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Integrating Local Knowledge and Forest Surveys to Assess *Lantana camara* Impacts on Indigenous Species Recruitment in Mazeppa Bay, South Africa

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Abstract Invasive alien species have variable impacts on peoples' livelihoods, plant communities and species at the local scale. Local people often have deeper insights into and experiences of these impacts than can be measured by scientific surveys. Here we examine the impacts of *Lantana camara* on the recruitment of indigenous forest species, many of which are used by local people. We integrate findings from conversations with elderly respondents with standard ecological surveys. Both sources of information indicate that the increasing presence of *Lantana* suppresses the number and species richness of recruits of indigenous forest species, which may retard forest succession. Dense thickets of *Lantana* also restricted access to non-timber forest products and species of cultural significance. The origin and date of the *Lantana* introduction in the area was identified by respondents as the 1960s and it escaped into the wild in the early 1970s. These findings can be incorporated into locally based management considerations.

Keywords Forest regeneration · Invasive alien species · Local ecological knowledge · Rural livelihoods · Non-timber forest products

Introduction

Many observers regard invasive alien species (IAS) as one of the greatest global threats to biodiversity, ecosystem functioning and consequently, at times, human wellbeing (Biswas *et al*. 2007; Dobhal *et al*. 2011). However, large-scale generalisations are inadequate at the local scale, where local responses to IAS can range from being unnoticed to negative or positive, depending on local contexts, most notably the immediate dependency of local livelihoods on land-based activities and ecosystem services, the local abundance of the IAS and whether or not it produces tangible useful products (Shackleton *et al*. 2007a). Importantly, these contexts vary through time and therefore so do many local responses to IAS (Shackleton *et al*. 2007a). These dynamics underlie IAS now being considered as significant drivers of global change (Sakhai *et al*. 2001; Bhagwat *et al*. 2012).

South Africa is at the forefront of research into and control of IAS. Being one of the most biodiverse countries in the world there is much concern at a national research and policy level regarding the impacts of IAS. Additionally, South Africa has a large rural population (approx. 20 million), most of whom rely on arable and livestock agriculture and gathering of wild resources for a measurable part of their total household cash and non-cash income (Shackleton et al. 2007b). The flagship IAS control programme, Working for Water, is reputedly the largest and longest running such programme in the world (Koenig 2009; van Wilgen *et al.* 2012). It pursues the dual goals of eradication of IAS (especially in riparian and sensitive ecosystems) and poverty alleviation through the use of manual labour to clear IAS. Although there is much research on the clearing efficiencies of the programme and some of the benefits, such as increased stream flows and increased indigenous species abundance after clearing (van Wilgen *et al.* 2012), most is at the catchment or larger scales. Scientific understandings of the impacts of IAS on local livelihoods before and after clearing operations and of local ecological knowledge pertaining to IAS are scarce.

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A widespread IAS targeted by Working for Water is *Lantana camara*. Internationally, it is viewed as an aggressive invader that is able to tolerate a wide range of environmental conditions (Sandham *et al*. 2010; Bhagwat *et al*. 2012; Vardien *et al*. 2012). The IUCN has classified *L. camara* amongst the world's top ten worst weeds (Sharma and Raghubanshi 2007; Dobhal *et al*. 2011). The invasion of *L. camara* can have extensive impacts on plant community structure, functioning and composition, with differential effects on specific species (Gooden et al. 2009a, b; Aravind *et al*. 2010; Sandham *et al*. 2010; Dobhal *et al*. 2011; Sundaram and Hiremath 2012; Vardien *et al*. 2012). These changes may also result in altered habitat and food resources for a variety of vertebrate and invertebrate species (Vardien *et al*. 2012). *L. camara* is presumed to dominate native vegetation by suppressing regeneration as well as competing for resources such as light, water and space (Gooden et al. 2009a, b; Sandham *et al*. 2010; Sundaram *et al*. 2012). Some authors suspect that *L. camara* also releases allelochemicals which retard recruitment of indigenous species (Sharma and Raghubanshi 2007). According to Vardien *et al*. (2012) there are over 50 varieties of *Lantana* recognised in South Africa.

It was recently suggested that *L. camara* may suppress tree species regeneration in the biodiverse forests of the Wild Coast region in the Eastern Cape, South Africa (Berliner 2011; Shackleton *et al*. 2013), mirroring suggestions from elsewhere, such as for a wet sclerophyll forest in Australia (Gooden et al. 2009a, b) and for dry forests in India (Sundaram *et al*. 2012). Indigenous forest is the smallest biome in South Africa, covering less than 0.5 % of the total land area (Eeley *et al*. 1999), with the Eastern Cape having the most. The Wild Coast is the core area of the internationally designated Maputuland-Pondoland-Albany biodiversity hotspot and the forests are regarded as the most species rich non-tropical forests in the world (CEPF 2010). In this area, the forest biome is naturally highly fragmented, with most forest patches being less than 1 km^2 within a grassland matrix. Such fragmentation can increase the likelihood of IAS invasion because of the high perimeter to area ratio (Sharma and Raghubanshi 2007). Potential for IAS invasion may also be facilitated through human actions such as disturbance or opening up of forests. In this area, local communities make widespread use of land around forests for homesteads, gardening, and arable and livestock farming. They also collect non-timber forest products (NTFPs) such as firewood, thatch grass, medicinal plants and bushmeat, from local landscapes including the forest patches (Shackleton *et al*. 2007c). The local landscapes also provide cultural species and sites important in maintaining local identity, rituals and links with ancestors for the amaXhosa people (de Klerk 2007; Cocks et al. 2012). However, with growing modernisation and cash incomes, the extent of agriculture and frequency of gathering of wild products is not as high as it used to be (de Klerk 2007; Fay 2013; Shackleton *et al*. 2013). Many arable fields have been abandoned in favour of gardens closer to the homestead, and many of the abandoned fields are being invaded by early successional forest shrub and tree species as well as IAS (Chalmers and Fabricius 2007; Mangwale 2010; Shackleton *et al*. 2013). Shackleton *et al*. (2013) mooted that the presence of thickets of *L. camara* in these abandoned fields may retard forest succession on these sites as well as restrict access to NTFPs and sites and species of cultural significance.

The integration of local ecological knowledge (LEK) and conventional science is becoming increasingly important as the need to balance environmental, economic and social concerns becomes more essential (Ballard *et al*. 2008; Sundaram *et al*. 2012). Such integration can lead to more nuanced understandings of system dynamics, especially regarding the rate and nature of change and how that differs in varying contexts, which are essential knowledge domains for adaptive management and sustainability (Ballard *et al*. 2008). This is obviously pertinent for understanding the rates of change and impacts of IAS (Kannan *et al*. 2013) because they can rapidly impact local ecology and ecosystem benefits to resource-dependent communities at a range of scales (Willow 2011). Such integration is therefore crucial in planning appropriate response strategies to IAS invasions, because some communities integrate IAS into their livelihoods (Shackleton *et al*. 2011; Kannan *et al*. 2014), or have much direct experience and insights into effective control measures (Sundaram *et al*. 2012).

Within this context, we sought to investigate whether the presence of *L. camara* has negative impacts on recruitment of forest tree species assessed via LEK and direct surveys in order to (i) determine whether the presence of *L. camara* is suppressing the regeneration of forest tree species and (ii) assess the local knowledge and perceptions of *L. camara* and forests in the study area.

Study Area

The Mazeppa Bay area (32.5°S; 28.7°E) of the Wild Coast is located in the Amatole District of the Eastern Cape, South Africa. The terrain is characterised by rolling hills and valleys, with an altitude ranging from sea level to approximately 300 m above sea level (Mucina and Rutherford 2006). The area has a warm, temperate and humid climate (Mucina and Rutherford 2006). Mean temperatures range between 27 ° C in the summer (October–May) and 8 °C in the winter (June–September). It receives mostly summer rainfall, averaging 800–1000 mm per annum, with relatively dry winters. The soils are poorly developed, acidic and relatively infertile, which constrains crop yields (Timmermans 2002). The vegetation consists of a mosaic of forest patches, thornveld and dune thicket all within a grassland matrix (Mucina and Rutherford 2006). The area falls within the Maputuland-

Pondoland-Albany biodiversity hotspot and includes the Manubi forest (CEPF 2010). It is home to an abundance of endemic and threatened species (CEPF 2010).

Homesteads are mostly scattered along the higher ground and ridges (Timmermans 2002). Population density is approximately 53 persons per km^2. The area is one of the poorest in South Africa with limited formal infrastructure, development and employment. Chiefs and tribal authorities are responsible for land allocation. Land is allocated for housing and a garden nearby and, for some, an arable field further away. The remaining land is zoned for grazing and collection of NTFPs such as medicinal plants, firewood, clay, building timber, thatch and bushmeat. Most households have multiple cash and non-cash income streams, including livestock (cattle and/or goats, chickens), some cultivation of crops and vegetables, NTFPs, migrant labour, petty trading, and State welfare grants, which are the primary source of cash income for most households. Adult illiteracy is at 22 %, unemployment at 49 % and more than 75 % of households live below the poverty line (Statistics South Africa 2012).

Methods

Native Tree Species Recruitment Density in the Presence of *L. camara*

Recent (2012) aerial photographs (1: 13,000) of the area were used to develop a random cluster sampling approach. A 250 m × 250 m (6.25 ha) grid was superimposed over the photos and each block was numbered to allow for random selection. On site, within each randomly selected block, we visually scoured the whole block and selected ten sites to span a range of *L. camara* cover (including zero *L. camara* cover), which we sampled by 5 m × 5 m plots. One hundred plots were sampled in total, with no more than 10 plots in each randomly selected block. Thirteen of the plots were control sites of intact forest with no *Lantana* present.

Within each sample plot we estimated several measures of *L. camara* abundance: (i) a visual estimate of the percentage aerial cover of *L. camara*, (ii) density of *L. camara* stems, (iii) the basal diameter of each *L. camara* plant (if the plant was multi-stemmed, then the largest stem was measured), and (iv) mean height of the *L. camara* canopy. Additionally, we identified and counted the number of recruits of indigenous tree species. We considered recruits to be any woody stem less than 0.2 m tall.

Local Perceptions and Knowledge Regarding *L. camara*

Thirty interviews were used to capture local perceptions and ecological knowledge regarding various aspects of *L. camara*. Because we wished to consider changes through time, the interviews were conducted with elders in the community (65+ years) who were located through snowball sampling. The interviews were unstructured, conversational and open-ended across a few key topics, including changes in the abundance of *L. camara* and forests through time, its perceived impacts on the indigenous forests, recruitment and peoples' livelihoods, and uses of or problems with *L. camara*. It was important that the respondents had lived in the area for a number of decades to obtain the necessary information. A picture or cutting of *L. camara* was shown to the respondents prior to the commencement of the conversation to avoid any confusion.

Data Analysis

Our primary interest was how the abundance of *L. camara* affected the density or species richness of indigenous tree recruits and peoples' knowledge of this. We therefore regressed these two dependent variables against the various measures of *L. camara* abundance, namely, cover, density, basal area and mean height, using Statistica Version 11. A qualitative, descriptive summary is provided regarding the responses from the open-ended interviews. Key aspects focused on the knowledge and perceptions of local people on the presence of *L. camara* and forests, their use of *L. camara* and forests and changes over time.

Results

The Impact of *L. camara* on Native Tree Species Regeneration

There was a mean of 28.8±28.3 *L. camara* stems per 25 m^2 plot (11,360 per ha). There was no influence of *L. camara* density on either the number of indigenous recruits (r^2=0.01, p>0.05) or species richness (r^2=0.0228, p>0.05). There is also no relationship between *L. camara* basal area per plot and the number of indigenous recruits (r^2=−0.01, p>0.05) or species richness (r^2=−0.007, p>0.05). However, as aerial cover of *L. camara* increased, the density of indigenous recruits (r^2=−0.21, p<0.04) and species richness (r^2=−0.86, p<0.002) decreased (Fig. 1). There was also a significant positive relationship between mean canopy height of *L. camara* and the number of indigenous recruits (r^2=0.18, p<0.01), as well as between the mean the canopy height and species richness (r^2=0.27, p<0.01) (Fig. 2).

The mean density of indigenous recruits in the forest plots without *L. camara* (51.2±34.7), was significantly higher (t=5.43; p<0.0001) than in plots with *L. camara* (18.3±17.4.0). The same applied to mean species richness of recruits, being 11.2±2.5 per plot in the absence of *L. camara* and 5.5±3.2 in plots with *L. camara* (t=6.10; p<0.0001). The

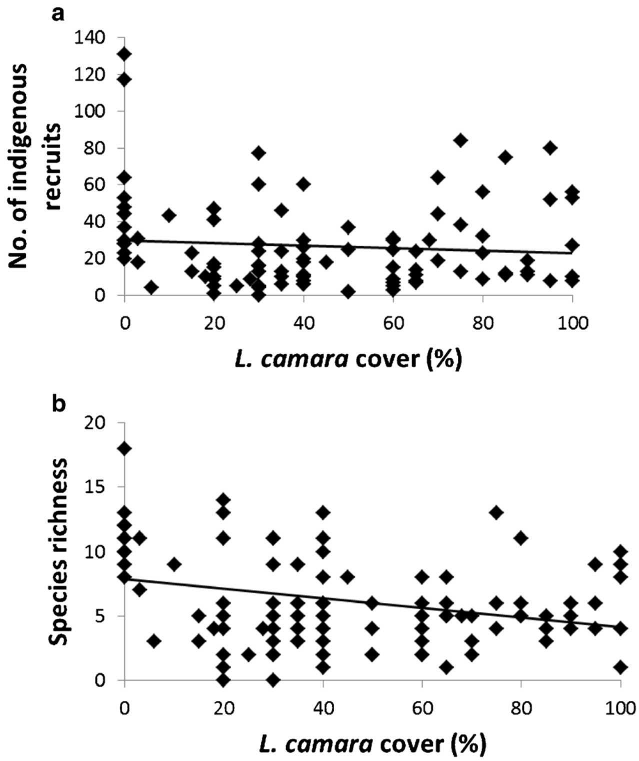

Fig. 1 The impact of *L. camara* aerial cover (%) on **a** the density of indigenous recruits and **b** species richness of indigenous recruits per 25 m^2 plot

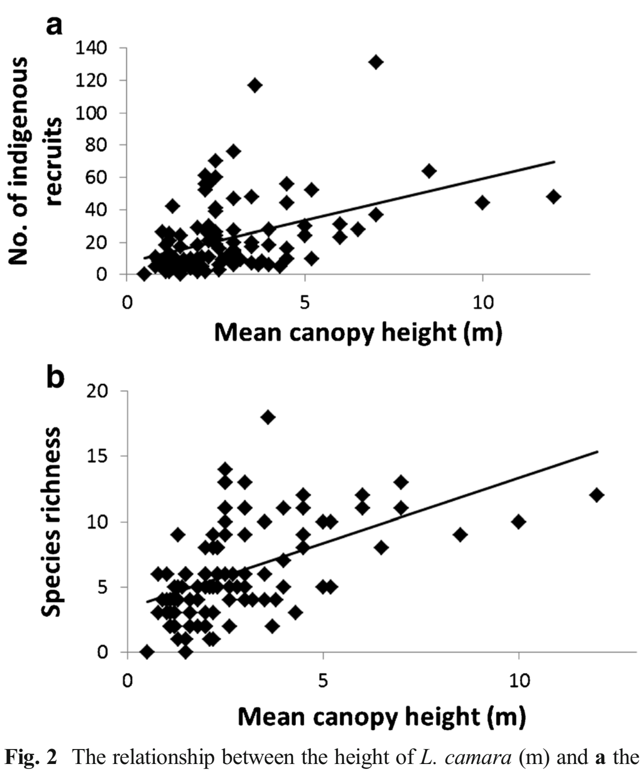

Fig. 2 The relationship between the height of *L. camara* (m) and **a** the density of indigenous recruits and **b** species richness of indigenous recruits per 25 m^2 plot

most common recruit species were *Milletia grandis*, *Vepris lanceolata*, *Ptaeroxylon capense*, *Tricalysia lanceolata* and *Diospyros lyciodes. Acacia karroo* was commonly found in invaded plots that were situated in abandoned fields and degraded pastures.

Local Knowledge and Perceptions of *L. camara*

All of the respondents said that they knew the plant and had seen it in the area; "Yes, I know it very well" and "Yes, I know it; it is such a huge problem in the area" were typical responses. Almost all of the respondents stated that *L. camara* is referred to as 'utywala bentaka' ('bird's beer') because birds love to feed on the ripe fruit, "just as the way people love to drink beer."

The majority of respondents reported that *L. camara* was a fairly recent arrival in the area, being either absent or in low abundance when they were young, and that it had only started to spread (and become a problem) in the last few decades. Some had first noticed it between the 1960s and 1990s; others were not sure when it first appeared but that it was not present in their childhood. Six respondents were able to identify precisely where they first noticed it at "Bobby's shop" located in a small group of houses situated next to the Manubi forest. Apparently, Bobby (the shopkeeper) grew a "more tame" variety of *L. camara* as a garden hedge for decoration because of its attractive flowers. He pruned this and kept it under control. The respondents stated that this particular variety of *L. camara* did not have thorns and did not grow as tall and uncontrollably as the present invasive form (possibly because he pruned it), but they said that it had the same flower and leaf. The shopkeeper left the area in 1971, after which the *L. camara* hedge was no longer pruned or maintained. The respondents suggested that it consequently produced lots of fruit which wild birds ate and distributed causing the current ubiquitous invasion.

All respondents stated that *L. camara* is spreading rapidly and is negatively affecting their livelihoods in one way or another. Just over half (16) reported that it had spread most extensively along the bank of the Qora River and on the north-facing fields that lead down to the river. One mentioned that it is "found along the river because there is plenty of water." They also reported that many unworked and abandoned arable fields are now dominated by *L. camara*; one commented "when people abandoned their fields and stopped ploughing, it gave the utywala bentaka a chance to grow." *Acacia karroo* and *Cestrum laevigatum* (an IAS) are also found in abundance in the abandoned fields as early successional species. Six respondents stated that *L. camara* was found both along the banks of the Qora River and abandoned fields as well as along the edges of the Manubi forest and the road. One respondent stated that the Department of Forestry is trying to remove the *L. camara* from the forest because it is widespread and destroying the young trees ("It destroys all the plants that grow underneath it, including young trees and grasses").

All respondents said that *L. camara* is having an adverse impact in the area and on their livelihoods, summed up by one who stated: "I don't just hate it, I am appalled by it." The most common reasons for peoples' dislike of it were (i) it destroys their crops and takes up space where crops could be planted ("It is too dense for crops and small trees to grow"); (ii) it is destructive to other plant species ("Where it grows nothing else is able to grow"; "It destroys other important trees, they can't breathe and grow properly if it is present"); (iii) it both practically and culturally useless; (iv) it is dense and thorny obstructing footpaths to NTFPs and some key sites; (v) it has invaded areas where thatching grass used to grow and therefore they can no longer harvest thatch to sell; (vi) livestock get lost in its dense thickets; (vii) it grows in productive grazing lands reducing grazing for livestock; and (viii) wild animals and snakes hide in its thickets, which are dangerous when they are close to homesteads.

Almost all respondents said that the area under natural forest in the region had increased during their lifetime. Some added that as the forest increased, so had the spread of *L. camara*. However, despite more widespread forest, over one-third of respondents believed that the invasion of *L. camara* had affected the quality of the forest ("The density of the forest has been negatively affected"), especially through its impact on specific species ("Certain species have become very rare due to utywala bentaka"; "We are still asking questions amongst ourselves. There are certain bird species that are no longer in the forest since utywala bentaka started to grow there"). Specific tree species that respondents observed as negatively affected by *L. camara* were *Ptaeroxylon obliquum* and *Vepris lanceolata*, both of which are of cultural significance. More generally, almost all respondents stated that the invasion of *L. camara* affected the regrowth of the forest ("Small plants grow, but they do not grow very big"; "It suppresses growth and trees only grow to a certain height because it is too dense for them to grow through"). Some also noted that outside forest patches *L. camara* stifles the growth of grass, which in turn reduces grazing, thatch supply and hampers the fires that are set to reduce ticks and stimulate fresh grass for livestock in the late winter (Kepe 2005).

All respondents reported that they have no substantial uses for *L. camara*, although a few had used it occasionally for minor uses, for example, kindling; sometimes children eat the ripe berries; and a few stated that they had added a small amount of *Lantana* leaves to their "imifino" (a mixture of wild leafy vegetables) to add a bitter taste. One respondent said that it was possible to grow *L. camara* as a hedge instead of building a fence, but nobody had done this. Nobody knew of any medicinal uses for it. A few respondents stated that both cattle and goats eat *L. camara*. Just under half stated that the cattle eat the leaves and the goats eat the berries. All respondents were unsure if wild animals ate it, because they had never seen any do so.

All respondents mentioned that if they found *L. camara* growing in their gardens or fields they would remove it, usually by digging it up by the roots and burning it. They noted the importance of continual vigilance to prevent regrowth. At the time of the study there had been no collective initiatives to remove *L. camara* more widely from communal grazing lands, forests and roadsides outside the Manubi forest. One or two respondents indicated their willingness, but felt that there was a lack of willingness among other community members, especially the youth. Another respondent stated: "It is the community's responsibility to clear *L. camara*. We need to gather and discuss how to destroy it, but this won't happen because people are no longer interested in ploughing the lands therefore they will not be interested in trying to remove it." All respondents stated that fire damages only the aboveground portion *L. camara* and as soon as it rains it returns. One respondent observed that despite frequent wild fires along the Qora river bank *L. camara* is growing in abundance there.

Discussion

There is clear agreement between the ecological survey results and the information provided by local respondents that the invasion of *L. camara* has had a negative impact on forest species recruitment. The plot data show that the density and species richness of indigenous species is negatively affected by *L. camara* cover and decreasing height. Increasing cover and lower height presumably decrease light penetration to the forest floor and may also increase competition. Respondents described this as a barrier through which indigenous species could not grow (see also Sundaram *et al*. 2012). Over one-third of the respondents said that *L. camara* was having a negative impact on the forest, specifically the tree species *Ptaeroxylon obliquum* and *Vepris lanceolata* which are important in local livelihoods and culture, especially for medicinal ritual purposes.

The local name for *Lantana*, 'utywala bentaka' (birds' beer) reflects that the primary means of dispersal is through birds. Prolific flowering and the production of fruit throughout the year heightens its invasive potential, especially in the warm and temperate climate conditions of the Wild Coast (Vardien *et al*. 2012). At the macro-scale *L. camara* was distributed around the South Africa (and other countries) as a popular ornamental plant (Vardien *et al*. 2012) and this was the case in our study area. The individual who introduced it as a garden hedge in the study area left in 1971, which pinpoints the beginning of the local invasions (see Sundaram *et al*. 2012). This timing corresponds with the findings of de Klerk (2007) who reported that local people in the Nqabara area, about 50 km to the northeast, observed that *Lantana* started to become a “significant” invader in the late 1980s and early 1990s, being first noticed along river banks.

Seemingly the most extensive invasion of *L. camara* was along the Qora River banks and in the abandoned north-facing fields. According to Vardien *et al*. (2012) riparian areas are particularly vulnerable to invasion. Shackleton *et al*. (2013) found that in a site just to the north IAS (mainly *Lantana*) made up nearly 20 % of the dominant species in abandoned fields. The abandoned fields were areas of disturbance through previous ploughing and heavy grazing, making them vulnerable to IAS invasion. De Klerk (2007) suggested that the hedges and fences around fields (abandoned or still in use) act as perching sites for birds and hence sites for establishment of weeds like *L. camara* (see also Vardien *et al*. 2012). Shackleton *et al*. (2013) also found that *L. camara* was significantly dominant in all sites other than the most intact forest, potentially having negative implications for the regrowth of native species. The possibility that *L. camara* slows down successional processes through suppression of indigenous species recruitment density and richness is supported by the findings in this study.

Many respondents reported their dislike of *L. camara* because it is destructive to other plant species. This is supported by our survey results showing the increase in percentage aerial cover of *L. camara* results in the decrease of indigenous recruits and species richness compared to non-invaded vegetation (see Gooden et al. 2009a, b and Sundaram *et al*. 2012 for similar results in Australia and India). Yurkonis *et al*. (2005) argued that for the successful establishment of an invader species in a disturbed site, the limitation of native species recruitment is an important factor. Sundaram *et al*. (2012) concluded that the invasion of *L. camara* has caused structural changes in the ecosystem, as there are many old trees with few young ones being present.

Our results indicated a relationship between the mean canopy height of *L. camara* and the number of indigenous recruits and species richness. Although our study does not indicate the mechanisms by which the invasion of *L. camara* limits the recruitment of native species, previous research by Sandham *et al*. (2010) and Sundaram and Hiremath (2012) suggests that it is driven by resource competition for light and nutrients and perhaps allelopathic properties. The effect through light reduction is supported by our results of a positive relationship with *L. camara* height and a negative effect of *L. camara* cover. Patches dominated by short, shrubby *L. camara* were suppressing recruitment of indigenous vegetation by restricting light and space. Shackleton *et al*. (2013) also found that grass cover was reduced as the growth of more woody species prevented light infiltration. Our respondents also said that the restriction of light by *L. camara* canopy was a significant factor limiting the growth of seedlings. The taller *L. camara* is the more light penetration there is and some, albeit fewer, native tree species are able to germinate and establish in its understory. However, whether some are then able to grow through the taller *Lantana* canopy is unclear. Local respondents claim that the indigenous species cannot grow through the thicket, but even if some do succeed under taller *L. camara* stands, the richness and density will still be lower than uninvaded sites (see also Ramaswami and Sukumar 2011).

Almost all respondents said that the area of natural forest had increased over time, which is consistent with findings of de Klerk (2007), Chalmers and Fabricius (2007), Mangwale (2010) and Shackleton *et al*. (2013) in the same broad region. Over 90 % of respondents attributed the increase in forest area to a reduction in farming, with woody plants (including *L. camara*) invading abandoned fields. Some respondents stated that *L. camara* was invading the edges of the Manubi forest. Biswas *et al*. (2007) reported that forest borders are particularly vulnerable to invasion due to disturbance through human activities, such as logging and fire.

Our respondents noted that fire does not kill *L. camara* (similar to the findings of Sundaram *et al*. 2012 in India). Interestingly, according to Sundaram and Hiremath (2012) fires that occur in *L. camara* invaded areas are hotter and thereby have an increased effect on the mortality of native tree species, creating a feedback loop that benefits *L. camara*.

There are various ways in which *L. camara* is having an impact on livelihoods. Rural people rely on forests and the landscape for collection of NTFPs to support their livelihoods. *L. camara* is invading abandoned fields where indigenous forests could have regenerated and thus provided woody resources. Due to its dense and thorny nature, it impedes access to important NTFPs such as medicinal plants and fuel wood as well as access to footpaths (see also Sundaram *et al*. 2012). It also suppresses thatching grass and grazing. The harvesting and selling of thatching grass and livestock husbandry are two important components of rural livelihoods. Woody species of significance in local culture were also impacted. Indigenous peoples and resource managers are collaborating on viewing the challenge from different perspectives to devise a range of responses implemented at different scales.

Conclusions

Both the social and ecological approaches have shown a large degree of congruence in understanding the impacts of the IAS *L. camara* on recruitment of forest tree species in the area. Residents’ knowledge from direct observations and our plot surveys show that both the density and species richness of tree recruits is suppressed by *L. camara*. Thus, whilst the overall expanse of forest is deemed to be increasing, the quality of the forest, and hence the benefits it supplies to local communities, is degraded through increasing abundance of *L. camara*. This has occurred within less than a lifetime and local responses to increasing *L. camara* in the landscapes are still evolving.

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