Changing livelihoods and protected area management: a case study of charcoal production in south-west Madagascar

Charlie J. Gardner, Firengea U. L. Gabriel
Freya A. V. St. John and Zoe G. Davies

Abstract Protected areas are usually conceived and managed as static entities, although this approach is increasingly viewed as unrealistic given climate change and ecosystem dynamics. The ways in which people use land and/or natural resources within and around protected areas can also shift and evolve temporally but this remains an under-acknowledged challenge for protected area managers. Here we investigate the factors driving a rapid rise in charcoal production within a new, multiple-use protected area in Madagascar, to inform appropriate management responses. We conducted a questionnaire survey of 208 charcoal producers to ascertain the mix of livelihood activities they practised in 2010/2011 and 5 years previously. Respondents had diversified their livelihood activities over time, and cultivation and pastoralism had decreased as primary sources of revenue. Reasons for the growing reliance on charcoal production include the reduced viability of alternative livelihoods (primarily farming), as a result of changing rainfall patterns and the loss of irrigation infrastructure, as well as a growing need for cash to support themselves and their families. Our results suggest that charcoal production is not a desirable activity but a safety net when times are difficult. Conservation efforts to ameliorate underlying factors driving livelihood change, such as dam restoration, could reduce the prevalence of charcoal production, but simultaneous action to cut demand is also required. We recommend that mechanisms to detect, understand and respond to social change are integrated systematically into protected area management planning, alongside traditional biodiversity monitoring.

Keywords Behaviour, biodiversity, climate change, conservation, energy, migration, poverty alleviation, social change

Charlie J. Gardner* (Corresponding author) and Firengea U. L. Gabriel† WWF Madagascar and Western Indian Ocean Programme Office, BP 738, Antananarivo 101, Madagascar. Email cg399@kent.ac.uk

Freya A. V. St. John and Zoe G. Davies Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, Kent, CT2 7NR, UK

*Also at: Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, Kent, CT2 7NR, UK
†Also at: Faculté de Sciences, Université de Toliara, Maninday, Toliara 601, Madagascar

Received 6 August 2014. Revision requested 27 October 2014.
Accepted 20 January 2015. First published online 20 April 2015.

Introduction

Covering > 12% of land surface, protected areas constitute the principal approach to biodiversity conservation and comprise the largest planned land use globally (Jenkins & Joppa, 2009). Described as 'clearly defined geographical space[s], recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values' (Dudley, 2008), the very concept of a protected area assumes that it will be preserved and/or managed in perpetuity, remaining a permanent fixture in the landscape. As such, historically they have been conceived and managed as static features that should persist unchanged through time (Bengtsson et al., 2003; Folke et al., 2005; Mascia & Pailler, 2011).

Increasingly the steady state paradigm of protected area management is viewed as inadequate, given the fact that ecosystems are inherently dynamic and that climate change will lead to the migration of species and habitats beyond protected area boundaries (Hannah, 2008). There is increasing awareness that protected areas are components of complex social–ecological systems (Ostrom, 2009; Milner-Gulland, 2012), with the resource use patterns of rural communities living within and around protected areas evolving through time (Geoghegan & Renard, 2002; Aung et al., 2004; Venter et al., 2008; Newton, 2011). Thus, temporal shifts in land use and livelihoods should be seen as the rule rather than the exception (Folke, 2003). However, whereas there is a considerable body of literature on protected areas as agents of social change (e.g. Ghimire & Pimbert, 1997; West et al., 2006; Schmitz et al., 2012), there has been little research, policy or practical focus on livelihood dynamics as a management challenge for protected area managers. For example, none of the relevant publications in IUCN's Best Practice Protected Area Guidelines series (Phillips, 2002; Thomas & Middleton, 2003; Dudley, 2008) provide explicit instructions or recommendations regarding how to detect or manage sites being influenced by shifting livelihoods.

Resource use by local communities is a key threat to the viability of many protected areas (Naughton-Treves et al., 2005; Gaston et al., 2008). If protected area managers are to respond effectively, in terms of designing and implementing appropriate evidence-based interventions, they must first understand the factors that influence livelihood

decision-making (St. John et al., 2013). This is particularly important for protected areas where management objectives include poverty alleviation or rural development alongside biodiversity conservation. However, the success rates associated with integrated conservation and development projects and community-based natural resource management have been low in general, in terms of both conservation and socio-economic outcomes. This is, at least in part, because managers have failed to appreciate and integrate local livelihood strategies and resource use patterns sufficiently into their planning (Newmark & Hough, 2000; Brown, 2003; Wells & McShane, 2004; Dressler et al., 2010; Brooks et al., 2013).

Here we investigate the drivers of rapid livelihood change, in the form of increased charcoal production, threatening biodiversity in south-west Madagascar. In 2009, staff of the international non-governmental organization WWF observed an increase in the amount of charcoal being produced within a new multiple-use protected area, Ranobe PK32, and transported into a nearby city. To develop suitable protected area management strategies, it was necessary to understand the shift towards this livelihood; managers needed to know what income-generating activities people had been practising previously and why they had switched occupation.

Study system

Almost 3 billion people depend on biomass such as fuelwood and charcoal for cooking (IEA, 2010). Charcoal is produced by the slow pyrolysis (heating in the absence of oxygen) of wood and is a favoured cooking fuel of urban communities because it has a higher energy density than fuelwood and is therefore easier to transport (Arnold et al., 2003). However, inefficiencies in the conversion process mean that charcoal use consumes greater quantities of wood than the use of fuelwood (Brouwer & Falcão, 2004).

The dynamics and impacts of the charcoal industry in southern Madagascar have been little researched, despite charcoal and fuelwood constituting the primary domestic fuels for most of the population (Minten et al., 2012). Charcoal producers in the region use only hardwood trees (Mana et al., 2001), thus causing forest degradation rather than outright deforestation (Casse et al., 2004), as is also the case in sub-Saharan Africa (Ahrends et al., 2010). Degradation of southern Madagascar's spiny forest, a Global 200 priority ecoregion (Olson & Dinerstein, 1998), triggers a transformation in bird communities from endemic forest specialists to non-endemic generalists, thereby reducing its conservation value (Gardner, 2014). In particular, charcoal production threatens the degradation-sensitive subdesert mesite *Monias benschi*, a locally endemic species belonging to a monospecific genus of an endemic family (Seddon et al., 2003). The species is categorized as Vulnerable on the IUCN Red List and was one of the motivations for the establishment of the Ranobe PK32 protected area. Additionally, the debris (e.g. leaves, small branches) left by charcoal production increases the standing fuel load of the forest, leaving it more susceptible to fires, which do not penetrate intact habitat (Koechlin, 1972; WWF, 2010).

The average Malagasy family uses c. 500 kg of charcoal per year (Meyers et al., 2006). In Toliara, the capital city of Atsimo Andrefana region (Fig. 1), $<$ 2% of households regularly use electricity or gas to cook, and demand for charcoal tripled during 2000–2007; 54% of this demand was met by charcoal produced along Route Nationale 9 (Partage, 2008), the sole road connecting Toliara with towns to the north.

The protected area Ranobe PK32 was created in 2008 and extended in 2010 as part of the 2003 Durban Vision initiative to triple the size of Madagascar's protected area network. The establishment of the protected area was led and funded by WWF, and it is administered by a shared governance structure comprising WWF, regional authorities and local community representatives (Virah-Sawmy et al., 2014). It is managed for biodiversity conservation and the sustainable use of natural resources for poverty alleviation and development, in line with the objectives of the country's expanded protected area system. Consequently, Ranobe PK32 has been proposed for designation as an IUCN category VI sustainable use area (Gardner, 2011). The protected area has the greatest species richness of lemurs and birds of any site in the spiny forest ecoregion (Gardner et al., 2009a,b).

The majority of the human population around Ranobe PK32 live along the Fiherenana Valley or Route Nationale 9, or in the agricultural plains south of the Manombo River, which were previously irrigated by a system of canals emanating from a colonial-era dam (Fig. 1). Livelihoods vary according to location and ethnicity; coastal villages are principally inhabited by Vezo fishers, whereas inland areas are inhabited mainly by Masikoro agro-pastoralists (WWF, 2010). The eastern part of the protected area lies on a Tertiary limestone plateau and is threatened by slash-and-burn maize cultivation (*hatsaky*), but the unconsolidated sands of the coastal plain to the west are of poor quality for agriculture. Instead, the forests here are threatened by the production of charcoal for the urban market in Toliara, facilitated by the proximity of Route Nationale 9 (Seddon et al., 2000; Virah-Sawmy et al., 2014). Charcoal producers living along this road target forests both inside and outside Ranobe PK32, although available hardwood resources are now concentrated within the protected area. Charcoal production is allowed within the protected area according to a zoning plan (i.e. outside core conservation areas) but all charcoal producers must obtain a permit from the State's Forest Service.

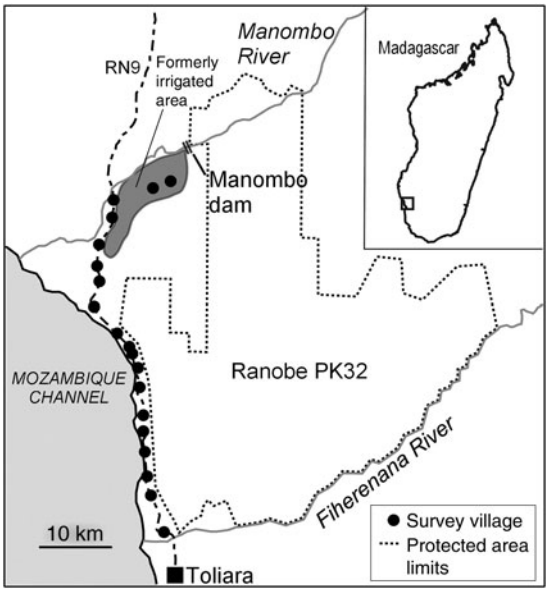

FIG. 1 Location of villages along Route Nationale 9 in the vicinity of Ranobe PK32 protected area where questionnaires were administered among charcoal producers. The rectangle on the inset shows location of the main map in Madagascar.

Methods

We administered a questionnaire face-to-face with charcoal producers resident in villages along Route Nationale 9 during December 2010–June 2011. As our aim was to understand the livelihood dynamics of people currently involved in charcoal production (rather than quantify the prevalence of charcoal producers in the population), non-probabilistic snowball sampling (Newing, 2011) was used to identify potential respondents. As we were investigating change in livelihoods, charcoal producers were considered eligible only if they had been earning a living independently for at least 5 years (i.e. they were not at school or otherwise dependent on their parents for a minimum of 5 years prior to interview). We also employed opportunistic sampling when producers were encountered along Route Nationale 9, transporting charcoal between villages by ox-cart.

On arrival in each village we met with the *Chef de Fokontany* (the head of the *Fokontany*, which is the smallest administrative unit, equivalent to a village or small cluster of villages) to explain the purpose of our research and ask him to suggest suitable participants. The homes of these individuals were visited in turn, with each questionnaire respondent asked to suggest additional potential participants within the village. The aims of the study were explained to all potential participants, and free and informed consent was sought prior to completing the survey. Individuals were assured that their responses would be anonymous and confidential. The questionnaire was administered in the local dialect of Malagasy by the second author (FULG), in a location chosen by the respondent (generally outside the home or in a public space).

The questionnaire consisted of both closed- and open-ended questions (an English translation of the survey can be requested from CJG), structured into four sections. The survey was developed with colleagues and piloted on 14 initial respondents; this led to modification of the questionnaire, and therefore the pilot data collected were discarded.

The first section collected basic socio-demographic information (e.g. age, level of education, ethnicity, village of current residence). Any participants found to be living away from their natal village (migrants) were asked, with an open-ended question, about the factors that had contributed to them leaving their previous home and their choice of destination. To detect any shifts in the relative importance of individual livelihood activities for household income, respondents were asked to rate activities on a three-point ordinal scale both at the present time (2010/2011) and 5 years previously (2005/2006): (1) an activity that is never carried out, (2) an activity that is conducted infrequently (e.g. 1 day per week or for 2 months per year) and/or is of secondary importance to other sources of household revenue during the year (henceforth minor livelihoods), or (3) an activity that is carried out often (e.g. 3 days per week or for 6 months of the year) and/or is an important source of revenue for their household (henceforth major livelihoods). A 5-year period was selected as it was sufficient to capture the increase in charcoal production that had been observed anecdotally by WWF staff, without being so long as to diminish the viability of recall data (Golden et al., 2013). In section three, individuals who indicated that the mix of livelihood activities they practised had changed over time were asked an open-ended question as to why this was the case, facilitated by prompts from the interviewer from a list of potentially relevant drivers (e.g. lack of rain, not enough fish to catch, problems in life or family requiring money). The precise nature of any 'family problems' was not enquired about, as our pilot revealed that this made respondents uncomfortable. The final section focused on charcoal production specifically, with open-ended questions used to explore when during the year this activity is carried out, for how long and, if for just part of the year, why it is seasonal. In addition, open-ended questions were asked regarding where charcoal is produced, how far away from home this location is, and what difficulties the individual faces when producing charcoal.

Responses to open-ended questions were coded and grouped by response-type. Quantitative analyses of temporal shifts and differences in livelihood activities between residents and migrants were tested using χ^2 analyses in *SPSS v. 20.0* (IBM, Armonk, USA). A paired *t*-test was used to ascertain whether the number of livelihoods practised by individual respondents had increased over time.

Results

A total of 208 questionnaires were completed in full by charcoal producers resident in villages along Route Nationale 9, representing 16% of the estimated population of charcoal producers in the study area (WWF, unpubl. data). The age range of study participants, who were all male, was 20–70 (median = 39.5, interquartile range = 33–47; mean = 39.7 ± SE 0.76), and 60.6% of individuals were living away from their natal village (Table 1). Of these, 15.1% (n = 19) had migrated from Toliara, 57.1% (n = 72) from elsewhere in Atsimo Andrefana region, and 27.8% (n = 35) from the far south of Madagascar (primarily Androy region). Respondents who had migrated cited a number of factors that influenced their decision to translocate, and which underpinned their selection of settling area (Table 2), all of which related to the need to earn money and the opportunities (or lack of) for doing so.

Only 7.2% (n = 15) of individuals who participated in the questionnaire produced charcoal as their sole revenue-generating activity. In addition to charcoal production, 63.9% (n = 133) of respondents also engaged in sedentary cultivation, 35.6% (n = 74) reared livestock and 20.2% (n = 42) fished or harvested other marine resources. Three activities increased significantly over the 5-year study period from 2005/2006: charcoal production (562.2% rise; $\chi^2 = 247.6$, $P < 0.01$), livestock rearing (224.2% rise; $\chi^2 = 20.8$, $P < 0.01$) and timber harvesting (300.0% rise; $\chi^2 = 5.2$, $P < 0.05$). People producing charcoal in 2010/2011 had diversified their livelihoods over time, from a mean of 1.4 to 2.5 activities per person ($t = 18.4$, $P < 0.01$), with the majority (92.8%, n = 193) reporting changes in the mix of livelihood activities they practised over the 5 years.

Amongst major livelihoods, the number of participants engaging in charcoal production (565.6% rise, from 15.4% in 2005/2006 to 87.0% in 2010/2011; $\chi^2 = 213.6$, $P < 0.01$) and shifting cultivation (from 0.0% in 2005/2006 to 1.9% in 2010/2011; $\chi^2 = 4.0$, $P < 0.05$) rose significantly over time. Conversely, sedentary cultivation (12.8% decline, from 71.1% in 2005/2006 to 62.0% in 2010/2011; $\chi^2 = 4.1$, $P < 0.05$) and livestock rearing (79.1% decline, from 11.5% in 2005/2006 to 2.4% in 2010/2011; $\chi^2 = 4.5$, $P < 0.05$) declined significantly during the 5 years. Although livestock rearing decreased as a major livelihood, it showed significant increases as a minor livelihood activity (772.1% growth, from 4.3% in 2005/2006 to 33.2% in 2010/2011; $\chi^2 = 56.0$, $P < 0.01$). Charcoal production was the only other activity to grow as a minor livelihood (541.7% rise, from 2.4% in 2005/2006 to 13.0% in 2010/2011; $\chi^2 = 16.4$, $P < 0.01$).

Variation in these trends was further examined for migrants and residents separately (Table 3). Few differences were apparent between the two groups, although there were significant declines in the proportion of migrants engaging in sedentary cultivation and rearing livestock as major livelihoods, which were not reflected in resident populations ($\chi^2 = 6.6$, $P < 0.01$, and $\chi^2 = 20.8$, $P < 0.01$, respectively).

Respondents cited a range of factors as having driven a shift in livelihood activities over the period investigated (Fig. 2), reporting a mean of 2.7 factors per individual. We grouped proximal causes into those that related to the needs of the respondent and his household (which we term endogenous factors) and those that affected his ability to meet those needs (exogenous factors). Exogenous factors diminished the viability of some livelihood activities, particularly sedentary cultivation. Over two-thirds of participants (n = 134) stated that their shift to charcoal production was a consequence of lack of rain or a change in the rainy season, 30.3% (n = 63) cited the loss of irrigation infrastructure (a dam and associated canals) south of the Manombo River, 15.4% (n = 32) referred to a decrease in fish/marine resources, and 7.7% (n = 16) cited growing rates of cattle theft as factors that contributed to their adoption of charcoal production. Endogenous factors accounted for almost half (47.5%) of the responses provided, with participants reporting rising living costs, having more children, and family problems as driving their increased need for cash, and hence a shift in livelihoods.

Over half of our study participants (52.4%, n = 109) produce charcoal for only part of the year, during the agricultural off-season (generally March–August) when they are not occupied in their fields; 7% (n = 14) produce charcoal whenever they need money (including for celebrations such as Christmas and Independence Day, and for emergencies); the remainder (n = 85) do so throughout the year.

Most participants stated that their lives were harder (58.7%, n = 122) or just as hard (27.4%, n = 57) in 2010/2011 as they had been 5 years previously, and 13.9% (n = 29) stated that their lives had improved. When asked about the difficulties experienced with charcoal production as a livelihood, respondents provided a range of answers (mean = 2.3 responses per person) reflecting the physical hardship, medical problems, shame and low revenues associated with the activity (Table 4).

Discussion

Following the observation that charcoal production had proliferated in south-west Madagascar and was causing forest degradation, particularly in and around the protected area Ranobe PK32, we sought to understand the reasons why people were taking up this livelihood. Our findings suggest that charcoal production is a means of earning money when other preferred options are no longer viable or sufficiently productive. Fewer than one in five participants in our study had been producing charcoal in 2005/2006 but the feasibility of pursuing alternative revenue streams, such as sedentary cultivation, had been diminished (by exogenous

Oryx, 2016, 50(3), 495–505 © 2015 Fauna & Flora International doi:10.1017/S0030605315000071

TABLE 1 Summary of socio-demographic data gathered during a questionnaire survey of charcoal producers in 19 villages along Route Nationale 9 in south-west Madagascar (Fig. 1), with village, number of respondents, age range, median age, mean number of children, education data (percentage of respondents that received some formal schooling, number of years of formal schooling, and median number of years schooled), proportion of migrants, and ethnicity.

		Age			Education				Ethnicity				
Village[1]	No. of respondents	Range	Median	Mean no. of children	% schooling	No. of years	Median years	% migrants	Masikoro	Vezo	Tanalana	Tandroy	Other
Belalanda	4	37–53	45	6.9	50	5–7	2.5	75.0	50	50	0	0	0
Tsongoritelo	4	29–52	40.5	4.8	50	3–6	1.5	50.0	0	75	25	0	0
Beravy	5	37–45	38	4.0	60	5–13	5	80.0	40	20	20	20	0
Ambalaboy	5	33–66	50	3.6	80	3–9	4	80.0	20	0	20	40	20
Tsivanoe	10	32–53	39.5	5.2	50	4–7	2	40.0	0	60	30	10	0
Mangily	10	20–60	44	3.8	80	1–9	2	90.0	20	50	10	20	0
Amboaboake	15	28–58	40	5.1	67	3–9	3	66.7	6.7	53.3	26.7	13.3	0
Madiorano	15	29–59	41	5.3	73	2–9	4	73.3	26.7	33.3	13.3	26.7	0
Betsibaroke	10	35–45	39.5	5.3	60	5–9	5	80.0	30	40	30	0	0
Ambolimailaka	20	30–54	40	4.5	70	2–9	4	90.0	30	10	25	30	5
Andrevo Haut	10	20–43	27	2.9	90	3–14	5.5	30.0	60	10	0	20	10
Antapoake	5	20–57	24	1.2	60	6–10	6	60.0	40	20	0	40	0
Ankatrakatraka	9	20–60	30	3.4	67	2–10	2	100	0	0	0	100	0
Ankilimalinika	15	20–70	25	3.9	67	2–13	5	33.3	66.7	0	6.7	13.3	13.3
Benetse	10	32–64	40	6.6	100	2–13	7	10.0	100	0	0	0	0
Saririake	6	38–52	42.5	5.3	33	1–9	0	16.7	83.3	0	0	16.7	0
Tsianisiha	9	22–51	35	5.0	100	2–9	5	44.4	100	0	0	0	0
Berave Antsoity	16	24–66	44	5.5	88	2–10	5.5	56.3	75	6.3	12.5	0	6.3
Tsiafanoka	30	20–64	40	6.5	80	1–13	5	60.0	73.3	6.7	3.3	10	6.7
All villages	208	20–70	39.5	4.9	73.1	1–14	5	60.6	46.6	19.7	12.0	17.8	3.9

[1]In order of increasing distance from Toliara

TABLE 2 Reasons cited by migrant charcoal producers (n = 126) encountered along Route Nationale 9 for migrating and selecting their current place of residence. Some participants provided multiple responses, and therefore the totals are > 100%.

Reason for migrating	% of respondents	Reason for selecting current location	% of respondents
Family reasons	28.6	Family lives here	46.0
Lack of work/activities	27.8	Availability of land	18.8
Insecurity	16.7	Existence of good forest	18.3
Extreme poverty/famine	11.9	Good fishing	7.1
Lack of cultivable land	9.5	Existence of agricultural infrastructure	5.4
Drought/lack of rain	6.4	To trade	4.0
Loss of agricultural infrastructure	4.0	To work for foreigners	3.2
Disappearance of forest	3.2	Looking for work	1.6
Fleeing life of crime	1.6	To herd livestock	0.8
Lack of fish	0.8	Secure location without cattle rustlers	0.8

TABLE 3 Percentage of resident and migrant charcoal producers along Route Nationale 9 (n = 208) carrying out various revenue generating activities in 2005/2006 and 2010/2011. Participants tended to engage in multiple activities, and therefore the totals are > 100%.

	Residents (n = 82)						Migrants (n = 126)					
	Major livelihood (%)			Minor livelihood (%)			Major livelihood (%)			Minor livelihood (%)		
Activity	2005/2006	2010/2011	Change[1]	2005/2006	2010/2011	Change[1]	2005/2006	2010/2011	Change[1]	2005/2006	2010/2011	Change[1]
Charcoal production	11.0	87.8	↑ **	0	12.2	↑ **	18.2	86.6	↑ **	4.0	13.4	↑ **
Sedentary cultivation	72.0	72.0		0	1.2	↑	70.6	55.6	↓**	1.6	2.4	↑
Shifting cultivation	0	2.4	↑	0	1.2	↑	0.8	1.6	↑	0	0.8	↑
Livestock rearing	0	3.7	↑	11.0	35.4	↑ **	19.0	1.6	↓ **	0	31.7	↑ **
Fishing and marine harvesting	17.1	18.3	↑	1.2	0	↓	15.1	18.3	↑	0	3.2	↑
Timber felling	4.9	7.3	↑	0	1.2	↑	0	4.0	↑	0.8	2.4	↑
Collection of non-timber forest products	3.7	0	↓	0	0		0.8	0	↓	0.8	1.6	↑
Trade/shop-keeping	2.4	6.1	↑	1.2	3.7	↑	7.1	7.9	↑	2.4	2.4	
Salaried work	1.2	0	↓	0	0		4.8	7.9	↑	0	0	
Making reed houses	1.2	4.9	↑	0	0		1.6	3.2	↑	0	1.6	↑
Other	3.7	3.7		0	1.2	↑	0	0		0	0	

[1]↑, increase in activity; ↓, decrease in activity
*P < 0.05; **P < 0.01

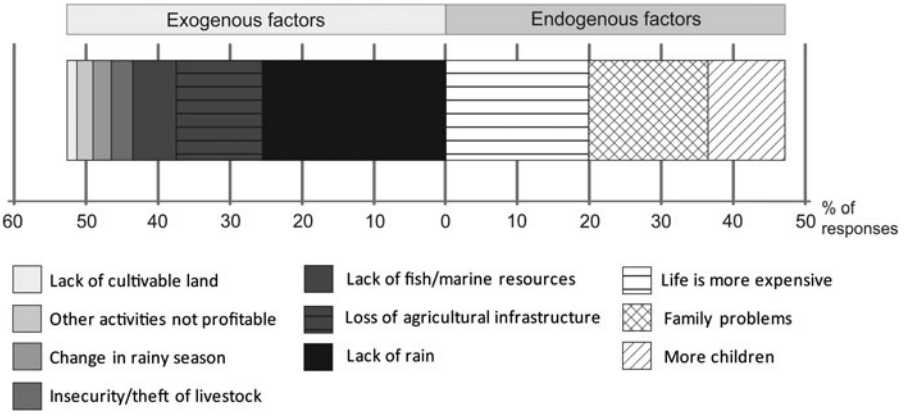

FIG. 2 Exogenous and endogenous drivers of livelihood change cited by charcoal producers encountered along Route Nationale 9 in south-west Madagascar (Fig. 1) who had altered their revenue-generating activities over the 5-year period 2005/2006–2010/2011 (n = 193). Horizontal bars represent the percentage of responses (n = 521; mean 2.7 per respondent).

TABLE 4 Factors reported by survey respondents (n = 208) as contributing to the difficulty of their lives as charcoal producers. There were multiple responses per participant, and therefore the total is > 100%.

Problems with charcoal production as a livelihood activity	% respondents
Work is tiring	53.4
The forest is further away than it was previously	39.4
Lack of tools (e.g. axes)	31.7
Lack of large trees	17.3
Insecurity; have to guard kiln at night	16.8
It is shameful work (prisoners' work)	14.0
Lack of transport (ox-cart)	13.0
Work provokes respiratory illness	12.5
Have to pay KASTI* in Ranobe for 'permit'	7.7
Have to stay in the forest for several weeks	6.7
It is not profitable; the price of charcoal has diminished	6.7
The whole family has to help with the work	5.8
Lack of suitable trees; forced to use stumps/roots	4.3
It is dangerous in the forest	1.9

*Community agents of the State's Forest Service

factors such as deteriorating infrastructure or drought), or they had a need to generate supplemental income (driven by endogenous pressures, including family problems and increasing family size). The participants had not abandoned their livelihood activities from 5 years previously; rather they had diversified their sources of revenue to meet their increased monetary needs. Charcoal production is also a gap-filler during the agricultural off-season, and a relatively rapid way of generating cash at short notice. As such, it can be characterized as a fall-back activity or safety net (Sunderlin et al., 2005). Some people who used to produce charcoal but no longer do may also reside within the study area; investigating what motivated these people to pursue other livelihood strategies would be another interesting line of enquiry.

This situation is one of many examples of the rural poor turning to forest resource use in the absence of more favourable options for income generation (Vira & Kontoleon, 2010) and as 'employment of last resort' (Angelsen & Wunder, 2003). It occurs because the chronically poor tend to live disproportionately in remote rural areas close to forests (Hulme & Shepherd, 2003), and because forests are generally easy to access, with few physical or technical barriers preventing their exploitation (Sunderlin et al., 2005). Analyses of illegal logging in Indonesia have shown that participation in the industry grew as a consequence of declining returns from agriculture (Angelsen & Resosudarmo, 1999) and the increasing need for cash in rural village communities (Yonariza & Webb, 2007); households with fewer options to generate income were more likely to participate in logging (Byron & Arnold, 1999). In Madagascar, other safety net livelihood activities include bushmeat hunting (Goodman, 2006; Gardner & Davies, 2014), collecting wild yams (Ackermann, 2003), and the use of forest products more broadly (Favre, 1996). Forests also provide a reserve of potential agricultural land, albeit of poor quality in general, that may be converted to shifting cultivation, primarily by migrants fleeing drought or seeking cash to invest in cattle (Réau, 2002; Scales, 2014).

Given the importance of charcoal production as a safety net, reducing the practice through rule enforcement (either by reducing the number of permits granted or taking action against charcoal production without a permit) would probably exacerbate poverty. This would be incompatible with the objectives of the Madagascar protected area system, which include both the conservation of biodiversity and the sustainable use of natural resources for poverty alleviation and local development (Gardner et al., 2013), and with calls for conservation to, at the very least, avoid worsening poverty among affected communities (Adams et al., 2004; Kaimowitz & Sheil, 2007). Enforcement is also hindered by corruption in natural resource extraction sectors (Randriamalala & Liu, 2010) and a lack of political will; attempts by the regional administration of Atsimo Andrefana to further regulate the charcoal sector in 2007 led to civil unrest in Toliara city and were withdrawn (Bertrand et al., 2010). Instigating a reversal in the trend towards increased participation in charcoal production within Ranobe PK32 will thus depend partly on reducing its attractiveness as a livelihood relative to potential alternatives. Theoretically this can be achieved by tackling the underlying factors that push charcoal producers into the industry, and our findings suggest several potential interventions worth exploring.

Endogenous and exogenous factors were cited in approximately equal frequency as drivers of livelihood change. The primary exogenous factors raised by our respondents centred on the diminishing productivity of agriculture as a result of a lack of rain, and degradation of the irrigation infrastructure in the north of the study area. Farmers have been forced to seek

additional or alternative sources of income because the Manombo dam is no longer operational, and our survey suggests that restoring the dam and associated canals, a task which is currently being conducted by the African Development Bank, could lead to c. 30% of questionnaire participants abandoning charcoal production to return to farming. Likewise, the establishment of climate-wise agricultural adaptation programmes, including the development and popularization of improved farming techniques and drought-resistant crops, would help mitigate the problems of low and unpredictable rainfall. This will become increasingly pertinent in the future, with climate change expected to have a substantial negative impact on agricultural production in southern Madagascar (Thornton et al., 2011). Without such action, other safety-net forest uses, such as shifting cultivation, may become more prevalent, in addition to charcoal production. Interventions aimed at decreasing cattle theft by improving rural security, and improving the sustainability of marine resources through fisheries management, would help restore the viability of pastoralism and fishing as alternatives to charcoal production.

Although these interventions (so-called distraction activities; Milner-Gulland & Rowcliffe, 2007) could diminish the relative attractiveness of charcoal production as a livelihood, higher income arising from development gains could be invested in charcoal production or other natural resource exploitation by beneficiaries. The interventions must therefore be accompanied by enforcement of regulations, or made conditional on reductions in environmentally damaging activities (Sievanen et al., 2005; St. John et al., 2013). Moreover, it is likely that a decline in charcoal production in Ranobe PK32 would be offset by leakage (Ewers & Rodrigues, 2008) if demand from the city remained constant, as the activity would be displaced elsewhere. Decreasing production at a regional scale would thus require a drop in demand for charcoal from natural forests, directly (e.g. through the popularization of fuel-efficient stoves, which has been promoted widely but with variable success; Anenberg et al., 2013) and/or indirectly through the introduction of an alternative supply (e.g. from fuelwood plantations or biomass briquettes). Many of our respondents expressed a desire for woodlots or small plantations of fast-growing tree species to be established near their villages, but further exploration of this topic was beyond the scope of our questionnaire.

Study participants referred frequently to endogenous drivers of increased charcoal production, including family problems and an increasing number of children. We did not probe into what constituted family problems, but findings from the pilot exercise indicated that this generally referred to either expensive medical emergencies or a death in the family or community. Funerals in southern Madagascar may consist of extremely lavish ceremonies, involving the construction of expensive tombs and the slaughter of zebu cattle (Casse et al., 2005). Family members are expected to contribute cattle as gifts, and such expenses, often at short-notice, may account for a significant proportion of a household's annual expenditure. Land-owners may sell land to generate the necessary funds (Blanc-Pamard, 2004), but for those lacking alternative assets charcoal production offers an opportunity to raise money relatively quickly. Considering that increasing family size was cited as a factor driving more than a quarter of our sample towards charcoal production, the provision of family planning services could contribute to decreasing household expenditures and thus the pressure to practise environmentally destructive activities such as charcoal production to generate cash (Allendorf & Allendorf, 2012; Harris et al., 2012).

Approximately two thirds of the charcoal producers we surveyed were migrants to the southern Route Nationale 9 area. Comparing the two social groups, we found no evidence that residents and migrants engage in a different mix of livelihoods or that the recent increase in charcoal production has been driven by newcomers. Malagasy societies are dynamic, and migration to the forest frontier is a typical response to resource scarcity (Keller, 2008). As such, numerous authors have remarked that migrant communities tend to engage in less sustainable resource-use practices than residents (e.g. Réau, 2002; Horning, 2003; Kaufmann & Tsirahamba, 2006; Andriamalala & Gardner, 2010). However, our findings do not support this observation. Furthermore, Bertrand et al. (2010) state that charcoal production in the Toliara region is linked to migration dynamics because charcoal is primarily produced as a secondary output from shifting cultivation; our data provide evidence to the contrary, as $< 2\%$ of our sample were also engaged in slash-and-burn agriculture.

The implementation of management responses to the charcoal problem in Ranobe PK32 has been hampered by a decrease in donor funding following a political coup in 2009; as a result, the protected area has lacked active management since mid 2013. Nevertheless, our research has demonstrated that livelihood change around protected areas can be rapid, involve large numbers of people, and have multiple underlying causes. Given that it can have severe impacts on biodiversity we suggest that protected area management planning should systematically include mechanisms to detect, understand, and mitigate or adapt to livelihood change to minimize its potentially negative effects. The detection of change requires the implementation of a monitoring programme, which is already recognized as a fundamental component of a management plan (Phillips, 2002; Thomas & Middleton, 2003). Nonetheless, such monitoring systems in protected areas typically focus on biodiversity (e.g. densities of indicator/important species) and therefore expose only the outcome of changing resource use after it has occurred. Instead, more attention needs to be given to examining the socio-economic conditions being

experienced within local communities, and understanding the factors that motivate shifts in behaviour, so that appropriate management responses can be developed. Both protected area managers and the funding bodies supporting their conservation efforts need to be sufficiently flexible to implement new management strategies rapidly in response to substantive livelihood change.

Acknowledgements

This research was carried out as part of the WWF Madagascar and Western Indian Ocean Programme Office's Toliara Land and Seascape project, funded by WWF Sweden. We are grateful to E. Rasolondranaly and R. Andrianarivony for their logistical support, and we thank A. Dorward and L. Jasper for constructive discussion.

References

Ackermann, K. (2003) The role of dry forests in Madagascar as a safety net in the rural livelihood system. Paper presented at the International Conference on Rural Livelihoods, Forests and Biodiversity, 19–23 May 2003, Bonn, Germany.

Adams, W.M., Aveling, R., Brockington, D., Dickson, B., Elliott, J., Hutton, J. et al. (2004) Biodiversity conservation and the eradication of poverty. *Science*, 306, 1146–1149.

Ahrends, A., Burgess, N.D., Milledge, S.A.H., Bulling, M.T., Fisher, B., Smart, J.C.R. et al. (2010) Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. *Proceedings of the National Academy of Sciences of the United States of America*, 107, 14556–14561.

Allendorf, T.D. & Allendorf, K. (2012) What every conservation biologist should know about human population. *Conservation Biology*, 26, 953–955.

Andriamalala, G. & Gardner, C.J. (2010) L'utilisation du *dina* comme outil de gouvernance des ressources naturelles: leçons tirés de Velondriake, sud-ouest de Madagascar. *Tropical Conservation Science*, 3, 447–472.

Anenberg, S.C., Balakrishnan, K., Jetter, J., Masera, O., Mehta, S., Moss, J. & Ramanathan, V. (2013) Cleaner cooking solutions to achieve health, climate, and economic cobenefits. *Environmental Science & Technology*, 47, 3944–3952.

Angelsen, A. & Resosudarmo, D. (1999) *Krismon, Farmers and Forests: The Effects of the Economic Crisis on Farmers' Livelihoods and Forest Use in the Outer Islands of Indonesia*. CIFOR, Bogor, Indonesia.

Angelsen, A. & Wunder, S. (2003) *Exploring the Forest–Poverty Link: Key Concepts, Issues and Research Implications*. CIFOR, Bogor, Indonesia.

Arnold, M., Köhlin, G., Persson, R. & Shepherd, G. (2003) *Fuelwood Revisited: What Has Changed in the Last Decade?* CIFOR, Bogor, Indonesia.

Aung, M., Swe, K.K., Oo, T., Moe, K.K., Leimgruber, P., Allendorf, T. et al. (2004) The environmental history of Chatthin Wildlife Sanctuary, a protected area in Myanmar (Burma). *Journal of Environmental Management*, 72, 205–216.

Bengtsson, J., Angelstam, P., Elmqvist, T., Emanuelsson, U., Folke, C., Ihse, M. et al. (2003) Reserves, resilience and dynamic landscapes. *Ambio*, 32, 389–396.

Bertrand, A., Ramamonjisoa, B. & Montagne, P. (2010) Les filières péri-urbaines d'approvisionnement en bois énergie des grandes villes de Madagascar. In *ARINA, le Charbon de Bois à Madagascar: Entre Demande Urbaine et Gestion Durable* (eds P. Montagne, S. Razafimahatratra, A. Rasamindisa & R. Crehay), pp. 23–36. CITE, Antananarivo, Madagascar.

Blanc-Pamard, C. (2004) Un jeu foncier de front pionnier en forêt des Mikea (sud-ouest de Madagascar): Pratiques, acteurs et enjeux. *Land Reform/Réforme Agraire/Reforma Agraria*, 2, 94–107.

Brooks, J., Waylen, K.A. & Borgerhoff Mulder, M. (2013) Assessing community-based conservation projects: a systematic review and multilevel analysis of attitudinal, behavioral, ecological, and economic outcomes. *Environmental Evidence*, 2, 1–34.

Brouwer, R. & Falcão, M.P. (2004) Wood fuel consumption in Maputo, Mozambique. *Biomass and Bioenergy*, 27, 233–245.

Brown, K. (2003) Integrating conservation and development: a case of institutional misfit. *Frontiers in Ecology and the Environment*, 1, 479–487.

Byron, N. & Arnold, M. (1999) What futures for the people of the tropical forests? *World Development*, 27, 789–805.

Casse, T., Milhøj, A., Ranaivoson, S. & Randriamanarivo, J.R. (2004) Causes of deforestation in southwestern Madagascar: what do we know? *Forest Policy and Economics*, 6, 33–48.

Casse, T., Nielsen, U., Ranaivoson, S. & Randrianamarivo, J.R. (2005) Farmer strategies and forest conservation: a case study from south-west Madagascar. *International Journal of Social Economics*, 32, 704–716.

Dressler, W., Büscher, B., Schoon, M., Brockington, D., Hayes, T., Kull, C.A. et al. (2010) From hope to crisis and back again? A critical history of the global CBNRM narrative. *Environmental Conservation*, 37, 5–15.

Dudley, N. (ed.) (2008) *Guidelines for Applying Protected Area Management Categories*. IUCN, Gland, Switzerland.

Ewers, R.M. & Rodrigues, A.S.L. (2008) Estimates of reserve effectiveness are confounded by leakage. *Trends in Ecology & Evolution*, 23, 113–116.

Favre, J.-C. (1996) Traditional utilization of the forest. In *Ecology and Economy of a Tropical Dry Forest in Madagascar* (eds J.U. Ganzhorn & J.P. Sorg), pp. 33–40. *Primate Report*, 44.

Folke, C. (2003) Reserves and resilience—from single equilibrium to complex systems. *Ambio*, 32, 379.

Folke, C., Hahn, T., Olsson, P & Nordberg, J. (2005) Adaptive governance of social–ecological systems. *Annual Review of Environment and Resources*, 30, 441–473.

Gardner, C.J. (2011) IUCN management categories fail to represent new, multiple-use protected areas in Madagascar. *Oryx*, 45, 336–346.

Gardner, C.J. (2014) *Reconciling conservation and development in Madagascar's rapidly expanding protected area system*. PhD thesis. University of Kent, Canterbury, UK.

Gardner, C.J. & Davies, Z.G. (2014) Rural bushmeat consumption within multiple-use protected areas: qualitative evidence from southwest Madagascar. *Human Ecology*, 42, 21–34.

Gardner, C.J., Kidney, D. & Thomas, H. (2009a) First comprehensive avifaunal survey of PK32-Ranobe, a new protected area in south-western Madagascar. *Phelsuma*, 17, 20–39.

Gardner, C.J., Fanning, E., Thomas, H. & Kidney, D. (2009b) The lemur diversity of the Fiherenana–Manombo Complex, southwest Madagascar. *Madagascar Conservation & Development*, 4, 38–43.

Gardner, C.J., Nicoll, M.E., Mbohoahy, T., Olesen, K.L.L., Ratsifandrihamanana, A.N., Ratsirarson, J. et al. (2013) Protected areas for conservation and poverty alleviation:

experiences from Madagascar. *Journal of Applied Ecology*, 50, 1289–1294.

Gaston, K.J., Jackson, S.F., Cantú-Salazar, L. & Cruz-Piñón, G. (2008) The ecological performance of protected areas. *Annual Review of Ecology, Evolution and Systematics*, 39, 93–113.

Geoghegan, T. & Renard, Y. (2002) Beyond community involvement in protected area planning and management: lessons from the insular Caribbean. *PARKS*, 12, 16–27.

Ghimire, K.B. & Pimbert, M.P. (eds) (1997) *Social Change and Conservation*. Earthscan, London, UK.

Golden, C.D., Wrangham, R.W. & Brashares, J.S. (2013) Assessing the accuracy of interviewed recall for rare, highly seasonal events: the case of wildlife consumption in Madagascar. *Animal Conservation*, 16, 597–603.

Goodman, S.M. (2006) Hunting of Microchiroptera in south-western Madagascar. *Oryx*, 40, 225–228.

Hannah, L. (2008) Protected areas and climate change. *Annals of the New York Academy of Sciences*, 1134, 201–212.

Harris, A., Mohan, V., Flanagan, M. & Hill, R. (2012) Integrating family planning service provision into community-based marine conservation. *Oryx*, 46, 179–186.

Horning, N.R. (2003) How rules affect conservation outcomes. In *The Natural History of Madagascar* (eds S.M. Goodman & J. P. Benstead), pp. 146–153. The University of Chicago Press, Chicago, USA.

Hulme, D. & Shepherd, A. (2003) Conceptualizing chronic poverty. *World Development*, 31, 403–423.

IEA (International Energy Agency) (2010) *World Energy Outlook 2010*. International Energy Agency, Paris, France.

Jenkins, C.N. & Joppa, L. (2009) Expansion of the global terrestrial protected area system. *Biological Conservation*, 142, 2166–2174.

Kaimowitz, D. & Sheil, D. (2007) Conserving what and for whom? Why conservation should help meet basic human needs in the tropics. *Biotropica*, 39, 567–574.

Kaufmann, J.C. & Tsirahamba, S. (2006) Forests and thorns: conditions of change affecting Mahafale pastoralists in southwestern Madagascar. *Conservation & Society*, 4, 231–261.

Keller, E. (2008) The banana plant and the moon: conservation and the Malagasy ethos of life in Masoala, Madagascar. *American Ethnologist*, 35, 650–664.

Koechlin, J. (1972) Flora and vegetation of Madagascar. In *Biogeography and Ecology in Madagascar* (eds R. Battistini & G. Richard-Vindard), pp. 145–190. Springer Netherlands, The Hague, Netherlands.

Mana, P., Rajaonarivelo, S. & Milleville, P. (2001) Production de charbon de bois dans deux situations forestières de la région de Tuléar. In *Sociétés Paysannes, Transitions Agraires et Dynamiques Ecologiques dans le Sud-ouest de Madagascar* (eds S. Razanaka, M. Grouzis, P. Milleville, B. Moizo & C. Aubry), pp. 199–210. CNRE-IRD, Antananarivo, Madagascar.

Mascia, M.B. & Pailler, S. (2011) Protected area downgrading, downsizing, and degazettement (PADDD) and its conservation implications. *Conservation Letters*, 4, 9–20.

Meyers, D., Ramamonjisoa, B., Sève, J., Rajafindramanga, M. & Burren, C. (2006) *Etude sur la Consommation et la Production en Produits Forestiers Ligneux a Madagascar*. JariAla & USAID, Antananarivo, Madagascar.

Milner-Gulland, E.J. (2012) Interactions between human behaviour and ecological systems. *Philosophical Transactions of the Royal Society, B*, 367, 270–278.

Milner-Gulland, E.J. & Rowcliffe, J.M. (2007) *Conservation and Sustainable Use: A Handbook of Techniques*. Oxford University Press, Oxford, UK.

Minten, B., Sander, K. & Stifel, D. (2012) Forest management and economic rents: evidence from the charcoal trade in Madagascar. *Energy for Sustainable Development*, 17, 106–115.

Naughton-Treves, L., Holland, M.B. & Brandon, K. (2005) The role of protected areas in conserving biodiversity and sustaining local livelihoods. *Annual Review of Environment and Resources*, 30, 219–252.

Newing, H.S. (2011) *Conducting Research in Conservation: A Social Science Perspective*. Routledge, Abingdon, UK.

Newmark, W.D. & Hough, J.L. (2000) Conserving wildlife in Africa: integrated conservation and development projects and beyond. *BioScience*, 50, 585–592.

Newton, A.C. (2011) Social–ecological resilience and biodiversity conservation in a 900-year-old protected area. *Ecology and Society*, 16, 13.

Olson, D. & Dinerstein, E. (1998) The Global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions. *Conservation Biology*, 12, 502–515.

Ostrom, E. (2009) A general framework for analyzing sustainability of social–ecological systems. *Science*, 325, 419–422.

Partage (2008) *Analyse de l'Offre et de la Demande en Energie Domestique au Niveau de la Commune de Toliara*. Partage, Antananarivo, Madagascar.

Phillips, A. (2002) *Management Guidelines for IUCN Category V Protected Areas: Protected Landscapes/Seascapes*. IUCN, Gland, Switzerland.

Randriamalala, H. & Liu, Z. (2010) Rosewood of Madagascar: between democracy and conservation. *Madagascar Conservation & Development*, 5, 11–22.

Réau, B. (2002) Burning for zebu: the complexity of deforestation issues in western Madagascar. *Norwegian Journal of Geography*, 56, 219–229.

Scales, I.R. (2014) The drivers of deforestation and the complexity of land use in Madagascar. In *Conservation and Environmental Management in Madagascar* (ed. I.R. Scales), pp. 105–125. Routledge, Abingdon, UK, and New York, USA.

Schmitz, M.F., Matos, D.G.G., De Aranzabal, I., Ruiz-Labourdette, D. & Pineda, F.D. (2012) Effects of a protected area on land-use dynamics and socioeconomic development of local populations. *Biological Conservation*, 149, 122–135.

Seddon, N., Butchart, S., Tobias, J., Yount, J.W., Ramanampamonjy, J.R. & Randrianizahana, H. (2000) Conservation issues and priorities in the Mikea Forest of south-west Madagascar. *Oryx*, 34, 287–304.

Seddon, N., Tobias, J. & Butchart, S.H.M. (2003) Group living, breeding behaviour and territoriality in the subdesert mesite *Monias benschi*. *Ibis*, 145, 277–294.

Sievanen, L., Crawford, B., Pollnac, R. & Lowe, C. (2005) Weeding through assumptions of livelihood approaches in ICM: seaweed farming in the Philippines and Indonesia. *Ocean & Coastal Management*, 48, 297–313.

St. John, F.A.V., Keane, A.M. & Milner-Gulland, E.J. (2013) Effective conservation depends upon understanding human behaviour. In *Key Topics in Conservation Biology 2* (eds D. W. Macdonald & K.J. Willis), pp. 344–361. Wiley-Blackwell, Chichester, UK.

Sunderlin, W.D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L. & Wunder, S. (2005) Livelihoods, forests, and conservation in developing countries: an overview. *World Development*, 33, 1383–1402.

Thomas, L. & Middleton, J. (2003) *Guidelines for Management Planning of Protected Areas*. IUCN, Gland, Switzerland.

Thornton, P.K., Jones, P.G., Ericksen, P.J. & Challinor, A.J. (2011) Agriculture and food systems in sub-Saharan Africa in a 4°C+ world. *Philosophical Transactions of the Royal Society A*, 369, 117–136.

Venter, F.J., Naiman, R.J., Biggs, H.C. & Pienaar, D.J. (2008) The evolution of conservation management philosophy: science, environmental change and social adjustments in Kruger National Park. *Ecosystems*, 11, 173–192.

Vira, B. & Kontoleon, A. (2010) Dependence of the poor on biodiversity: which poor, what biodiversity? In *Linking Biodiversity Conservation and Poverty Alleviation: A State of Knowledge Review* (ed. D. Roe), pp. 13–28. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Virah-Sawmy, M., Gardner, C.J. & Ratsifandrihamanana, A.N. (2014) The Durban Vision in practice: experiences in the participatory governance of Madagascar's new protected areas. In *Conservation and Environmental Management in Madagascar* (ed. I.R. Scales), pp. 216–251. Routledge, London, UK, and New York, USA.

Wells, M.P. & McShane, T.O. (2004) Integrating protected area management with local needs and aspirations. *Ambio*, 33, 513–519.

West, P., Igoe, J. & Brockington, D. (2006) Parks and peoples: the social impact of protected areas. *Annual Review of Anthropology*, 35, 251–277.

WWF (2010) *Plan de Gestion pour la Nouvelle Aire Protégée Ranobe PK32*. WWF, Antananarivo, Madagascar.

Yonariza & Webb, E.L. (2007) Rural household participation in illegal timber felling in a protected area of West Sumatra, Indonesia. *Environmental Conservation*, 34, 73–82.

Biographical sketches

Charlie Gardner's research focuses on reconciling conservation and development in Madagascar's expanded protected area system, and spanning the researcher–practitioner divide. Firengea Gabriel is interested in human interactions with Madagascar's environment and biodiversity. Freya St. John's research interests centre on the interface between biodiversity conservation and human populations that use natural resources, with a particular focus on understanding people's decision making and behaviour. Zoe Davies conducts interdisciplinary research centred on improving conservation practice and policy, human–wildlife interactions, and the impacts of environmental change (e.g. habitat fragmentation, climate change, urbanization) on species, assemblages and ecosystem service provision.