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A reassessment of the interface between conservation and behaviour

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The field of conservation biology was formed to conserve biodiversity in the face of widespread anthropogenic impacts and is inherently a multidisciplinary endeavour, drawing from a variety of fields from the natural and social sciences (Soulé 1985). The disciplines of animal behaviour and behavioural ecology can certainly provide important guidance to conservation biology by contributing valuable theories, approaches, data and scientific expertise to biodiversity conservation efforts. For example, behavioural research involving captive breeding, cultural evolution and learning, communication, foraging, predation, movement and dispersal, spread of invasive species, endocrinology and stress, social behaviour and mating systems all may contribute to a greater understanding of conservation problems. One decade ago a flurry of publications began to highlight these possible linkages between the two disciplines, emphasizing how behavioural research could inform conservation efforts and calling for increased overlap between the two fields. These publications have included a series of essays and review papers (Caro & Durant 1995; Curio 1996; Ulfstrand 1996; Strier 1997; Martin 1998; Sutherland 1998; Caro 1999; Holway & Suarez 1999; Shumway 1999; Fox 2003; Blumstein & Fernández-Juricic 2004; Linklater 2004; Blumstein 2006) and at least four edited volumes on behaviour and conservation (Clemmons & Buchholz 1997a; Caro 1998a; Gosling & Sutherland 2000; Festa-Bianchet & Apollonio 2003). Recognizing this interest, the Animal Behavior Society (ABS) formed the ABS Conservation Committee in 1997 to promote research at the interface between behaviour and conservation. This committee publishes a regular newsletter, *The Conservation Behaviorist*, and maintains a Web site with resources devoted to the topic (http://www.animalbehavior.org/Committees/Conservation).

Although the linkage between behaviour and conservation seems both intuitive and promising, to what extent has the emerging interest in this linkage actually impacted the two fields? A literature review of papers published in 1996 revealed few publications (9 of 97 total) in the journal *Conservation Biology* on the subject of animal behaviour and no publications in the journal *Animal Behaviour* on the subject of conservation (Sutherland 1998). A similar review found that only 7% of papers in the journal *Conservation Biology* mentioned behaviour between 1993 and 1997 (Shumway 1999; see also Dingle et al. 1997 for similar findings between 1993 and 1995). Linklater (2004) conducted a broader review of the literature (including articles, books, reports, newsletters, Web-based resources) between 1965 and 2002. Although he detected an increase (ca. 6–19%) in the proportion of the literature that mentioned both conservation and behaviour, particularly between 1995 and 2002, very little of this work was published in behaviour journals and most of it was descriptive (Linklater 2004). This left us to wonder to what degree the increased interest in behaviour and conservation has actually translated into the primary research published in leading behaviour and conservation journals as well as membership in professional societies.

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We quantified the interface between the disciplines of behaviour and conservation with several approaches: (1) we performed a keyword search in three primary behaviour journals and three primary conservation journals to assess the prevalence of studies that addressed both fields over a 10-year period; (2) we measured the degree to which those primary conservation and behaviour journals cited each other; (3) we used an existing database to determine the degree to which studies published in the highest-ranked conservation journals address behavioural topics and whether that trend changed over a 20-year period; and (4) we compared the North American membership of ABS and the Society for Conservation Biology (SCB) to assess the degree of overlap between two preeminent professional societies in each field. If there was an emerging interest in behaviour and conservation, we would expect to record a trend for increased focus on conservation in the leading behaviour journals, increased focus on behaviour in the leading conservation journals, greater cross citation between those journals, and high levels of cross membership between the two societies.

Assessing the Interface between Disciplines

Our first two methods for assessing the interface between behaviour and conservation involved analyses of three leading behaviour journals (*Animal Behaviour, Behavioral Ecology, Behavioral Ecology and Sociobiology*) and three leading conservation journals (*Conservation Biology, Biological Conservation, Ecological Applications*). We chose these six publications because they are premier journals with high impact factors (all >2.0; Journal Citation Reports 2006, Institute for Scientific Information, Philadelphia, PA, U.S.A.), publishing some of the most widely read research in their fields. These journals facilitate research contributions through their online submission systems and their lack of (or voluntary) publication charges, both of which help to encourage the publication of a wide array of international research.

We used the Institute for Scientific Information's Web of Science (Thomson Scientific 2006) to search for the term 'conserv*' to find the words 'conservation', 'conserve' and 'conserving' within titles and abstracts of articles published between 1996 and 2005 in the three behaviour journals. We excluded articles that used these words in contexts other than biodiversity or species conservation (e.g. water or phylogenetic conservation). We also conducted this search within two leading journals in the fields of ecology (*Ecology*) and ecological genetics (*Molecular Ecology*) for 2005. These are fields that have made major contributions to conservation (Soulé & Wilcox 1980; Soulé 1985; Meine et al. 2006), and thus can serve as a standard for comparison to measure the contributions of animal behaviour. We similarly searched for the term 'behav*' to find the words 'behavio(u)r(s)', 'behave' and 'behavio(u)ral' within titles and abstracts of articles published between 1996 and 2005 in the three conservation journals. We excluded articles that used these words to refer to the behaviour of models, humans, systems, or ecological processes (e.g. fire). Note that our metric may be an underestimate by omitting articles that discussed conservation or behaviour implications without using the terms conservation or behaviour in the title or abstract. However, as we use this metric consistently across years, this should not bias our interpretation of possible temporal trends.

To evaluate the degree to which the conservation and behaviour literature cited each other, we tallied the frequency of citations of conservation journals by articles in behaviour journals (same journals as above) and vice versa for the years 1996 and 2005. To do so, we performed a text search for citations within electronic versions of the journals, except for the 1996 volume of *Ecological Applications*, which we searched manually in the hardcopy of the journal because we did not have access to it electronically. We also tallied the frequency of citations of conservation journals by articles in *Ecology* and *Molecular Ecology*. This allowed for comparison to fields that are widely accepted to have made contributions to conservation biology.

We took another, more comprehensive approach to estimate overlap between the behaviour and conservation fields by more closely examining a broader array of conservation papers. We used a database developed by Lawler et al. (2006) designed to track trends in published conservation research over time. From the database, we analysed 676 papers (44 from 1984, 130 from 1994 and 502 from 2004) from top-ranked ecological journals with a conservation focus. Journals were included in the database if (1) they were in the top 60% of ecology journals as ranked by the Journal Citation Reports (1984, 1994, 2003, Institute for Scientific Information) and (2) if 50% of the papers in the journal addressed conservation topics (see Lawler et al. 2006 for details of methods). Papers that investigated processes that produce, sustain or threaten biodiversity in the face of anthropogenic disturbance were classified as addressing conservation topics. These criteria resulted in two journals for 1984, five journals for 1994 and 14 journals for 2004 (Lawler et al. 2006). Forty per cent of all papers in each of these journals for each of the 3 years were sampled. For each of these papers, one of 10 observers determined whether the study being reported could be categorized as a behavioural study and how often that paper had been cited. Citation rates as of November 2005 were determined using the Institute for Scientific Information's Web of Science (Thomson Scientific 2006). Only those papers with a conservation focus were included in the analyses that we conducted in the present study. Using this database, we analysed whether (1) the number of conservation papers addressing behaviour, (2) the proportion of papers addressing behaviour and (3) the relative citation rate of papers with and without a behavioural focus had changed across the 3 years.

Finally, to assess membership overlap between a behaviour and a conservation professional society, we identified identical names within the 2006 membership lists for ABS and SCB. When possible, we checked the institutional affiliation of overlapping members to verify that the same name represented the same person. SCB membership lists from earlier years were not available, preventing us from determining whether there was

increasing overlap between the behaviour and conservation societies over time. Also, for legal reasons, we were not allowed access to membership lists of other behaviour societies, including the Association for the Study of Animal Behaviour and the International Society for Behavioural Ecology. Thus our behavioural membership analysis was restricted to the members of ABS, which are smaller in number and primarily North American, as compared with the larger, more international membership of SCB. Because of this, we restricted our analysis of membership overlap to the North American members of SCB and ABS. For comparison, we also calculated the overlap between North American members of SCB and the Ecological Society of America (ESA).

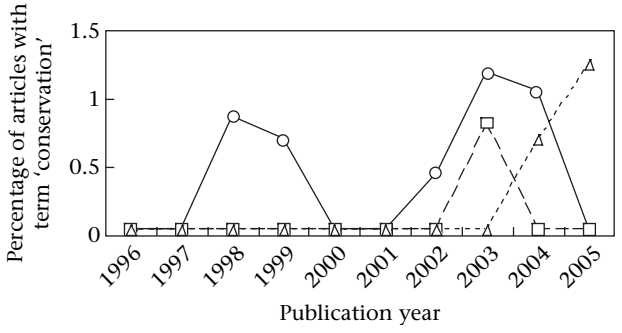

Figure 1. The percentage of articles published in three primary behaviour journals that used the term 'conservation' in their titles or abstracts from 1996 to 2005. ○: *Animal Behaviour*; □: *Behavioral Ecology*; △: *Behavioral Ecology and Sociobiology*.

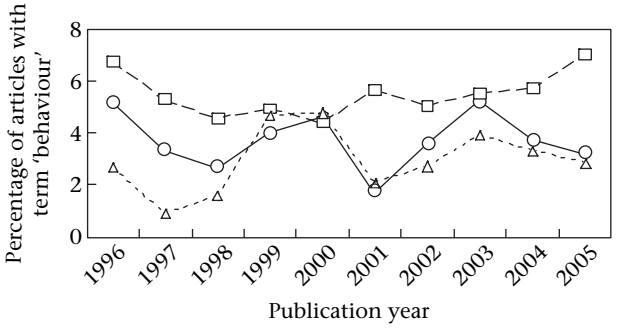

Figure 2. The percentage of articles published in three primary conservation journals that used the term 'behaviour' in their titles or abstracts from 1996 to 2005. ○: *Conservation Biology*; □: *Biological Conservation*; △: *Ecological Applications*.

Increasing Overlap between Disciplines?

Has heightened interest in the links between behaviour and conservation translated into a greater focus on conservation in leading behaviour journals and a greater focus on behaviour in leading conservation journals? Our results indicated little change from 1996 to 2005 as reflected in the words used in titles and abstracts within the six primary behaviour and conservation journals (Figs 1, 2). The term 'conservation' was rarely used in titles and abstracts of behaviour articles (0.3% of 5161 behaviour articles published during 1996–2005; Fig. 1), and the term 'behaviour' was infrequently used in titles and abstracts of conservation articles (4.2% of 5703 conservation articles published during 1996–2005; Fig. 2). Of the three behaviour journals, *Animal Behaviour* had the highest percentage of articles with 'conservation' in the title or abstract across the decade (0.4%; *Behavioral Ecology and Sociobiology*: 0.2%; *Behavioral Ecology*: 0.09%). In an *Animal Behaviour* review, Sutherland (1998) argued that approximately 10% of animal behaviour papers should have applied implications. Although our keyword search may underestimate the actual applied content of articles, our results still suggest that none of the three behaviour journals met Sutherland's goal based on the trivial proportion of papers with the term 'conservation' in the title or abstract (all <0.5% of articles). These values also fell well below the percentages for two leading journals in the fields of ecology and ecological genetics, fields which have made a substantial contribution to conservation biology; 5.6% of *Ecology* articles and 9.9% of *Molecular Ecology* articles mentioned conservation in their titles or abstracts in 2005. Of the three conservation journals, *Biological Conservation* had the highest percentage of articles with 'behaviour' in the title or abstract (5.6%; *Conservation Biology*: 3.7%; *Ecological Applications*: 3.0%). Although the percentage of *Biological Conservation* articles with 'behaviour' in the title or abstract did not change over time, the absolute number increased during 1996–2005 (9 of 134 articles mentioned 'behaviour' in 1996; 22 of 316 articles did so in 2005). Of the six journals that we investigated, this was the only journal to show such an increase.

If increased focus on the links between behaviour and conservation has had a noticeable impact on the scientific literature, we would expect articles published in the leading behaviour and conservation journals to cite each other more frequently. Instead we found that the three behaviour and three conservation journals rarely cited each other in 2005, with little evidence for change as compared to 1996 (Figs 3, 4). Of the three behaviour journals, *Behavioral Ecology and Sociobiology* had the highest rate of citing articles in the three conservation journals in 2005 (0.15 citations per article; *Behavioral Ecology*: 0.07 citations per article; *Animal Behaviour*: 0.06 citations per article) and had the greatest increase in this rate as compared with 1996 (Fig. 3). For comparison, papers published in *Ecology* and *Molecular Ecology*, the two journals representing other fields that have made contributions to conservation biology, cited the three conservation journals at a much higher rate (*Ecology*: 1.31 citations per article; *Molecular Ecology*: 0.688 citations per article). Of the three conservation journals, *Biological Conservation* had the highest rate of citing articles in the three behaviour journals in 2005 (0.23 citations per article; *Ecological Applications*: 0.14 citations per article; *Conservation Biology*: 0.06 citations per article), but this did not represent an increase in rate as compared with 1996 (Fig. 4). Overall, of the three behaviour and three conservation journals that we investigated, *Biological Conservation* revealed the most links between disciplines, as measured by the percentage of articles with 'behaviour' in the title or abstract and the frequency of citing behaviour journals.

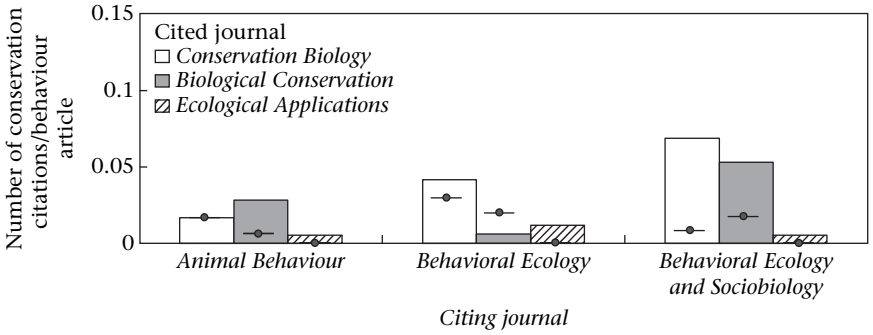

Figure 3. The frequency of citations of three primary conservation journals per behaviour article in 2005. Points (—●—) represent frequency in 1996 for comparison.

If animal behaviour has become integrated with conservation biology over time, we would expect behavioural research to be more prominent among the conservation literature now than it was 20 years ago. Our comprehensive analysis of conservation articles published between 1984 and 2004 revealed an absolute increase in the number of conservation papers with a behavioural focus; the number in our sample quadrupled between 1994 and 2004 (from $N = 12$ to $N = 48$ papers), suggesting an increase in the amount of conservation research focused on behaviour. However, there was no concomitant increase in the ratio of conservation papers with a behavioural focus relative to other conservation papers (Fig. 5). That is, the number of conservation studies focusing on behaviour has not increased at a greater rate than the conservation literature in general. Indeed, the proportion of all conservation papers that have a behavioural focus declined from 18% (8 out of 44) in 1984 down to 9% in 1994 and 2004, although the decrease was not significant (chi-square test: $\chi^2_2 = 3.44$, $P = 0.18$; Fig. 5).

Although the proportion of conservation papers with a behavioural focus has not increased over time, we tested the hypothesis that papers with a behavioural focus have had a disproportionate impact on the field of conservation biology by quantifying the number of times that each paper had been cited (by November 2005). We found that conservation papers with a behavioural focus were not cited more per article than those without a behavioural focus in any year (Table 1). In fact, the total citations of all conservation papers with a behavioural focus decreased significantly from almost 30% of all citations of conservation papers published in 1984 to less than 9% in 1994 and 2004 (chi-square test: $\chi^2_2 = 739\,644.7$, $P < 0.0001$; Fig. 6).

Finally, we expected considerable levels of cross membership between ABS and SCB in 2006 if there are strong linkages between the two disciplines. We identified only 137 individuals as North American members of both societies. This represented 7.5% of the North American ABS membership (1835 total) and 1.5% of the larger North American SCB membership (9062 total). For comparison, 1184 North American members of ESA were also members of SCB. This represented 14.8% of the North American ESA membership (7998 total) and 13.1% of the North American SCB membership. Hence, the average ABS member was only half (0.53) as likely as the average ESA member to also belong to SCB, suggesting that behaviourists are much less likely than ecologists to join a conservation society. Interestingly, ABS members that were affiliated with zoos were more likely to belong to SCB than the average ABS member (8 of 35 zoo affiliates or 22.9%). This probably reflects the combined emphasis on behaviour and conservation in many zoological programmes (Kleiman 1992; Curio 1998; Wielebnowski 1998).

Possible Barriers and Bridges

Overall we found little evidence for current or increasing overlap between the fields of animal behaviour and

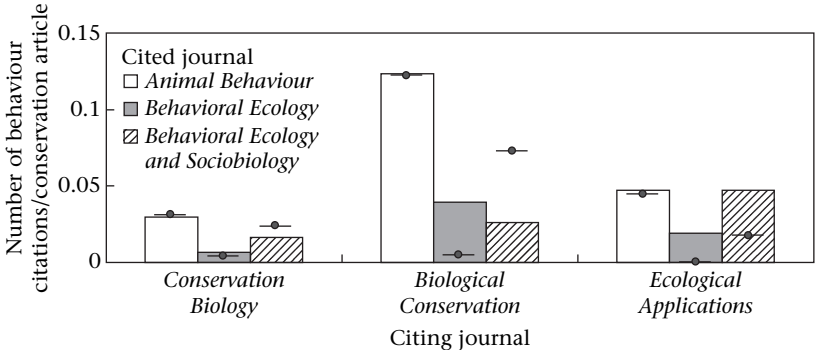

Figure 4. The frequency of citations of three primary behaviour journals per conservation article in 2005. Points (—●—) represent frequency in 1996 for comparison.

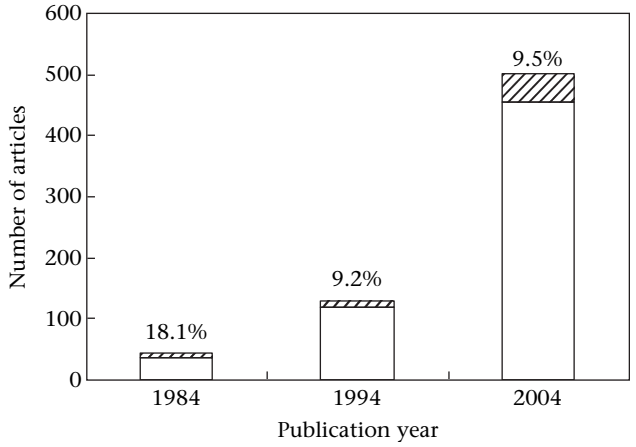

Figure 5. The number of articles with a conservation focus published in ecological journals with a minimum impact factor of 1 in 1984, 1994 and 2004. The hatched part of each bar represents the number of conservation articles with a behavioural focus. The percentage of all conservation articles with a behavioural focus is given above each bar.

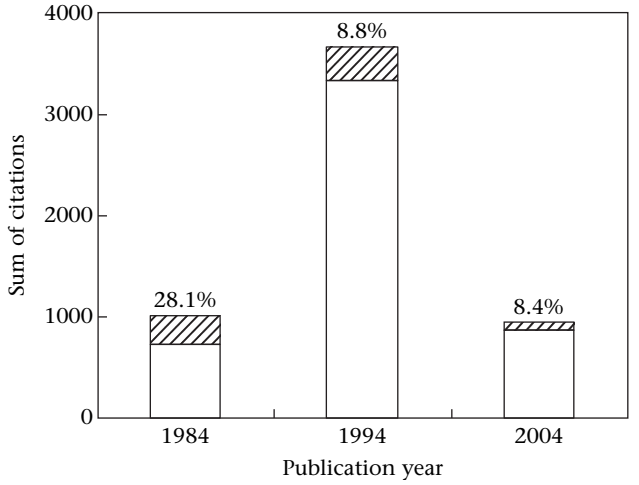

Figure 6. Sum of citations of conservation articles, by the year in which they were published, through November 2005. The hatched and open portions of each bar represent the number of citations of conservation articles with a behavioural and nonbehavioural focus, respectively. The percentage of all citations of behavioural articles in conservation biology, given above each column, appears to be waning.

conservation biology: (1) keywords and cross-citation rates in three primary behaviour and conservation journals revealed little evidence for change since 1996; (2) the number of conservation studies with a behavioural focus increased since 1984, but not at a greater rate than the growing body of conservation literature; (3) conservation articles with a behavioural focus published since 1984 may have had less impact, based on a decline in the total number of citations of such articles relative to other conservation papers; and (4) there was little overlap between the membership of an animal behaviour and that of a conservation society. All of our analyses suggest that the full potential of animal behaviour to inform conservation efforts, as set forth over the past decade, is currently unrealized. This divide between the fields is corroborated by a recent study investigating trends in animal behaviour research between 1968 and 2002 (Ord et al. 2005) and a recent review of the key outstanding questions remaining in behavioural ecology (Owens 2006). Neither article identified conservation as an important focus, past or present, for the disciplines of animal behaviour and behavioural ecology. Indeed, conservation was never mentioned in either article. Additionally, the research topics represented at a 2006 behavioural ecology conference and a 2006 conservation biology conference showed little overlap of scientific questions (Caro 2007). All of these findings highlight the wide gap between the dominant research foci of the two disciplines.

How can we explain the disconnect between conservation and behaviour despite recent efforts to bridge the two fields? Perhaps part of the problem is the historical, institutional separation of the two disciplines. Behavioural ecologists and conservation biologists are often housed in different departments and colleges on university campuses, are trained to ask very different research questions that have been historically separated, apply for research funds from different agencies, and strive to publish in different journals that, as shown here, publish few papers linking the two disciplines. It has been argued that the journals themselves contribute to the continued separation of the fields, with behaviour journals rejecting applied articles (or recommending removal of those sections) and with conservation journals rejecting behaviour papers that may not demonstrate an immediate, direct impact on population dynamics (Blumstein & Fernández-Juricic 2004). This historical and cultural separation of the two fields is a likely contributor to the divide between behavioural ecologists and conservation

Table 1. Number of times that conservation papers* with (B) or without (NB) a behavioural focus were cited (by November 2005) for publication years 1984, 1994 and 2004

Year	1984		1994		2004	
Type of paper	B	NB	B	NB	B	NB
Median citations per paper	18.5 (*N*=8)	10 (*N*=36)	20.5 (*N*=12)	19 (*N*=118)	1 (*N*=48)	1 (*N*=454)
Mann–Whitney *U* (*Z*)	184 (−1.19)		750 (−0.33)		10 867 (0.03)	
P	0.23		0.74		0.98	

*In the database of conservation science publications described in Lawler et al. (2006).

biologists (Sutherland & Gosling 2000). Indeed, two of us (L.A. and K.R.C.) symbolize this disconnect, as a married behavioural ecologist and a conservation biologist in the same institution who, until recently, rarely collaborated scientifically.

A historical separation of disciplines, however, cannot be the only explanation for this lack of overlap, as many other disparate fields have integrated their work into biodiversity conservation, such as ecology, population genetics, systematics and sociology (Soulé & Wilcox 1980; Soulé 1985; Shumway 1999; Meine et al. 2006; Caro 2007). Many potential mechanisms underlying the separation between behaviour and conservation have been proposed (e.g. see Clemmons & Buchholz 1997a; Caro 1998a; Gosling & Sutherland 2000; Linklater 2004), and we highlight a few recurring key themes here. For instance, it is argued that the two disciplines are focused on different biological scales that can be challenging to link, with behavioural ecologists working at the level of the individual and conservation biologists focused on population and community dynamics (Beissinger 1997; Clemmons & Buchholz 1997b; Caro 1998b, 1999; Martin 1998; Shumway 1999; Sutherland & Gosling 2000). Scientists studying animal behaviour also may feel that they have little to contribute to conservation biology, or that the applied nature of the subject makes it less intellectually challenging and objective (Ralls 1997; Rubenstein 1998; Sutherland 1998; Caro 1999, 2007; Sutherland & Gosling 2000). In turn, those studying conservation biology may feel that animal behaviour, in particular the evolutionary emphasis of behavioural ecology, has little relevance to their work (Arcese et al. 1997; Sutherland 1998; Shumway 1999; Blumstein & Fernández-Juricic 2004; Linklater 2004; Buchholz 2007). Finally, behavioural studies take time, and conservation biologists, because their field is a crisis discipline, need quick solutions (Caro 1998c, 1999, 2007; Buchholz 2007).

If greater overlap between animal behaviour and conservation biology is desired, how could this be achieved? Although conservation biologists could work to familiarize themselves with behavioural topics and to include behavioural ecologists in conservation teams (Arcese et al. 1997; Blumstein & Fernández-Juricic 2004; Buchholz 2007), most of the suggested solutions to bridge this gap rely on increased efforts of the behaviour community (Beissinger 1997; Clemmons & Buchholz 1997b; Sutherland 1998; Caro 1998c, 1999, 2007; Shumway 1999; Festa-Bianchet 2003; Blumstein & Fernández-Juricic 2004; Linklater 2004; Blumstein 2006, in press). Scientists studying animal behaviour would have to meet with conservation practitioners to learn about their needs prior to developing research and use that information to ask more diverse levels of behavioural questions. Then they would have to stress the conservation applications of their work to other scientists at conferences and symposia, and in papers published in both behaviour and conservation journals; similarly they would need to translate their work into useful conservation products and quickly disseminate their findings to resource managers and the public through workshops, reports, public speaking and popular writing. It is also suggested that the goals of conservation would be advanced if behavioural ecologists chose to study animals that occur in environments with human disturbance and that fascinate the public, including charismatic vertebrates, flagship species, species of conservation concern and captive animals, recognizing that such systems may not allow for large sample sizes or replicated experiments and that caution must be used to ensure that the research does not further disturb already threatened populations (Caro 1998c, 1999, 2007; Shumway 1999; Linklater 2004; Blumstein 2006). Finally, behavioural ecologists and conservation biologists can gain insight by looking to examples where a behavioural perspective has already informed conservation and management decisions for wild and captive populations (Buchholz 2007; Caro 2007).

Despite much recent interest in combining these fields, there is still a disconnect between behaviour and conservation. There are multiple explanations for this divide as well as multiple approaches to bridge the gap. One obvious step is for individuals like ourselves to take the initiative and collaborate across disciplines to advance the application of animal behaviour in conservation biology.

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