Failure of research to address the rangewide conservation needs of large carnivores: leopards in South Africa as a case study

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Abstract

Science and conservation are often driven by different agendas, partly because many researchers are reluctant to tackle applied topics perceived to be less competitive for publishing or too impractical to study. Consequently, research often fails to contribute meaningfully to conservation outcomes. We use leopards *Panthera pardus* in South Africa to illustrate this mismatch between research and conservation priorities. A review of the scientific literature showed that leopard studies in South Africa focused disproportionately on basic research, particularly on leopard feeding ecology inside protected areas. Academics were responsible for most articles but avoided applied studies, even though they were published in higher impact journals and took less time to undertake. An assessment of active leopard projects further demonstrated that studies were clumped in areas of low conservation concern and most failed to publish their findings. Many projects were also funded by commercial volunteer programs with financial incentives for conducting research. We recommend that leopard researchers in South Africa and carnivore researchers more widely engage with practitioners to ensure the most pressing issues are addressed. Scientists must also situate their research in a broader conservation context and evaluate the outcomes of management decisions. Finally, continued funding and permissions for research should at a minimum be contingent on research outputs being published in the peer-reviewed literature.

Keywords
Academic priorities; carnivore conservation; leopard; *Panthera pardus*; research-implementation gap; responsible science; South Africa.

Introduction

As rates of species loss escalate, there is an increasing need for applied research that contributes to effective conservation (Soulé & Orians 2001; Lawler *et al*. 2006). This is particularly true for large carnivores which constitute some of the most vulnerable elements of biodiversity (Schipper *et al*. 2008). However, much research on large carnivores has little practical value and their management is often guided more by intuition than by hard science (Ray *et al*. 2005). This partly reflects a divide between the scientists conducting research and the practitioners responsible for implementing conservation actions. Many researchers hold academic positions and conservation biology is often regarded as a 'soft science" because studies may not fit rigorous experimental designs, it is challenging to establish clear a priori hypotheses, results may not lend themselves to robust statistical analyses and sample sizes are usually small (Laurence *et al*. 2012). Conservation research may therefore be considered less competitive for publishing in high-impact scientific journals, a key metric upon which academic performance is gauged (Knight *et al*. 2008; Arletazz *et al*. 2010; Laurence *et al*. 2012). Furthermore, studies are frequently conducted by postgraduate students, and university supervisors may be reluctant to encourage applied research that is inherently unpredictable and may not generate significant results in the timeframes available (du Toit & Broomhall 2000). This failure of research to influence conservation outcomes

has been identified as an area requiring urgent attention (Knight *et al*. 2008; Laurence *et al*. 2012).

Here we examine the match between research undertaken on leopards *Panthera pardus* in South Africa and conservation priorities for the species. Leopards act as a valuable model for investigating the challenges of establishing useful research agendas for large carnivores. Leopards are the most widespread wild felid, occupying a diverse variety of habitats (Hunter *et al*. 2013). However, like most large carnivores, leopards have suffered a dramatic reduction in numbers and range; for example, they have disappeared from an estimated 37% of their historic African range (Ray *et al*. 2005). The primary drivers of decline are similar to those affecting carnivore species worldwide, namely the loss and fragmentation of suitable habitat, depletion of natural prey and direct persecution by people (Ray *et al*. 2005). Habitat loss and a lack of prey appear less influential to leopards in South Africa where the spread of commercial game ranching, and the concomitant increase in abundance of small to medium-sized ungulates, has allowed leopards to persist or recolonise outside protected areas (Lindsey *et al*. 2009). However, the growth of game ranching has also fostered increased competition between leopards and ranchers for wild prey (Lindsey *et al*. 2009). Large numbers of leopards are also killed due to the real and perceived threat they pose to livestock and through legal sport hunting (Balme *et al*. 2009a). The illegal trafficking of leopard skins for cultural regalia represents another potential threat (Hunter *et al*. 2013).

We reviewed the scientific literature on leopards from South Africa and elsewhere in their range to determine whether past research has adequately addressed threats facing leopards and advanced the conservation of the species. Specifically, we assessed the balance between basic and applied leopard research, as well as the factors affecting the allocation of research effort. We hypothesised that researchers, particularly those from academia, avoided conservation-related topics because such topics are perceived to be less competitive for publishing or take longer to study. We also investigated whether active leopard projects in South Africa address shortcomings in the literature and we reviewed the accessibility of research results. Using leopards as a widely distributed and frequently studied example, we sought to highlight limitations in carnivore research practice in South Africa and more widely, with a view towards improving the utility of such research in future.

Methods

To identify past trends in leopard research, we conducted a literature review covering the period 1982–2012. We searched several databases (e.g., ISI Web of Science, Google Scholar, IUCN Cat Specialist Group library) for articles, which included the words leopard or *P. pardus* in their title, keywords or abstract. We restricted our review to refereed journal papers and book chapters because they are systemically accessible and serve as a suitable record of scientific progress (Lawler *et al*. 2006). For each article, and where data were available, we recorded the country/s where the research was conducted, the scale at which the research was undertaken (site-specific: within a single, contiguous site; regional: across multiple sites; international: across multiple countries), the size of the study area (for site-specific studies), whether the research was conducted mainly inside or outside of a protected area and the study duration (the period of data collection). We also determined the affiliation of the lead author (academic; nongovernment organization (NGO); government agency) and whether they were local or foreign. In addition, we screened the acknowledgements of articles to establish whether studies were funded by local or foreign sources.

We ascertained whether articles had an applied focus or concentrated mostly on basic research. Applied articles had three main themes: (1) informing conservation policy, (2) guiding management, and (3) conducting population surveys (Fazey *et al*. 2005). In contrast, basic articles were more theoretical, focusing mostly on aspects of leopard behavior and ecology. We distinguished the following research themes for basic articles: (1) demography, (2) feeding ecology, (3) intraspecific interactions, (4) interspecific interactions, and (5) other (includes articles on leopard anatomy, physiology, paleobiology, and phylogeny). Some articles were designated more than one research theme. In such cases, we decided whether the primary focus of the article was applied or basic (e.g., Hayward *et al*. 2007 was designated as "guiding management" and "feeding ecology" but the article was considered applied). Where applicable, we also identified the main threats assessed in applied leopard articles; specifically, loss and fragmentation of habitat, depletion of natural prey, disease and anthropogenic killing (divided into conflict with livestock farmers, conflict with game ranchers, trophy hunting and poaching for the illegal skin trade). We determined the ISI impact factor for journals in which papers were published (as per the 1 October 2012) and calculated the mean impact factor and study duration for each research theme. We also subjectively assessed whether the content in articles was purely biological or included nonbiological disciplines such as sociology, economics, or the political sciences.

To examine contemporary patterns in leopard research, we used our network among academic

institutions, wildlife agencies and independent carnivore researchers to identify leopard-centric research projects active in South Africa between 2000 and 2012. Projects may have multiple goals, funding sources or study sites but were managed by a single principal investigator (PI). We used project reports or contacted the project PI to determine where projects were conducted, the scale at which they were undertaken and the minimum period that projects were active. We calculated the distance between study area centroids for projects located in the same geographic region and established whether projects were funded by commercial volunteer programs (i.e., where laypeople—typically foreign students or recent graduates—pay to experience and assist with research). We also determined the number of peer-reviewed scientific articles published by projects. We only considered projects initiated earlier than 2008 since the median time elapsed from when a project begun to its first publication was 4.3 years (range = 1.0–33.4 years).

We computed all statistical analyses using IBM SPSS 19.1 (SPSS Inc., Chicago, USA) and tested significance at $P < 0.05$. Unless otherwise stated, we present means with standard errors as a measure of precision.

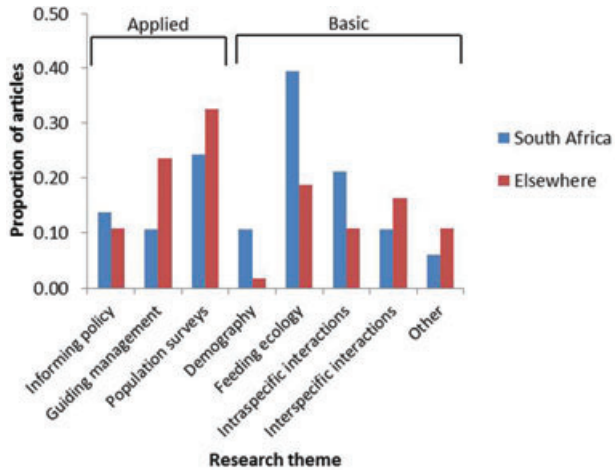

Figure 1 Proportional breakdown by research theme of scientific articles on leopards from South Africa and elsewhere in leopard range published between 1982 and 2012.

Results

Leopard literature review

We found 232 peer-reviewed articles that met our search criteria from studies undertaken in 43 countries. Studies in South Africa accounted for the highest number of articles ($n = 66$), followed by India (31), Tanzania (14), Namibia (13), Kenya (12), and Botswana (11). All other countries had fewer than 10 articles published on leopards (mean = 2.5 ± 0.3).

There was a disparity in the research themes addressed by articles from South Africa and those from elsewhere in leopard range ($\chi^2_1 = 8.229$, $P = 0.004$; Figure 1). Most leopard studies from South Africa focused on basic research (64% of articles), particularly on feeding ecology (39%), with less emphasis on applied research (36%). In contrast, publications from other countries focused more on applied issues (57%). As a result, leopard papers from elsewhere were more crossdisciplinary (21% included a nonbiological discipline) than those from South Africa (14% included a nonbiological discipline). They also focused more on multispecies assemblages (55%) than articles from South Africa (35%), which were primarily leopard-specific. The main threat assessed by applied articles was conflict with livestock farmers ($n = 42$). Trophy hunting (10), disease (9), loss and fragmentation of habitat (8), depletion of natural prey (7), conflict with game ranchers (3), and poaching for the illegal skin trade (1) received less attention.

Most (63%) leopard articles were produced by academics (Figure 2a). In South Africa, more articles published by government agencies (56%) and NGOs (62%) had an applied focus than those published by academics (37%; $\chi^2_2 = 6.727$, $P = 0.035$). This was not the case for studies elsewhere in leopard range where academics addressed mostly applied themes (60%; $\chi^2_2 = 3.944$, $P = 0.139$). The lead author for most (72%) South African publications was local, whereas most (59%) articles from other countries were written by foreigners ($\chi^2_1 = 20.106$, $P < 0.001$; Figure 2b). Similarly, more leopard studies were funded locally in South Africa than elsewhere ($\chi^2_2 = 21.094$, $P < 0.001$; Figure 2c).

Contrary to our expectations, applied articles were generally published in higher impact journals (mean impact factor = 2.5 ± 0.1) than articles on basic leopard research (1.8 ± 0.1; $U = 4{,}612.500$, $Z = -3.509$, $P < 0.001$; Figure 3). Leopard studies addressing applied topics were also generally shorter (mean study duration = 2.5 ± 0.3 years) than those that focused on basic research (5.0 ± 0.9 years; $U = 2{,}199.500$, $Z = -2.307$, $P = 0.021$; Figure 4).

Most (66%) published leopard studies from South Africa were site-specific (median study area size = 230 km^2; range = 5–19,500 km^2) with fewer regional (17%) and international studies (17%). The majority (90%) of site-specific studies were conducted in leopard habitat classified by Swanepoel *et al.* (2013) as highly suitable (habitat suitability index >0.50) and mostly (85%) inside protected areas (Figure 5).

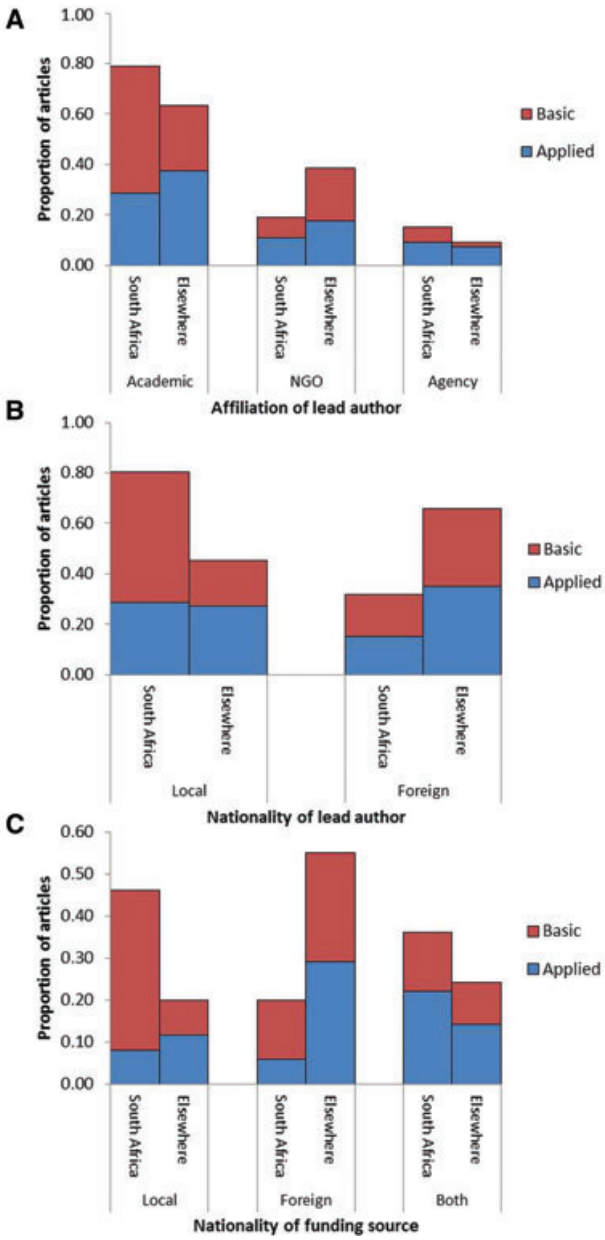

Figure 2 Organizational affiliation (A) and nationality (B) of lead authors, and nationality of funding sources (C) of applied and basic leopard articles from South Africa and elsewhere in leopard range published between 1982 and 2012.

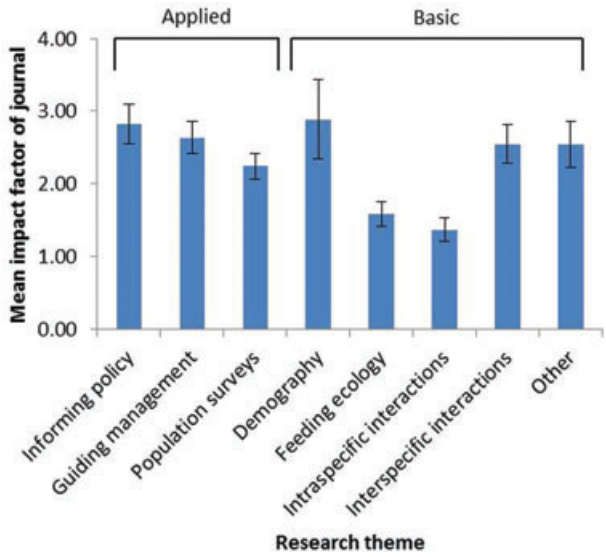

Figure 3 Mean ISI impact factor (as per the 1 October 2012) of scientific journals publishing leopard articles between 1982 and 2012 plotted against the research themes of those articles. Bars represent standard errors.

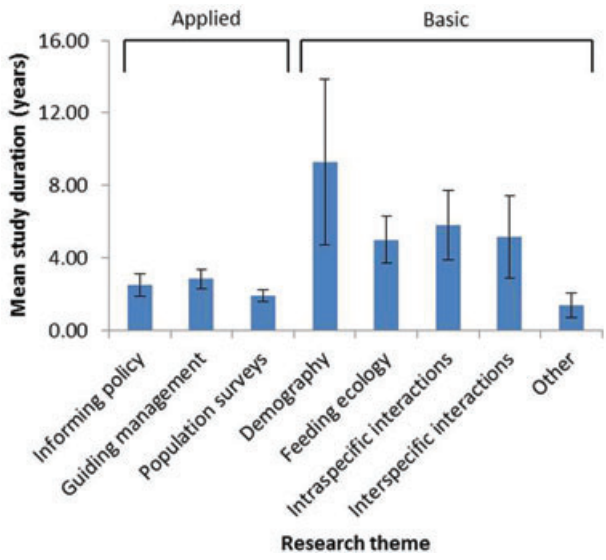

Figure 4 Mean study duration (years) of scientific leopard articles published between 1982 and 2012 plotted against the research themes of those articles. Bars represent standard errors.

Contemporary leopard research in South Africa

We were aware of at least 39 leopard projects active in South Africa between 2000 and 2012. Projects were clustered in several hotspots (Figure 5); for example, nine projects in the Waterberg region in Limpopo (mean distance between study area centroids = 37.2 ± 8.6 km), seven projects in the greater Kruger region of Mpumalanga and Limpopo (71.0 ± 7.7 km), five projects in the Mkhuze region in KwaZulu-Natal (35.5 ± 5.8 km), four projects in the Soutpansberg region in Limpopo (64.0 ± 12.9 km) and four projects in the Grahamstown region of the Eastern Cape (57.8 ± 8.0 km). Most projects were based in highly suitable leopard habitat (n = 37) inside protected areas (n = 33). The mean number of peer-reviewed articles produced by projects established before 2008 (n = 30) was 0.7 ± 0.2 (range = 0–5

articles). Nineteen projects produced no scientific publications, even though some ran for up to 12 years (mean minimum study duration for projects producing no scientific literature = 6.4 ± 1.1 years). At least 14 projects were funded or partly funded by commercial volunteer operations. Eight of these projects produced no peer-reviewed publications.

Discussion

Research from South Africa accounted for a significant proportion of the peer-reviewed literature on leopards; more than double that of any other range state. However, unlike leopard research conducted elsewhere, South African studies focused primarily on ecological themes, rather than conservation and management. This does not seem to reflect a general avoidance of applied research in South Africa; du Toit and Broomhall (2000) showed that conservation was in fact the most common focus of published South African mammal research. Nonetheless, it seems prudent that of all taxa, research on large carnivores should concentrate on subjects of societal relevance, given their propensity to impact human lives and livelihoods (both positively (Lindsey *et al*. 2005b, 2012) and negatively (Thirgood *et al*. 2005), and their vulnerability to human-mediated population declines (Woodroffe *et al*. 2005; Packer *et al*. 2009). A review of the IUCN/SSC action plans accordingly revealed that 83% of the recommended research priorities for large African carnivores relate explicitly to conservation (Nowell & Jackson 1996; Woodroffe *et al*. 1997; Mills & Hofer 1998). While studies on behavioral ecology can potentially contribute to conservation actions (Buchholz 2007; but see Caro 2007), targeted research that directly addresses conservation threats is likely to be more effective (Knight *et al*. 2008).

Although academics produced most leopard publications from South Africa, they tended to avoid applied topics. Smith *et al*. (2009) showed a similar pattern in the conservation planning literature; government agencies and NGOs typically published articles of greater practical value than the academic community. Our findings refute the hypothesis that conservation research was academically inferior or impractical to undertake. Applied leopard studies were generally published in higher impact journals and were conducted over shorter periods than those focused on basic research. This is partly explained by the small sample sizes often associated with ecological research on large carnivores, especially research which relies on expensive techniques such as radio-telemetry, as it constrains the population-level inferences achievable by studies (Hebblewhite & Haydon 2010). There was also extensive duplication of research effort in the South African leopard literature. Over a third of all articles were devoted to leopard feeding ecology, particularly to leopard diet. Dietary research may inform carnivore conservation, especially if it relates closely to human–carnivore conflict, but most leopard studies from South Africa were conducted in protected areas and often in the same geographic region. Swanepoel *et al*. (2013) estimated that only 32% of suitable leopard habitat in South Africa is protected. Conflict levels are also likely to be higher outside protected areas. Consequently, there appears a mismatch between where leopard research is conducted in South Africa and where the need is greatest. The same is likely true for many carnivore species; for example, most cheetah *Acinonyx jubatus* research has been undertaken inside protected areas, and yet the majority of cheetah range is unprotected and this is where the species is most threatened (Ray *et al*. 2005).

In his landmark paper, Soulé (1985) argued that conservation biology is a holistic, multidisciplinary science with processes studied at macroscopic levels. Given the paucity of applied leopard research in South Africa, it was not surprising that most studies were species and site-specific and omitted nonbiological disciplines. Large carnivores have potential to act as a focal or surrogate species for achieving wider conservation outcomes (Dalerum *et al*. 2008). However, the rationale behind such single-species approaches has been questioned (Lindenmayer *et al*. 2002) and management strategies that take into account and address the needs of multiple species simultaneously generally appear more successful (Baillie *et al*. 2013). Conservation interventions are also implemented over a range of spatial scales and research should correspond accordingly (Baillie *et al*. 2013). There will always be a need for site-specific studies, particularly those that assess the utility of local management activities (Sutherland *et al*. 2004), but a wider perspective is generally required to inform conservation policy (Lauber *et al*. 2011). Insight from social scientists, economists and politicians—something which is notably lacking in large carnivore research—also facilitates effective policy making (Lauber *et al*. 2011).

Although applied research was generally neglected in South Africa, certain threats to leopards were particularly poorly addressed. Many of these threats extend to other large carnivores and are similarly understudied. For example, the illegal trafficking of skins is also considered a key threat to tiger *Panthera tigris* and snow leopard *Uncia uncia* populations, yet few data exist on the scale and impacts of the trade for any species (Nowell & Jackson 1996). Commercial game ranches comprise a significant proportion of suitable habitat for several carnivore species in South Africa, including leopard,

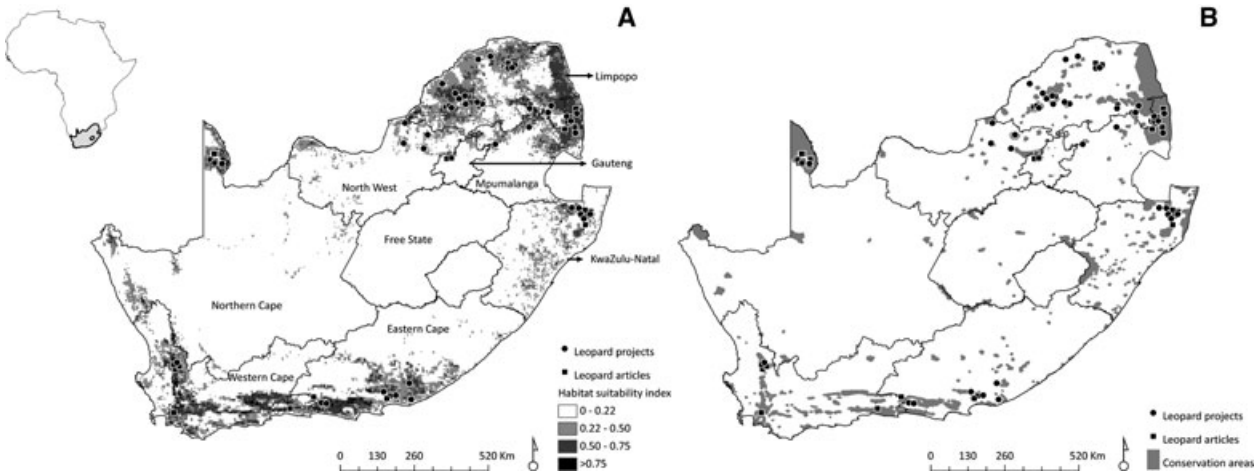

Figure 5 Location of site-specific leopard articles (squares) and projects (circles) in relation to (A) suitable leopard habitat (as determined by Swanepoel *et al*. 2013) and (B) conservation areas in South Africa. Only the main study area is shown for projects with multiple sites. Inset shows position of South Africa in Africa.

cheetah and brown hyena *Hyaena brunnea* (Lindsey *et al*. 2009), but the status of populations and the attitudes of landowners in these areas are little understood (but see Lindsey *et al*. 2005a; Thorn *et al*. 2012). Similarly, the role of infectious diseases in regulating carnivore populations remains unknown in many species (Murray *et al*. 1999), as does the direct and indirect effects of the bushmeat trade (Lindsey *et al*. 2013). All of these threats require attention if leopards and other carnivores are to be safeguarded in South Africa and more widely.

Although South Africa's output of leopard research is impressive compared to other range states, a more in-depth assessment suggests that many projects produce few novel or useful insights. Indeed, most local leopard projects made no contribution to the refereed literature. This failure to contribute to the scientific literature, particularly the peer-reviewed conservation literature, is not restricted to leopards. A review of the bibliographies of large African carnivores in the IUCN Red List for Threatened Species revealed that only 27% of citations stem from peer-reviewed journals (IUCN 2012). Such an underdeveloped literature severely limits the growth of new management tools and advancement of conservation science (Calver & King 1999).

As with the scientific literature, many leopard projects in South Africa were located in close proximity to one another (often within ranging distance of individual leopards; Fattebert *et al*. in press) and inside protected areas. Commercial volunteer programs provide an attractive source of funding for research and are increasingly used to finance biological studies (a brief online review revealed at least 48 companies that offer volunteer-orientated vacations in South Africa, 31 of which focused on large carnivores; G.A. Balme unpublished data). However, it seems that some research projects are initiated and tailored specifically to enable volunteer programs, rather than the other way around. Volunteers also favor "hands-on" research and most projects use invasive research methodologies such as radio-collaring that require animals to be restrained, often with limited expertise or oversight and putting individuals at risk to capture-related injuries (Hayward *et al*. 2012). While volunteer programs offer a viable mechanism to fund research at a time when resources are increasingly limited, it is important that they are conducted responsibly, address relevant questions and contribute to explicit conservation goals (Silvertown *et al*. 2013).

Recommendations

Our literature review and assessment of contemporary leopard projects in South Africa revealed several shortcomings. Notably, leopard studies focused primarily on basic research, there was much repetition among research topics, studies were typically not conducted in the areas of greatest conservation concern, there was an excess of species and site-specific studies, there was a lack of crossdisciplinary research and most projects contributed little to the scientific literature. Many of these shortcomings extend to other carnivore species. However, most are easily overcome with some effort on the part of motivated scientists, tighter regulation by statutory authorities and increased pressure from funding organizations. This is particularly true in South Africa where most research is undertaken and funded locally. Below we present a number of recommendations that aim to ensure that

science plays a larger role in the conservation of leopards in South Africa, and carnivores more widely.

(1) Prioritize applied research of societal relevance. A more balanced focus is required between basic and applied leopard research in South Africa, and large carnivore research in general (Ray *et al*. 2005). Authors often claim tenuous conservation relevance in largely ecological publications, usually tacked on as a perfunctory paragraph near the end of the article (e.g., Balme *et al*. 2007). These studies have limited use to practitioners who require clear, explicit guidelines supported by robust data (Smith *et al*. 2009). Targeted research that directly addresses management concerns is therefore the priority. Scientists should engage practitioners and other stakeholders early in their studies to collaboratively formulate research agendas. This will ensure that the most pressing, relevant questions are tackled, as well as facilitate the translation of conservation research into conservation action (Braunisch *et al*. 2012).

(2) Situate research in a broader conservation context.

If research is to be usefully applied, it must be situated in a real-world context (Knight *et al*. 2008). More large carnivore research is required outside of protected areas, where carnivores cause (or at least are perceived to cause) most conflict and are at the greatest risk (Ray *et al*. 2005). Projects should also be dispersed throughout a species' range (both within and between countries) and not clumped in hotspots, to prevent duplication of research effort and provide a wider perspective on the status of populations (Ray *et al*. 2005). A better understanding is also required of the socio-political factors affecting carnivore conservation. Studies should favor a multidisciplinary approach, going beyond biological insights by incorporating analyses from the social, political and economic spheres (e.g., Lindsey *et al*. 2012; Marchini & Macdonald 2012). Similarly, studies that transcend taxonomic boundaries and address the needs of multiple species (e.g., Macdonald *et al*. 2013) will more likely inform effective conservation than research focused only on single species. The conservation of leopards in South Africa would be better placed if both the scope and scale of studies increased, even if this means a reduction in the overall number of projects.

(3) Evaluate management outcomes.

Studies that evaluate the success of management interventions are fundamental to advancing conservation practice (Pullin *et al*. 2004; Sutherland *et al*. 2004). Despite this, we found only six leopard articles (9%) from South Africa and 13 (6%) articles in total that specifically set out to test or review conservation actions (and many of these had limited scope, e.g., Hayward *et al*. 2006). Without evidence, it is difficult for practitioners to judge which management options are effective and the circumstances under which they are likely to work. Failure to evaluate actions can also lead to the acceptance of flawed dogma (Gross 2005) and wastage of limited resources (Sutherland *et al*. 2004). Greater emphasis should therefore be placed on carnivore research that assesses the suitability of conservation approaches, ideally within an experimental framework (Pullin *et al*. 2004). This requires that early baselines be established and rigorous monitoring protocols developed that are easily repeatable (Nichols & Karanth 2006). For leopards, several survey methods exist to gauge population trends reliably and cost-effectively (Balme *et al*. 2009b), and the same is true for most carnivores (Long *et al*. 2008).

(4) Publish research outputs in the peer-reviewed literature.

Local wildlife authorities and funding organizations can better ensure the validity of research by stipulating that it be published in the scientific literature. This could be established as a prerequisite upon which continued permissions or support is dependent. The peer-review process ensures that the relevance and quality of studies be independently evaluated, reducing the potential for inappropriate research and the circulation of erroneous or biased results (Calver & King 1999). Many journals also require that authors demonstrate compliance with agreed codes of professional standards, further discouraging unsanctioned or overly invasive research. Refereed publications are also more accessible than unreviewed material, and hence they have a better chance of contributing to wider conservation efforts (Calver & King 1999). However, publication in the scientific literature does not by itself guarantee that research will be incorporated in conservation planning (Pullin *et al*. 2004). The onus is on researchers to ensure that practitioners are aware of and understand their results, be it through the popular media, social learning mechanisms or other appropriate fora (Johns 2005).

Conclusion

Our findings highlight a common failing among wildlife researchers to contribute to real-world conservation actions. Although a "research-implementation" gap

has been documented previously (Knight *et al*. 2008; Laurence *et al*. 2012), here we demonstrate that there is no sound reason for its existence, at least in the context of leopard research. Indeed, researchers that show initiative and start tackling applied issues relevant to the wider public will likely to be rewarded, both professionally and from a sense of personal accomplishment (Arletazz *et al*. 2010). Fortunately, there is encouraging evidence of an increasing focus on conservation outcomes (Meine *et al*. 2006). The growth in fora devoted to evaluating results, including the proliferation of conservation-focused journals, assessments of the effectiveness of interventions (e.g., Williams *et al*. 2012), and recommendations for conservation-relevant research (Soulé & Orians 2001; Lawler *et al*. 2006) are positive trends. However, there is clearly a need for rapid and significant escalation, as our case study demonstrates for one threatened and declining species. For leopards and many species like it, the case for conducting research on basic ecology or behavior in protected areas without contributing directly to conservation is rapidly waning.

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