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Comparative evaluation of tiger reserves in India

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Abstract Evidence is vital. Understanding what interventions are effective is critical for the conservation of wild tigers and conservation biology in general. We evaluated the effectiveness of tiger reserves within India, a country with more than half of the estimated wild tiger population, with comparative effectiveness research. Other complex environments, medicine and business use these techniques where cause and effects are often non-linear. These techniques also allowed us to evaluate data from the small sample size often seen in conservation interventions. The opinions of three tiger experts were used to generate a list of seven tiger reserves classified as successful and five reserves as failures. We also used expert opinion to identify any key individuals that garnered widespread support for tiger conservation at any of the identified reserves. Using data from the Indian Census, World Database on Protected Areas, and the Socioeconomic Data and Applications Center, we analyzed the human population around the tiger reserves. We found two surprising insights that have received scant attention in the peer-reviewed literature. First, one can achieve tiger conservation success even within a densely populated human landscape where a high percentage of the population is involved in agriculture. Second, the presence of "conservation champions" can dramatically affect the performance of individual reserves and have positive outcomes for tiger conservation.

Keywords Tiger · Conservation · Evaluation · Effectiveness · Outcome · Biodiversity · Champion

Introduction

To avoid a dramatic loss of biodiversity we need to know what interventions are effective (Howe and Milner-Gulland 2012; Saterson et al. 2004; Sutherland et al. 2004). Despite this

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obvious concern, most evaluations of conservation strategies focus on implementation rather than outcome, even though outcomes are a much better predictor of conservation success (Kapos et al. 2009). The evaluation of interventions and outcome success is difficult (Jones 2012; Kapos et al. 2008) and is made more difficult, in large part, because conservation of biodiversity occurs within complex biologic, socioeconomic and geopolitical spheres, where incomplete knowledge is the norm (Robinson 2006). In other complex environments where ultimate causality may be unknown, various methods for correlating outcomes with variables are used (DeWitt Hamer et al. 2012; Earl and Carden 2002; Persaud and Nestman 2006). Here, we apply comparative evaluation methodology from both the social sciences (Gilligan and Sergenti 2008; Sutherland and Peel 2010; Vähämäki et al. 2011) and medicine (Lowrance et al. 2010; Sox and Greenfield 2009; Wilt et al. 2008) to evaluate the effectiveness of tiger reserves within India, a country which holds more than half of the current estimated wild tiger population (Seidensticker 2010; Walston et al. 2010; Wikramanayake et al. 2011). The use of these techniques allows one to compare variables with conservation outcomes, and, as is most germane to the question in review with its small sample size; there are only 42 tiger reserves in India. These techniques yielded two insights that have received scant attention in the peer-reviewed literature. Surprisingly, one can achieve tiger conservation success even within a densely populated human landscape where a high percentage of the population is involved in agriculture. Secondly, what may make the most difference is the presence of "conservation champions" who achieve positive outcomes for tiger conservation despite considerable odds against them.

Materials and methods

We classified tiger reserves based upon Cambridge Conservation Forum's Definitions (http://www.cambridgeconservationforum.org.uk/projects/measures/approach/#definitions). Thus, we classified them as successful if they increased the likelihood of persistence of the tiger population and as failures if there was a decline in the tiger population within the protected area over the period 1995–2005. Using this definition, we polled three tiger experts to generate a list of successful and failed tiger reserves. After each expert independently constructed their lists, only those reserves rated successful or failed by all three experts were included in the analysis. We excluded seven reserves due to mixed ratings. Utilizing expert opinion is a technique used increasingly in the conservation sector (Donlan et al. 2010; Kuhnert et al. 2010).We also asked these experts to identify any key individuals that garnered widespread support for tiger conservation at any of the identified reserves and acted as a "champion" according to the definition of Andersson and Bateman (2000). The phenomenon of the conservation champion, the number of champions that exist within the field of conservation biology, and evidence on champions' work in the field is currently being evaluated (D. Gallagher, personal communication). This research may help us understand a potential confounding variable, if champions are more likely to be recognized when they are associated with success or are themselves the agent of success.

We analyzed human population and demographic data available from the official 2001 Indian census (http://www.censusindia.gov.in/maps/censusgis/Census_GIS/page/India_WhizMap/IndiaMap.htm). This information was available at the scale of individual districts. When reserves spanned more than one district, we analyzed all relevant districts. There were seven reserves located within one district and five reserves located within two districts. The reserves were located within 17 of 640 districts, and within 8 of the 28 states throughout India (17 of which contain tiger reserves). Human population data for the year 2000 was downloaded from the Socioeconomic Data and Applications Center (http://sedac.ciesin.columbia.edu/data/collection/gpw-v3) and projected to the appropriate UTM Zone for each analyzed tiger reserve. Shapefiles for each of the 12 tiger reserves were brought into ESRI ArcMap 10.1 and projected appropriately. Three buffers were created (10, 20, and 50 km) for each tiger reserve (Joppa et al. 2009). Following buffer creation, tiger reserves were erased from each buffer so that population estimates would only count people living outside of the reserve boundary and within the buffered area. Data was extracted and imported into Microsoft Excel for further analysis.

We compared outcome with measureable variables such as human density and socio-economic data. The demographic covariates of human population density, human population in the buffer zone, percentage of the human population involved in agriculture, and the presence of conservation "champions" were evaluated.

Variables that shape conservation strategies and their ultimate success emerge from disciplines ranging from behavioral economics to sociology, psychology and ecology. This level of complexity is not unique to conservation. Medicine encounters it frequently. Therefore, we adapted a comparative effectiveness research method (Conway and Clancy 2009; PLoS Medicine Editors 2009) developed to evaluate cancer treatment (Lowrance et al. 2010).These evaluations assess the correlation of variables with outcome, rather than causation—a fact particularly significant in complex systems. In comparative effectiveness research, patient-centered outcomes are evaluated (Conway and Clancy 2009). We adopted this approach to evaluate species of interest-centered outcomes. Comparative research of this type is important for uncovering the complex relationship between human socio-economic systems and conservation outcomes in protected area management (Pollnac et al. 2010). We also included techniques from benchmarking (Sutherland and Peel 2010), success case methodology (Brinkerhoff 2003) and positive deviancy (Sternin and Choo 2000) by evaluating only the most and least successful reserves. By combining these approaches we were able to glean valuable information from a small sample size.

Results

The polled experts rated seven tiger reserves as success and five as failures—out of 42 total in India. These reserves were in eight states out of 17 Indian states that contain tiger reserves. The experts identified conservation "champions" at four of the seven successful tiger reserves but at only one of the five failed tiger reserves between 1995 and 2005.

Human population density around the tiger reserves ranged from a low of 27 people per square km around Namdapha to a high of 437 people per square km around Kaziranga. Tiger reserves deemed failed and successful spanned a wide range of human population densities (Fig. 1). On average, the total human population densities and the density of people within the 10 km buffer zone (Fig. 2) were higher near successful reserves and the two reserves situated in areas of the lowest densities failed.

The percent of the total human population involved in agriculture around the tiger reserves ranged from a low of 35.3 % around Nagarhole to a high of 81.9 % in the districts surrounding Kanha (Fig. 3). Involvement in agriculture amongst the rural population ranged from 47.3 % around Nagarhole to 87 % around Pench (Fig. 4). In the tiger reserves evaluated, we found both successful and failed tiger reserves in areas where a large percentage of both the total and rural population were involved in agriculture.

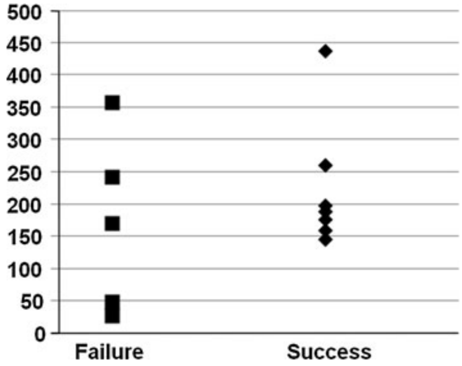

Fig. 1 Population density in (people/km^2). The tiger reserves classified as "Failure" are Palamau, Dampa, Panna, Sariska, and Namdapha, and the tiger reserves classified as "Success" are Kanha, Corbett, Pench, Kaziranga, Bhadra, Bandipur, and Nagarhole

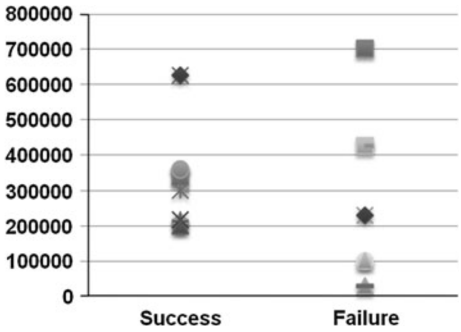

Fig. 2 Human population in 10 km buffer. The tiger reserves classified as "Failure" are Palamau, Dampa, Panna, Sariska, and Namdapha, and the tiger reserves classified as "Success" are Kanha, Corbett, Pench, Kaziranga, Bhadra, Bandipur, and Nagarhole

Discussion

Human population density around tiger reserves in India did not correlate with the success or failure of the reserves. Successful and failed tiger reserves were within regions where a high percentage of both the total and rural population was involved in agriculture.

Although conservation outcome evaluations are often logistically, scientifically and politically impractical and usually require long periods to assess properly (Kapos et al. 2008), they are a better predictor of conservation success than the more frequently reported implementation evaluations (Kapos et al. 2009).

Any study evaluating tiger population size must address the questionable accuracy of tiger counts within India (Karanth et al. 2011a) with conservation professionals utilizing different methodologies for estimating tiger populations (Jhala et al. 2010; Karanth et al. 2011a, b). To overcome this obstacle, we drew upon the first-hand knowledge of three independent tiger experts, a technique used in the modeling of endangered species distribution where data are often deficient (Murray et al. 2009). One limitation of this study was our reliance on expert opinion. We tried to minimize the inherent bias of the individual experts by only including in our evaluation reserves that were classified unanimously as either success or failure over a 10 year time frame rather than at a single point in time.

Although the definition of success or failure as it relates to individual reserves or a particular species is not defined, recent papers elaborate the importance of both defining successful vertebrate conservation on a global scale (Redford et al. 2011) and promoting the assessment of conservation success at other scales (Sodhi et al. 2011).

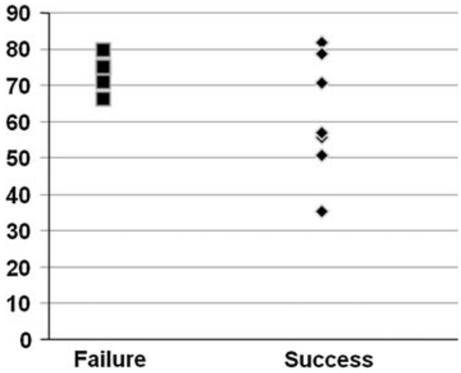

Fig. 3 Percent of total population involved in agriculture. The tiger reserves classified as "Failure" are Palamau, Dampa, Panna, Sariska, and Namdapha, and the tiger reserves classified as "Success" are Kanha, Corbett, Pench, Kaziranga, Bhadra, Bandipur, and Nagarhole

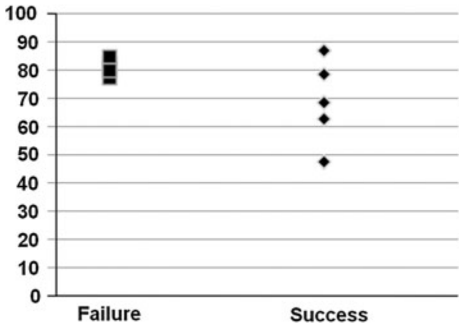

Fig. 4 Percent of rural population involved in agriculture. The tiger reserves classified as "Failure" are Palamau, Dampa, Panna, Sariska, and Namdapha, and the tiger reserves classified as "Success" are Kanha, Corbett, Pench, Kaziranga, Bhadra, Bandipur, and Nagarhole

High human population density causes elevated anthropogenic pressure on large mammals and can lead to their decline (Arjunan et al. 2006; Ceballos et al.2005; Davidson et al. 2009; Harihar and Pandav 2012; Johnson et al. 2006; Nugraha and Sugardjito 2009), this study shows that there are successful reserves with healthy tiger populations in areas of high human population density. Conversely, there are failing tiger reserves in areas of relatively low human population densities. Human densities within reserves and within a 10 km walking distance of the reserve may be a better predictor of success (K.U. Karanth, personal communication), however, our data demonstrate that reserves still can be successful even when surrounded by high human population densities. We did not evaluate other potentially important geographic factors such as location of watersheds, presence of migration corridors, and types of surrounding land uses (DeFries et al. 2010). Better livestock husbandry practices (Johnson et al. 2006), decreased levels of livestock grazing (Madhusudan 2003), increased tangible benefits local people receive from the tiger reserves (Sekhar 1998), improved law enforcement (Karanth et al. 2004; Li et al. 2012; Stokes 2010) and the effective resolution of human-tiger conflicts (Nugraha and Sugardjito 2009) can lead to an increased tiger population. We were not able to evaluate these variables and they may contribute to the effectiveness of tiger reserves located in areas of high human population density. It is not the human *density* around the tiger reserves that truly affect tiger conservation; rather it is the type of human *behavior* that significantly impacts tigers. Although reserves such as Namdapha have very low surrounding human density, there is heavy human interference in terms of hunting (B.P., unpublished data). The Lisus and the Nishis (tribes that live in the area around Namdapha) have virtually wiped out most prey species from the region by hunting for both for subsistence as well as trade (B.P., unpublished data). Thus, low human density does not necessarily insure the availability of prey or habitat necessary for tigers (Karanth et al. 2004). Namdapha also lacked a “champion” to build support for effective tiger conservation. In contrast, the Kaziranga and Nagarhole reserves, though surrounded by high human population density, have minimal human activity within their borders. Human interference does take place at the periphery of Nagarhole, Kanha, Kaziranga and Corbett, but the core areas within remain inviolate. In addition, conservation “champions” were associated with these reserves. Their efforts have allowed tigers to breed and proliferate in these successful reserves.

The use of land for agricultural purposes is typically associated with a negative impact on tiger conservation (Damania et al. 2003; Madhusudan 2003; Rao et al. 2002; Sekhar 1998), yet we found both successful and failed tiger reserves in close proximity to heavily farmed areas. We evaluated both the total and rural population involved in agriculture separately, as the latter have disproportionately larger effects on wildlife (Rao et al. 2002; Sekhar 1998). We did not evaluate the type of crops produced (Rao et al. 2002; Sekhar 1998) or the tangible benefits people receive from the reserve (Sekhar 1998) and these variables may affect conservation outcomes. The existence of successful tiger reserves even in areas of high agricultural use, where crop damage can be substantial and human-wildlife conflict involving tigers occur (Gubbi 2012), is worthy of additional study.

Our results indicate that successful conservation interventions are possible, even amidst conditions typically associated with conservation failures. The examination of these “outliers” may still yield valuable information. Positive Deviance is an approach to behavioral and social change based on the observation that in any society, there are people whose uncommon but successful strategies enable them to find more effective solutions to a problem than their peers, despite the context of the problem being similar (Sternin and Choo 2000). The success case method (Brinkerhoff 2003) leverages information gleaned from examples of both extreme successes and failures to inform managers. Utilizing methodologies such as these and closely analyzing the successful tiger reserves located within regions of high human population density and where a high percentage of both the total population and rural population are involved in agriculture may reveal effective conservation strategies.

Not only is evaluation important, but using appropriate, context dependent methodology is critical (Petticrew 2011). While the use of Randomized Controlled Trials (RCT) is the gold standard of most medical research (Sackett et al. 1996), it may not be the best method for evaluating complex, nonlinear systems (Craig et al. 2012) as RCTs assume linearity (Campbell et al. 2000; Oakley et al. 2003). Biodiversity and its conservation are incredibly complex and dynamic (Sterling et al. 2010). These nonlinear systems can be evaluated using methodologies such as comparative effectiveness research (Voils and Maciejewski 2011) as well as systematic reviews (Shepperd et al. 2009). While randomized controlled trials work best to determine if a medical intervention works in a controlled environment, comparative effectiveness research is superior in evaluating whether medical interventions work in specific situations (Conway and Clancy 2009). Conservation biologists, similarly, want evidence on what is effective in very real and specific scenarios (Caro et al. 2009).

A multitude of factors may affect outcome in conservation interventions (Redpath et al. 2013). Evidence in conservation biology is exceedingly important (Cook et al. 2010, 2012) and we must understand that there is no universal gold standard of evidence, but rather that the most appropriate evidence and practical methodology is determined by the context of the problem being evaluated (Campbell et al. 2000; Petticrew 2011). The large sample sizes and controls that are commonplace in medical research are rarely obtainable when evaluating conservation interventions (Geldmann et al. 2013; Pullin et al. 2013). In addition, the randomized clinical trials, routine in medicine, would have to be enormous to detect the effects that outcome evaluation using natural experiments have the power to reveal (Craig et al. 2012). Even with these limitations, the utilization of appropriate methodologies can lead to effective evaluations of conservation interventions.

Complete understanding of cause and effect in conservation biology is often lacking (Sterling et al. 2010) but one does not need to understand cause and effect mechanistically to evaluate outcome in real world situations (Craig et al. 2012). This should not impede the evaluation of interventions and outcomes. Despite limited knowledge about the causes of cancer and the genetic and molecular mechanisms of cancer, significant progress was made in cancer therapy prior to the twenty first century (Varmus 2006). Gaining even imperfect evidence can lead to successful outcomes.

Employing methodologies from the medical field and the social sciences allowed us to evaluate conservation interventions from different perspectives. These techniques revealed that factors typically associated with successful conservation outcomes might not always be necessary. They also uncovered a potentially important factor for conservation interventions, "champions." The concept of "champions" as individuals that bring about widespread support for an idea through confidence, enthusiasm, persistence, and involving key actors is well defined in the social science literature (Andersson and Bateman 2000; Gallagher 2009; Howell 2005). These individuals are cited as central in obtaining successful outcomes in fields as diverse as environmental justice (Gallagher 2009), technological innovation (Howell and Higgins 1990) and military inventions (Schon 1963). Conservation "champions" may have a dramatic effect on conservation outcomes and may help explain the effectiveness of certain tiger reserves (Post 2010). Evaluating the remaining 30 tiger reserves in India and other conservation outcomes around the world using methodologies described in this paper will help move practitioners to an evidence-based approach and help increase the effectiveness of conservation interventions (Sutherland et al. 2013).

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