns about the viability of corridors in the Central Indian landscape (Sharma et al., 2013a; Yumnam et al., 2014; Borah et al., 2016). Most studies unanimously suggest that reducing anthropogenic pressure (Joshi et al., 2013) and restoring habitat (Yumnam et al., 2014) are solutions for the long term sustainability of corridors. In addition, others have suggested involving local communities through community centered conservation programmes and eco-tourism (Ravan et al., 2005; Rathore et al., 2012), which may ensure that local communities are still able to derive their livelihood from the corridor forests. Elevating the legal status of corridors lands (Ravan et al., 2005; Yumnam et al., 2014) and use of smart green infrastructure in critical corridor habitats (Yumnam et al., 2014; Habib et al., 2015) has also been advocated as an alternative solution to safeguard corridors in the landscape. In areas where corridors span across multiple states, co-operation between different state agencies has been suggested (Ravan et al., 2005).

TRIAGE: IS IT THE WAY TO GO?

Conservation "is about conserving" (Harcourt, 2000); it's about making things happen on the ground. Carrying out one research project after another, proposing laws, drafting policies, and holding meetings, may not provide the desired outcomes if it cannot transform into any conservation action on the ground (Knight et al., 2006, 2008; Boreux et al., 2009; Braunisch et al., 2012).

Recommendations emanating from scientific studies need hard implementation on the ground for corridor conservation to benefit from all the scientific efforts being invested in it. On the ground, implementation of the above recommendations face numerous hurdles and requires extensive negotiations and prioritization of conservation actions. The negotiation and prioritization process often takes the form of a to and fro dialogue between the advocates (conservation agencies) and the opponents (developmental agencies) of conservation. This increases the time lag between a management recommendation made in a scientific study and its implementation on the ground (Arlettaz et al., 2010). We may need to focus conservation efforts in areas or on issues which are of more pressing nature or where negotiations may yield better results or follow implementation pathways which best suits available funds or alternatives.

Derived from the French word *trier* or "to sort," the word Triage has been popularly used to connote this process of prioritization (Random House, 1997). The term originated from battlefields and hospital emergency rooms, which casts its analogy on conservation biology as a "crisis discipline," a target oriented science where decisions need to be taken rapidly, often without the availability of complete knowledge and limited resources (Soulé, 1985). It echoes the political saying "choose the battles that you can win" (Ochoa-Ochoa et al., 2011).

There have been varying reactions from different quarters regarding the triage approach of conservation (Bottrill et al., 2008, 2009; Jachowski and Kesler, 2009; Parr et al., 2009; Ochoa-Ochoa et al., 2011; Rappaport et al., 2015). The argument for or against triage so far seems balanced as there are almost an equal number of publications supporting each view. Buckley (2016) has argued that when triage is followed to allocate scarce resources for conservation efficiently, it may send negative political signals by implying that global or local scale extinction of some species is acceptable. In the process, the damage caused far outweighs the attempted good that the triage approach may have achieved. In addition, Buckley (2016) states that the practice of conservation is a human socio-political process since conservation is driven or constrained by legislation and politics. In the triage approach, the process of prioritization may need the establishment of a threshold value and drawing a threshold is unscientific, leading to inevitable species extinction (Buckley, 2016). Furthermore, others argue that the triage approach which was adapted from battlefield and hospitals cannot fit scenarios applicable to conservation (Jachowski and Kesler, 2009).

Extinction is unacceptable according to the fundamental concepts of conservation biology since the general inherent consideration is that all species have an inherent value (Soulé, 1985). Some suggest that the conservation triage paradigm rejects this fundamental belief by neglecting some species, since conserving all species is costly and so-called inefficient, and ultimately push these species toward extinction (Jachowski and Kesler, 2009). Some research groups have gone to the extent of comparing the cost of conservation to the expenses allocated for space exploration (Balmford et al., 2002), and they argue that since conservation is not the costliest affair on this planet, we can allocate sufficient resources to conserve most species. Parr et al. (2009) say that we should not choose from species while letting some go extinct in the process of efficiently allocating resources.

While the preceding authors have identified the limitations in adopting a triage approach, we advocate triage as a tool available to a conservationist, under penny scarce conservation scenarios. We cite an Indian scenario where triage need not mean choosing from species, populations or sites while neglecting others. We define it as a prioritization process which lets one accumulate conservation funds from unconventional but potential sources; sources who's main mandate is not conservation, but the funds available from them can be leveraged to assist conservation if channeled in the right direction.

TRIAGE: AN OPTION FOR TIGER CORRIDOR CONSERVATION

Recommendations by various research groups to safeguard the tiger and its habitat in India often hits the same road block: the dilemma of triage. The importance of protected areas (PA) for conserving natural resources has been highly recognized worldwide (Hockings, 2003; Rodrigues et al., 2004) and successful conservation strategies often consider connectivity with adjacent PAs (Jackson and Gaston, 2008; Ladle and Whittaker, 2011). A recent corridor study has identified 9371 km^2 of area outside PAs that are crucial for the dispersal and movement of tigers in the Eastern Vidarbha Landscape (EVL) in Central India (Mondal et al., 2016). This area includes reserve forest, unprotected forests, and privately owned lands covered by forested or agricultural landuse. These areas come under the "Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act" (Ministry of Law Justice, 2007) enabling local communities to derive their livelihood from these lands, including the forest. Due to the proximity of intensive human use areas, these multiple use forest areas suffer from anthropogenic pressures like resource extraction, grazing, mining, infrastructural developments and noise, light and air pollution. Despite the plethora of impediments, these corridors are still functional to allow the movement of animals across the landscape (Joshi et al., 2013; Sharma et al., 2013b). Many areas along these corridors are in a critical state due to fragmentation, degradation, and resource extraction. Habitat connectivity is uncertain at these spots and loss of contiguity here may render the entire length of the corridor non-functional. Overlap of human use and tiger presence leads to the prevalence of human-tiger conflict, including direct attacks on humans and livestock depredation (Miller et al., 2016). Such events contribute to negative attitudes of the local community toward tiger conservation in the area. On multiple occasions, deforestation occurring along corridor habitats occur outside of notified forest boundaries (Joshi et al., 2016) and the forest administration, as an advocate of conservation, hardly has a say.

The above points highlight the magnitude of mitigation measures that need to be employed for successful conservation of tiger corridors in the EVL, which includes protecting corridor forests, restoring degraded habitats, buying lands along corridors, paying compensation to villagers suffering from human-tiger conflict. In the 3rd Asia Ministerial Conference on Tiger Conservation 2016 held in New Delhi, the Honorable Prime Minister of India stated that "conservation of tigers is not a choice, it is an imperative." He further added, "I believe Tiger Conservation and Conservation of Nature is not a drag on development, both can happen in a mutually complimentary manner, all we need is to reorient our strategy by factoring the concerns of the tiger in sectors, where tiger conservation is not the goal." At the same meeting, the Honorable Minister of Environment, Forests and Climate Change addressed the government's initiative to save tiger corridors: "We will incentivize project proponents to give land for compensatory afforestation in tiger corridors. By such measures, we can free tiger corridors from private incumbents, and it will become forest land. It will protect tiger corridors which will protect the growing tiger population." All this reflects a general positive public will toward tiger conservation, with further assurance being provided by available Government funds and above mentioned policies. To effectively tap into all these resources and public will, we must follow an unconventional triage approach as a means to prioritize alternative funding streams.

This we call, "triage of means": a process where we channel available resources by prioritizing from among various schemes of government ministries/departments for tiger corridor conservation. Under provisions of clause 135 of the Companies Act, 2013[1] funds are available from the corporate sector as well in the form of 2% of their average net profit in the previous 3 years toward Social Corporate Responsibility (CSR). Such CSR funds can also be used for tiger conservation. The merit of this proposed triage approach is its ability to draw resources from sectors, where tiger conservation is not the primary goal. Such indirect funds can be leveraged by mainstreaming the conservation agenda in these sectors.

TRIAGE OF MEANS

The key strategy of the triage of means that we present is to harness resources available from several areas, which typically lie in the purview of different ministries of the Central Government of India (GoI)[2]. This can only be achieved if environmental concerns are internalized in policymaking in a large number of sectors. The major portion of funds available for conservation in India is under various programs of the Ministry of Environment, Forest and Climate Change (MoEF & CC). These funds are available in the form of core (direct and immediate biodiversity impact), and non-core funding (pollution, hazardous substances management, etc. which facilitate biodiversity conservation of river streams, wetlands) from MoEF & CC (MoEF, 2012). Out of the MoEF & CC's aggregate budget of USD 362.52 million for the year 2013–14, the core funding constitutes USD 233.38 million while the non-core accounts for USD 38.76 million (MoEF, 2014). Apart from MoEF & CC, states in India also allocate a part of their budget for biodiversity conservation. It amounts to USD 749.75 million as per their 2013–14 budget. The indirect peripheral funding amounting to USD 351.3 million is available from 77 schemes from 23 Ministries/Departments of GoI. They support activities that benefit biodiversity but for which biodiversity conservation is not the main focus. Core and some part of non-core funding from MoEF & CC are directly available to be used in protected areas or lands, yet it fails to consider areas outside the purview of this protection and financial assistance. Our triage of means is about opportunistically amalgamating resources from peripheral funding sources (**Figure 1**).

IMPLEMENTING TRIAGE OF MEANS

Corridor habitats in India often consist of degraded forest surrounded by human-dominated landscapes. Due to this

[1]www.mca.gov.in/Ministry/pdf/CompaniesAct2013.pdf
[2]www.cbd.int/financial/doc/india-assessment-funding-support-en.pdf

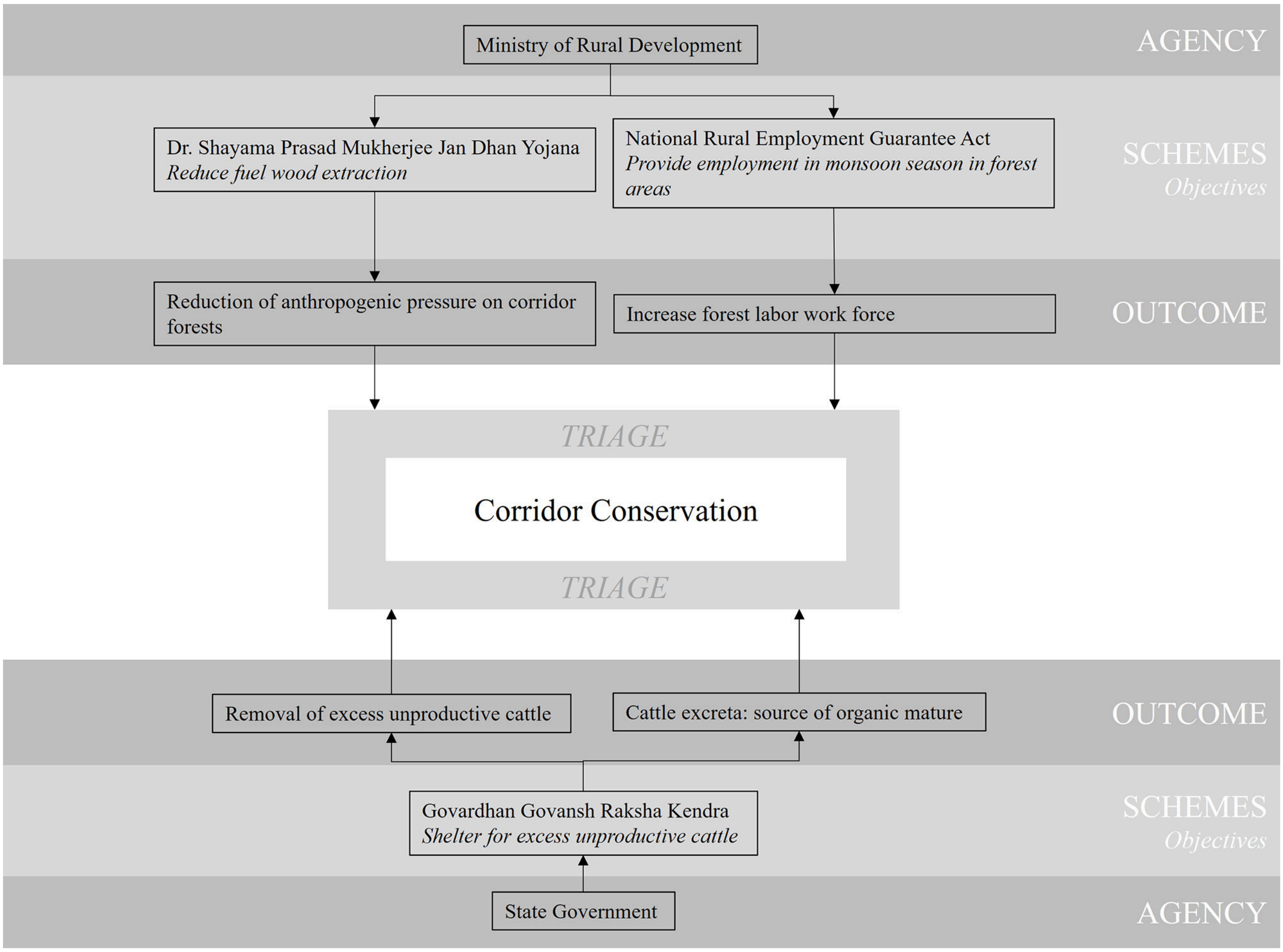

FIGURE 1 | The figure is showing various tasks which can be carried out by the agencies from other Ministries of Govt. of India where conservation is not the goal (triage of means).

close interface, the corridors are facing intense anthropogenic pressures, such as extraction of fuelwood and fodder, the presence of invasive species and excessive grazing. Here we try to suggest options how we can mobilize resources from other sectors to reduce these pressures on the corridors.

The National Rural Employment Guarantee Act (NREGA) 2005, under the Ministry of Rural Development, provides secure livelihood to rural populations in the form of 100 days of wage employment for unskilled manual labor.[3] It has been recognized as the most ambitious example of rural social security and public works programme in the World Development Report, 2014 by World Bank (2013). However, in the monsoon season, this scheme fails to provide any jobs to the local villagers due to flooding and muddy conditions. On the other hand, this workforce of thousands of manpower can be well employed in corridor forest areas in weed removal exercises and habitat restorations. This way the NREGA scheme picks up even in monsoon providing employment to thousands of villagers, and at the same time improve habitat quality in the corridor areas.

Dr. Shayama Prasad Mukherjee Jan Dhan Yojana (scheme) by the Ministry of Rural Development aims to provide the rural population with cooking gas (Liquid Petroleum Gas) or biogas (made from cattle dung) as an alternate source of daily household energy needs in the state of Maharashtra. Such schemes, when targeted in villages near corridor areas, can reduce their dependency on forests and reduce extraction of firewood and fodder. Lesser ventures into the forest to gather such resources also reduces the chances of encounters with tiger and thus has the potential to reduce conflict.

Recently due to a ban on cow slaughter in the state of Maharashtra[4] the cattle population in the state has increased dramatically.[5] This has led distressed farmers to abandon their unproductive cattle thereby increasing the number of unattended cattle which are venturing into forest areas to graze. Consequently, this high amount of uncontrolled grazing is

[3]http://rural.nic.in/sites/downloads/right-information-act/02%20_CIC_PartII_MG_NREGA(F).pdf.

[4]http://bombayhighcourt.nic.in/libweb/acts/Stateact/2015acts/2015.05.PDF
[5]http://goo.gl/eqphXu.

leading to degradation of the corridor forests. A new initiative of the State Government of Maharashtra is to set up cow shelters in selected districts to mitigate this problem. These shelters are being called the "Govardhan Govansh Raksha Kendra."[6] This scheme will be conducted through local NGOs, where abandoned unproductive and non-lactating cattle will be contained inside the walls of these shelters and cattle excreta will be used to manufacture organic manure.[7] When implemented in villages near tiger corridors, this initiative helps triage with its 2-fold benefits: reduction of grazing pressure in corridor habitats and promotion of the use of organic fertilizers.

CONCLUSION

We believe that triage is more than just focusing on single species conservation, but more broadly prioritizing of conservation actions when resources are scarce. We argue that funds can be funneled from diverse sectors when dedicated funding available for conservation may not be enough and provide an example of how this may work using the Indian tiger conservation challenge. Adoption of triage provides us with a logical and intuitive approach for efficiently distributing available resources among management actions to achieve a targeted conservation goal. By explicitly choosing among available resources using a transparent triage approach, we may be able to highlight any deficit in available funds which otherwise may go unnoticed (Bottrill et al., 2008). The practice of conservation is a human socio-political process since conservation is driven or constrained by legislation and politics (Buckley 2016). Adoption of a transparent decision-making process through triage will rule out the possibility of charismatic taxa or emotive causes diverting funding from a more rationally valid cause (Metrick and Weitzman, 1996). Conservation efforts that follow the principle of triage are logical, can be duplicated across time and space (Bottrill et al., 2009).

The triage of means that we suggest can clearly and objectively apportion funds from peripheral sources for corridor conservation that have been hitherto invisible and/or seldom tapped into. If meticulously pursued, *Triage of Means* may become the best *means of triage* for safeguarding tiger corridors in India. The crux lies in intelligently formulating policies and schemes to mainstream conservation for agencies without conservation mandates.

[6]http://goo.gl/utbEQ4
[7]http://goo.gl/hRkBVU.

AUTHOR CONTRIBUTIONS

IM, BH, GT, and PN designed, drafted and revised the paper, and approved the final version of the manuscript before submission.

ACKNOWLEDGMENTS

We are grateful to the Director, Dean and Research Coordinator of the Wildlife Institute of India for facilitating this research. We are thankful to the National Tiger Conservation Authority (NTCA) for funding our research. We are also thankful to the Maharashtra State Forest Departments for logistic support during field work. The authors also thank the University Grants Commission for the fellowship.

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