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Revisiting the 4 R's: Improving post-release outcomes for rescued mammalian wildlife by fostering behavioral competence during rehabilitation

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Rescue, rehabilitation, and release ('rescue-rehab-release') of wildlife is an increasingly widespread practice across ecosystems, largely driven by habitat loss, wildlife exploitation and a changing climate. Despite this, its conservation value has not been realized, in part due to the scarcity of what has been termed "the 4th R", research. Similar to conservation breeding and headstarting, rescue and rehabilitation entails close association of humans and the wildlife in their care over impressionable and extended periods. However, unlike these interventions, rescue and rehabilitation require an initial, and sometimes sustained, focus on crisis management and veterinary needs which can impede the development of natural behaviors and promote habituation to humans, both of which can compromise post-release survival and recruitment. In this perspective, we discuss the pathways toward, and implications of, behavioral incompetence and highlight opportunities for testable interventions to curtail negative outcomes post-release, without compromising the health or welfare of rescued individuals. We propose that practitioners 'switch gears' from triage to fostering behavioral competence as early in the rehabilitation process as is possible, and that research be implemented in order to develop an evidence-base for best practices that can be shared amongst practitioners. We focus on four mammalian species to illustrate specific contexts and considerations for fostering behavioral competence by building on research in the conservation translocation literature. Finally, we discuss a way forward that calls for greater cross-

pollination among translocation scenarios involving extended time under human care during developmentally sensitive periods.

KEYWORDS

wildlife rescue, rehabilitation, behavioral competence, post-release monitoring, behavioral training, reintroduction biology

Introduction

Wildlife rescue, rehabilitation and release ('rescue-rehab-release') is widespread, spanning continents, taxa, and contexts (Guy et al., 2013; Pyke and Szabo, 2018). It can be high-profile and high-stakes when focused on charismatic megafauna or species that may harm humans, and involves considerable labor and financial resources (Molina-López et al., 2017; Englefield et al., 2019; Morgans et al., 2019; Haering et al., 2021). Scenarios prompting rescue-rehab-release vary and are typically reactive, stemming from catastrophic events posing danger to populations or creating unsuitable habitat [e.g., oil spills (Hong et al., 2020), algal blooms (Lefebvre et al., 2016), wildfires (Parrott et al., 2021), drought (Mo et al., 2021)]; and recurring threats that drive defaunation and compromise welfare [e.g., illegal wildlife trade (Moore et al., 2014; Castro Cortés et al., 2022), orphaning, injury, human-wildlife conflict (Marker et al., 2021)], or threats from occupying human-dominated areas [e.g. vehicle collisions, dog attacks (McAlpine et al., 2008; Kwok et al., 2021)]. Crisis translocations like these and others that are reactive (e.g., mitigation translocations) will intensify worldwide with accelerated habitat loss, climate change, and other threats (Pyke and Szabo, 2018; Bradley et al., 2022).

Rescue-rehab-release provides an important touchpoint between wildlife practitioners and the public through ambassador and education programs (Normande et al., 2015; Osterberg et al., 2015; Romero et al., 2019); and through social media, which facilitates sharing of heart-warming stories, engages local and global communities, and engenders support for wildlife (Stokes et al., 2018). Not all rescue-rehab-release has conservation value *per se* (Cope et al., 2022), but its potential to contribute to species recovery and population health has not been adequately recognized, nor realized (Molony et al., 2006; Pyke and Szabo, 2018; Blair et al., 2020; Paterson et al., 2021).

Releasing wildlife after time under human care ('HC') is a shared objective among reactive rescue-rehab-release and proactive conservation strategies like conservation breeding and headstarting, which seek to reinforce or reintroduce free-ranging populations and protect/restore genetic diversity (Thomas et al., 2019) and are distinct from other contexts like mitigation translocations that do not keep animals under HC for lengthy periods (Bradley et al., 2022). The aims of rescue-rehab-release's later stages overlap with those of proactive breeding/headstarting for translocation, including determining whether wildlife are releasable, preparing them for release, and monitoring post-release (Figure 1). Yet this intersection is infrequently acknowledged or leveraged, and has rarely been documented in the literature. For example, rescue-rehab-release is not considered under the larger umbrella of the IUCN translocation guidelines (IUCN/SSC, 2013), which may contribute to the lack of evidence for appropriate pre-release practices compared to proactive translocations (Alberts, 2007; Guy et al., 2014; Fuller et al., 2021). Pyke and Szabo (2018) articulated the undeniable need to capitalize on research opportunities associated with rescue-rehab-release (the "4 R's"), outlining how studying rescue-rehab-release could improve understanding of wildlife needs and meaningfully contribute to conservation.

HC of wildlife poses unique challenges to post-release success for all conservation translocations (Alberts, 2007; Greggor et al., 2018); however, reactive HC adds numerous challenges. First, from the outset of HC, proactive breeding/headstarting programs benefit from pre-intervention planning and iterative implementation of husbandry and health regimes designed to foster natural behaviors and minimize dependence on humans. This is often not an option with rescued wildlife, and in some cases (e.g., pet trade) rescued animals have been deliberately human-imprinted. Second, rescued wildlife often come into HC after experiencing trauma, which in turn requires caregivers to restore well-being. Especially with juveniles, this may involve caregivers simulating conspecific interaction or providing emotional comfort, which often strengthens bonds with and diminishes fear of humans. Rescued wildlife may learn that humans are not threatening, are a food source, or are conspecific replacements (Jule et al., 2008; Fàbregas et al., 2020), which may be a particular challenge where human-wildlife conflict mitigation strategies employ fear-based deterrents (Mumby and Plotnik, 2018). Third, the consistent resources and safety provided while under HC may inhibit learning of survival-relevant behaviors and dynamic ecological cues. These points are especially concerning for juveniles.

Behavioral incompetence may be dire for released animals, in particular where animals may cause harm to human lives or

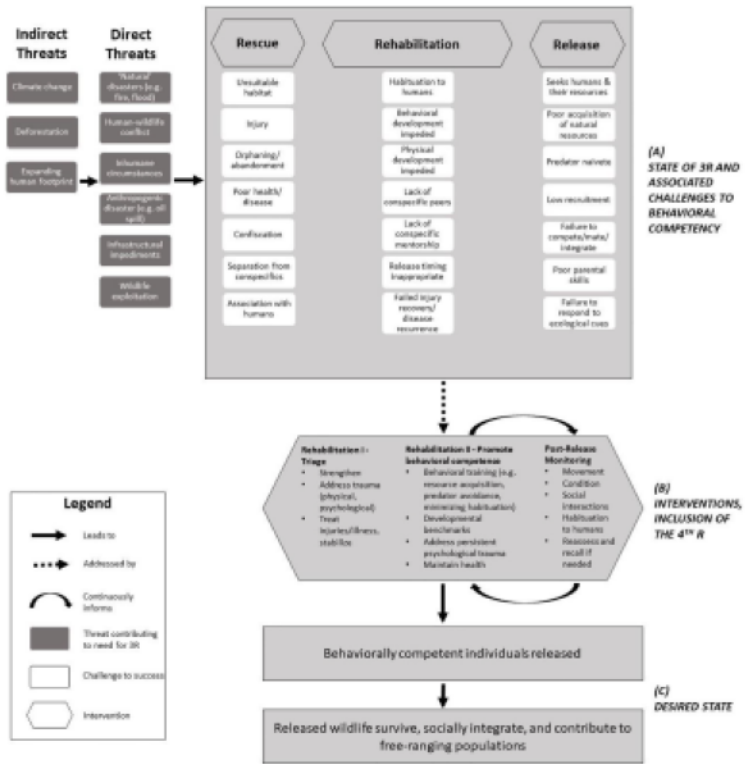

FIGURE 1
(A) Generalized situation model (CMP, 2020) of rescue-rehab-release. During rehabilitation, several factors may contribute to post-release behavioral incompetence, which may contribute to poor outcomes. These are overlapping considerations for conservation breeding and headstarting. **(B)** Targeted transition during Rehabilitation from triage activities (I) to interventions that promote behavioral competence (II). Post-release monitoring builds on Rehabilitation II interventions and is iterative and adaptive. Incorporating the 4th R, research, is essential for achieving **(C)** the desired state for rescued and released wildlife.

livelihoods (Gusset, 2009; Bansiddhi et al., 2020). Post-release success can be difficult to achieve, requiring iteration and evaluation, as noted often in the conservation translocation literature (Wolf et al., 1996; IUCN/SSC, 2013; Guy et al., 2014; Berger-Tal et al., 2020). There is a need for adaptive management practices that support releasing behaviorally competent individuals and evaluating post-release outcomes for rehabilitated wildlife (Lander and Gulland, 2003; Guy et al., 2013; Myers and Young, 2018; Campera et al., 2020). This approach may produce leading indicators of success that can be measured earlier and over a shorter term (Morris et al., 2009) than lagging indicators (e.g., survival, recruitment). Vetted leading indicators are a needed complement to lagging indicators, especially given the many resources and sustained monitoring needed to document lagging indicators.

Here, we focus on leveraging rehabilitation to better prepare wildlife for release and, in so doing, maximize contribution to free-ranging populations. This will require species-, and context-specific approaches that incorporate research during rehabilitation. Because behavioral issues are a primary factor in post-release failures for mammals (Berger-Tal et al., 2020), and behavioral conditioning generally improves post-release outcomes in mammals (Tetzlaff et al., 2019), we emphasize fostering the development of behavioral competence during a structured 'second phase' of rehabilitation that is implemented as early as possible. While other contexts for wildlife translocations exist (Bradley et al., 2022), we focus on those with the common theme of prolonged time under HC during which wildlife may be studied and their behavior modified. Below, we discuss examples from four mammalian species to illustrate interventions across divergent rescue-rehab-release contexts, acknowledging that any given species may encounter multiple behavioral challenges simultaneously. We use this discussion to promote guideline development that explicitly recognizes the need to switch gears in rehabilitation practices toward behavioral needs, and that draws on commonalities across translocation contexts where wildlife are temporarily under HC (Cope et al., 2022).

Case studies and discussion

Theory of change logic (CMP, 2020) for example interventions for African savannah elephant (*Loxodonta*

africana), koala (*Phascolarctos cinereus*), Asiatic black bear (*Ursus thibetanus*), and California sea lion (*Zalophus californianus*) is depicted in Figure 2. All of these species are rescued for reasons related to threats to individual animals (e.g., koala: vehicle strikes; sea lion: disease; elephant: stranding; bear: illegal wildlife trade). Koalas and sea lions are also rescued for habitat-scale threats to populations (koala: bushfires, floods; sea lion: algal blooms) (Adams-Hosking et al., 2011; Gallahar et al., 2021; Parrott et al., 2021). The ages of rescue vary, with koalas, bears and sea lions rescued at all life stages and elephants as juveniles. Thus, developmentally sensitive periods are well represented, and learning/unlearning are clear intervention opportunities (Tetzlaff et al., 2019).

Risk avoidance (African savannah elephant)

Releasing naïve individuals vulnerable to predation is a common problem in the breeding/headstarting literature (Griffin et al., 2000). It has been addressed through predator recognition training and aversive conditioning (Rowell et al., 2020; Edwards, 2021; Morris et al., 2021), with many instances of success. For example, Shier and Owings (2006) paired predator alarm calls with predator exposures in captive black-tailed prairie dogs, increasing antipredator behaviors and post-release survival, while (Blumstein et al., 2019) exposed bettongs and bilbies to low densities of feral cats prior to reintroduction to elicit antipredator behaviors.

Elephants, threatened by habitat loss and illegal trade, spend juvenile and subadult years learning from conspecifics to identify and respond to threats (Moss, 1988; McComb et al., 2011). Throughout their range, these threats also underpin the orphaning/stranding of juveniles, prompting rescue with the hope of eventual release. However, spending those years under HC can impede learning to avoid lions (Shannon et al., 2022) or humans, leading to undesirable outcomes (e.g., crop-raiding or occurring in proximity to lions/humans). As with other social species (Shier and Owings, 2006), learning antipredator behavior from knowledgeable conspecifics is not always possible under HC. In such cases, a next-best approach may be priming calves to respond to predator cues, followed by opportunities to learn from knowledgeable conspecifics upon release.

Testable interventions for juvenile elephants to enhance antipredator behavior toward lions and unfamiliar humans may follow precedents of aversive conditioning. Pairing olfactory or auditory cues that signal the presence of lions or unknown humans with stimuli known to elicit attention may prime calves to be more alert when they encounter those cues post-release. Hazing (e.g., with horn blasts, drone buzzes) (Petracca et al., 2019) may further encourage negative association or refine antipredator responses. Leading indicators that such conditioning is effective include increased avoidance and defensive behavior. Lagging indicators include survival into adulthood and appropriate avoidance responses when encountering lions or humans post-release (Edwards, 2021).

Resource acquisition (koala)

Prior exposure to foods needed upon release is critical to promoting behavioral competence. An accepted approach includes exposing animals to diverse foods and providing opportunities to practice handling them (Harvey 2018, Stoinski and Beck, 2004), ideally matched to resources at release sites (Stamps and Swaisgood, 2007). Recently, equipping wildlife to forage effectively includes considering gut microbiota due to greater understanding of its role in behavior

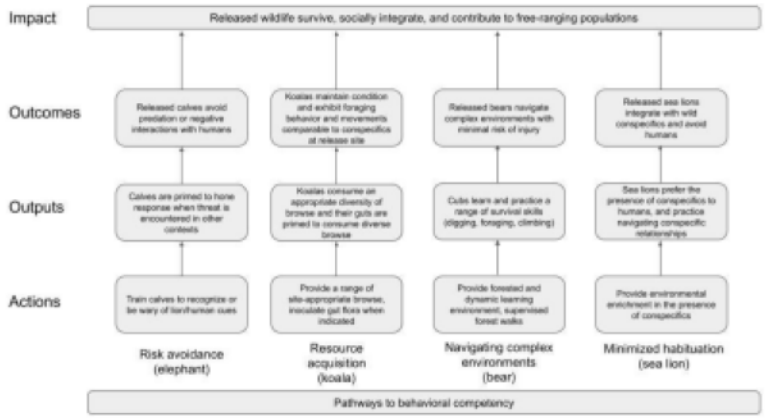

FIGURE 2
Theory of change for example interventions at the Rehabilitation II stage.

(Ezenwa et al., 2012; Davidson et al., 2020), including food preference (Yang et al., 2020). Blyton et al. (2019) showed that altering gut microbiota *via* inoculations changes koala browse preference. Yang et al. (2020) linked diet training in Yangtze sturgeon to shifts in gut microbial communities, which in turn were linked to diet preference.

Once on a trajectory of recovery, koalas are threatened by catastrophic climate change-driven bush-fires and habitat loss, with megafires resulting in the rescue, rehabilitation and planned release of scores of individuals. Koalas are dietary specialist obligate folivores that consume only a small selection of available tree species, and may vary from one another in the species they select (McAlpine et al., 2008; Gallahar et al., 2021). The microbiome is an important consideration for translocation success since it is linked to general health and condition and varies based on site and habitat (Blyton et al., 2019; Brice et al., 2019; Littleford-Colquhoun et al., 2022). It is not yet understood how a koala's established preferences for certain species of browse *in situ* influence subsequent behavior and condition in HC, where diet is likely to change due to several factors including caregivers lacking prior knowledge of *in situ* diet and limited access to browse collection sites. Furthermore, diet changes and associated gut microbiota changes under HC could impact digestibility and browse selection post-release.

Given this growing understanding of the importance of microbiota to wildlife health (Williams et al., 2018), rehabilitators have begun to address poor body condition during rehabilitation using "poop shakes", fecal material from healthy koalas, to reinoculate the gut and assist in digestion. Such an intervention, paired with exposure to different browse types at release sites, may affect survival behaviors like selecting appropriate browse. Candidate leading indicators of success include a change in food preferences or consumption, improved condition and fecal outputs, and similarity in gut composition with koalas at rescue sites. Lagging indicators include survival, species-typical movements and home range re-establishment. Since rescue and release sites cannot always be matched, a potential additional lagging indicator of intervention efficacy is similarity in gut microbial composition between released and wild koalas at the same site.

Navigating complex environments (Asiatic black bear)

For solitary mammal species, how to navigate complex and dynamic habitats is often learned during a period of prolonged parental rearing. Thus, orphaning and human-rearing of such species in facilities without physical complexity, dynamic ecological cues, or appropriate conspecific mentors can result in behavioral incompetence (Stoinski and Beck, 2004). However, evidence suggests these disadvantages can be minimized by increasing the complexity and size of physical learning environments (Stamps and Swaisgood, 2007) and providing species-appropriate environmental enrichment (Reading et al., 2013).

Asiatic black bears, threatened by habitat degradation and illegal trade (including the pet trade), are largely solitary with a ~2.5-year maternal care period. Rescued cubs often arrive at sanctuaries in ill health after experiencing trauma, necessitating triage-care. While many rescues result in life-long HC, release into the wild can improve welfare, reduce pressure on limited resources and contribute to population health. Behavioral incompetence resulting from HC may result in injury, illness or death post-release if bears do not know how to obtain adequate resources in complex forested and seasonally dynamic environments, compete for territory and resources, and avoid conflict with humans.

Testable interventions to foster a diverse repertoire of behavioral skills include designing forested enclosures with enrichment like deadfall logs, climbing structures, and puzzle feeders; and exposure to complex forest environments during critical developmental stages. Forest walking–the practice of caregivers accompanying rescued cubs into unfenced, forested-habitat to expose them to their natural range–is an approach to behavioral training that has been successful for multiple bear species (Fredriksson, 2005; Ashraf et al., 2008; Steinmetz et al., 2021). Leading indicators of efficacy include increased exploratory behavior, refuge seeking in trees, and increased behavioral diversity. Beyond post-release survival, lagging indicators could include few to no injuries in the years following release, species-appropriate ranging patterns (Abidin et al., 2018), absence of conflict with humans and recruitment into a wild population. While rescue of bear cubs has been ongoing for decades, and hundreds are under HC, release is a nascent endeavor and evidence-based behavioral interventions are desperately needed.

Minimizing habituation (California sea lion)

Habituation toward humans and perceiving them as a food source is a challenge faced by many translocation projects (Beringer et al., 2004). In addition to minimizing unnecessary interactions with humans under HC, caregivers can facilitate strong conspecific relationships as an alternative to humans (Fàbregas et al., 2020). Social relationships play an important role in post-release success for translocations (Shier and Swaisgood, 2012; Snijders et al., 2017; Goldenberg et al., 2019). Opportunities to develop relationships and hone social skills may provide an alternative to seeking human attention during rehabilitation.

Every year, thousands of California sea lions are stranded with various ailments and are transferred to facilities for rehabilitation. Sea lions thrive in HC and are quick to associate food and other rewards with humans (Cox et al., 1996). Thus, habituation to humans is a universal challenge facing sea lion rehabilitators, and each year some individuals are deemed unsuitable for release due to concern they will become nuisance animals. In addition to practices

like avoiding talking and limiting human presence, offering conspecific alternatives to humans is a promising and testable intervention. This may include group housing, exposure to enrichment items in group settings, and site design to promote navigating dominance hierarchies and group hunting of live fish. Leading indicators of success for these interventions include reduced incidence of gazing toward, tracking, and approaching humans. Lagging indicators include absence of nuisance behaviors post-release and contribution to recruitment.

In addition to the design of interventions, their cadence and strength should be planned in consideration of release environments (Homberger et al., 2014; Nogueira et al., 2014). Released wildlife will encounter fluctuations in resource availability, predation threat, and conspecific interaction. Priming animals to respond appropriately to changing ecological cues may better position them to adjust to periods of scarcity or assess degrees of threat. This may at times conflict with welfare aims to ensure wildlife under HC always feel secure, but is in line with the Five Domains of animal welfare that encompass broader ranges of experiences, including negative experiences (Mellor, 2017).

Way forward

A common feature uniting the examples above, and simultaneously making a strong case for their integration across rescue-rehab-release, conservation breeding, and headstarting, is small sample size and species specificity (Shaw et al., 2021; Cope et al., 2022). The fragmented and separated nature of translocation programs (i.e., welfare vs. conservation organizations) exacerbate this challenge. The efficacy of behavioral interventions is difficult to determine from one project alone; establishing meta-programs comprising a community of practitioners that build evidence for guidelines will improve outcomes for released wildlife. In turn, guidelines established through such collaborations would provide starting points for ecologically similar but less frequently rescued/lesser understood species (Alberts, 2007).

To facilitate knowledge exchange, rescue-rehab-release projects should implement the same standards of research fundamental to proactive translocations (Pyke and Szabo, 2018; Cope et al., 2022). There have been important research contributions from rescue-rehab-release, but this space is as yet largely untapped (Guy et al., 2013). In addition to scrutiny of rehabilitation protocols and an intentional focus on behavioral competence, post-release monitoring, where lagging indicators of success can be documented, is essential to understand if existing protocols are effective and what interventions are needed. This has been a recurring theme in the proactive conservation translocation literature (Berger-Tal et al., 2020), and should be equally valued in rescue-rehab-release. As post-release monitoring in conservation translocations has made clear, failures are to be expected and provide direction for improvement. Dedicated scenario planning to identify potential post-release problems drawing on lessons learned and experiences of other programs would more clearly define research needs. Incorporating lessons learned from both failures and successes, as well as setting realistic expectations for the supporting public, will improve outcomes for wildlife and garner long-term support for the complex, iterative, and often messy process of wildlife release.

We recognize that resource scarcity–including resources available for research–remains a persistent challenge to establishing effective strategies for wildlife under HC. However, we argue that the development and testing of leading/lagging indicators can facilitate more effective use of limited resources. Determining measurable release criteria indicative of behavioral competence may help identify unreleasable individuals earlier in the rehabilitation pipeline, thereby driving targeted resource distribution. Additionally, extensive post-release monitoring may become unnecessary or may be more strategically deployed after validating the reliability of leading and lagging indicators.

The examples above highlight interventions that are relevant across mammalian species and are supported in the wider conservation translocation literature, though we acknowledge that many other interventions merit testing. A greater embrace of intervention validation in the rescue-rehab-release realm that can be shared across translocation contexts will greatly improve post-release outcomes. Such a direction would ensure returning rescued animals to the wild benefits conservation and makes best use of resources available for wildlife.

Author contributions

SG, MO, JMP, KL, MH, and HN drafted the first version of this manuscript. All authors contributed to discussions on the topic and provided comments and edits on drafts.

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Conflict of interest

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