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RESEARCH ARTICLE

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Who knows, who cares? Untangling ecological knowledge and nature connection among Amazonian colonist farmers

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Abstract

1. Conservationists often assume that connection with and caring about nature's well-being is strongly linked to ecological knowledge. Existing evidence on the link between ecological knowledge and psychological nature connection is mixed, geographically limited to countries in the Global North, and does not scrutinise potential differences in determinants of ecological knowledge and nature connection.
2. We investigate the relationship between psychological nature connection and ecological knowledge of local bird species, and assess their associations with potential drivers, including access to, contact with, and reliance on nature and socio-demographic characteristics. Our study is carried among a novel participant population of colonist farmers living along a major deforestation frontier in the Brazilian Amazon.
3. Our study context has high conservation relevance and provides an ideal setting to assess the extent to which conservation psychology's insights from the Global North hold true elsewhere. Tropical farm-forest frontiers suffer from intense habitat and biodiversity loss, and farmers with migrant origins are important yet rarely studied conservation stakeholders. Importantly, farmers' experiences of nature are likely to vary considerably due to the wide range of socio-demographic, economic, geographical and cultural diversity.
4. Interviewees scored highly on two indices of nature connection, but scores were higher among older people and those with greater contact with nature. Bird identification knowledge was generally low to moderate, and higher among men and younger people. Species more frequently recognised were regionally common, larger-bodied or associated with non-forest habitats.
5. Ecological knowledge of birds and nature connection were not correlated, and they did not have any predictors in common. Our results indicate that colonist

farmers are capable of forming strong connections with nature, even if they rarely possess detailed knowledge of local forest biodiversity. Considering the complex and apparently context-dependent relationship between knowing and caring about nature, it is unwise to assume that changing one would automatically affect the other.

KEYWORDS
Amazon, birds, conservation psychology, ecological knowledge, farmers, nature connection

1 | INTRODUCTION

Severe declines in regional biodiversity are accompanied by the simultaneous loss of knowledge about natural ecosystems within traditional and non-traditional human societies (Aswani et al., 2018; Miller, 2005). Loss of ecological knowledge raises concerns that it may undermine both our ability to manage ecosystems and our interest and willingness to protect them. Decades of research in conservation psychology and environmental education have demonstrated that the relationship between knowledge, attitudes and pro-environmental behaviours is complex and nonlinear (Kollmuss & Agyeman, 2002; Rickinson, 2001; Varela-Losada et al., 2015; Wals et al., 2014). However, many conservationists—most of them trained in natural sciences (Bennett et al., 2017)—still believe that a sense of connection and caring about nature is based on knowledge and understanding of the natural world, particularly the knowledge of different species (Table 1).

TABLE 1 Examples of the belief that caring for nature is related to ecological knowledge expressed in environmental NGO materials and academic papers in conservation science

Quote	Context	Source
NGO examples		
'In the end, we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught'	Quote by Baba Dioum (1968) used as inspiration in an educational poster campaign for schools, WWF UK One Planet Schools 'Learn' Programme	WWF UK Webpage (2008)
'We approach our elephant work in the same spirit as Baba Dioum. Our endeavour to protect elephants is inspired by love and deep respect for them as a species and as individuals, which, in turn, is based on our understanding of them gained through long-term study'	ElephantVoices, quoting Baba Dioum (1968) at the top of the Education section of their webpage	ElephantVoices Webpage (2018)
Academic examples		
'People care about what they know'	Study demonstrating that UK children had greater identification knowledge of synthetic Pokémon 'species' than common British wildlife	Balmford et al. (2002)
'[T]he levels of ecological knowledge studied here (names of living components of ecosystems and the functions and uses of each component) provide an indication of a community's connectivity and willingness to care for the local environment, since naming things with which we are familiar is human instinct and we are unlikely to care about that which we do not know' (p. 1007)	Cross-cultural study demonstrating an inverse relationship between levels of ecological knowledge and wealth measured at the level of nation and community	Pilgrim et al. (2008)
'[The] loss of familiarity and knowledge [of nature] is cause for profound concern as it may lead to reduced appreciation of the natural world, reduced motivation to protect species, [and] less willingness to support nature (…)'	Study exploring socio-demographic factors influencing plant identification knowledge among adults in UK	Robinson et al. (2016)
'People who care, may make choices to conserve; but people who don't know [nature], don't even care. What is the extinction of a condor or an albatross to a child who has never known a wren?' (p. 207)	Opinion piece emphasising the need for fostering deep connections to nature	Pyle (2003)
'Natural history, the scientific study of plants and animals in their natural environments, is the cornerstone of ecological literacy. It not only instructs in the knowledge of place but instils an emotional enthusiasm and empathy toward natural phenomena' (p. 118)	Study highlighting deficient levels of natural history knowledge among university students in Mississippi, including those with course work in ecology	Hammond and Herron (2012)

Crossing the sub-disciplinary divides of applied ecology and environmental psychology, the literature on the relationship between ecological knowledge of species and nature connection includes substantial gaps. Studies explicitly examining this link are few, the findings are mixed, and the evidence is limited to richer Global North countries. Despite long-standing recognition that conservation hinges upon the knowledge and cooperation of local people (Berkes, 2004), there is little information on the levels of ecological knowledge and nature connection among people living in proximity to many important biodiversity areas in the Global South. One significant specific gap surrounds levels of ecological knowledge and nature connection among non-indigenous colonist farmers who migrated to farm-forest frontiers, where they are important local conservation stakeholders (Campos & Nepstad, 2006). It is also unclear whether ecological knowledge and nature connection have the same or different individual- and landscape-scale determinants, and thus the extent to which their development may be interdependent.

We address these gaps by investigating relationships between ecological knowledge of wild bird species and psychological connection with nature—and their drivers—among colonist farmers living at a major deforestation frontier in the Brazilian Amazon. We test the correlation between ecological knowledge and nature connection, and we identify and compare their geographical, socio-demographic and experiential correlates among local farmers.

1.1 | Theoretical underpinnings of nature connection and ecological knowledge

Psychological nature connection is a multidimensional construct defined as the extent to which a person self-identifies with nature (cognitive connection, also known as *connectedness*; Schultz, 2002) and the extent to which a person feels emotionally attached to nature (called emotional or affective connection; Kals et al., 1999; Perkins, 2010; Schultz, 2002). According to the Inclusion of Nature in Self theory, the stronger someone's nature connection is, the greater is their propensity to empathise and feel concerned for nature's well-being (Schultz, 2002; Tam, 2013b). Thus, nature connection explicitly triggers the biospheric motivation for nature protection, concerned with nature for nature's sake (Schultz, 2001). Numerous measures of nature connection, emphasising different aspects of this multidimensional construct, have been shown to be strongly statistically convergent and underpinned by the same latent general variable (Tam, 2013a). This means that results from studies using different measures related to nature connection can be meaningfully compared under a single framework.

Familiarity with local species and the ability to name them is a component of 'ecological knowledge', defined as the cumulative body of knowledge, practice and beliefs concerned with site-specific interactions between living beings (including humans) and between organisms and their environment (Berkes, 1999; Olsson & Folke, 2001). Ecological knowledge that is accumulated, evolved, and culturally transmitted over generations is termed 'traditional ecological knowledge' (TEK). Groups such as colonist farmers may lack this cultural and historical continuity of interactions with their (new) environments; nonetheless, they can build 'local ecological knowledge' (LEK), based on some mixture of practical knowledge, media and peer learning (Olsson & Folke, 2001). Researchers recognise different, interrelated components of ecological knowledge, such as (a) the names and taxonomy of living and physical components of an ecosystem; (b) the functions, behaviours, uses and properties of each component; (c) management practices and institutions to govern ecosystem use and (d) belief systems informing the ethics of people's interactions with their environment (reviewed in Berkes, 1999). The propensity to name and categorise organisms is evident cross-culturally; humans appear to have an innate system primed for the recognition of life forms and their ordering into taxonomies (Medin & Atran, 2004). Thus, the ability to name species, though not exhaustive of ecological knowledge, can be regarded as its fundamental form—the first layer of familiarity with one's ecosystem.

1.2 | Evidence for and against a link between ecological knowledge and nature connection

Several studies indicate that ecological knowledge relates positively to nature connection and other related concepts, such as 'environmental sensitivity' or positive attitudes towards birds. For example, Hammond and Herron (2012) found that university students in Mississippi with higher self-reported 'environmental sensitivity' ('having empathy for or relating to other living things or nature in general', p. 120) were more knowledgeable about identification and natural history of local fauna and flora than their peers. Cox and Gaston (2015) showed that the extent to which British people liked different bird species and 'felt connected to nature when watching birds in their gardens' was positively related to their bird identification skills. Finally, White et al. (2018) found that bird identification knowledge and positive attitudes towards birds among British schoolchildren were positively correlated, although changes in attitudes and changes in knowledge following a 6-week bird feeding and monitoring programme were unrelated.

However, Lumber et al. (2017) found very different results in a UK-based psychological study using a validated nature connection measure in online surveys and a quasi-experimental intervention based around a nature walk in a university campus park (Lumber et al., 2017). Their results suggested that knowledge-based activities were ineffective at increasing nature connection, which was instead enhanced by activities based on finding contact, emotion, beauty, compassion, and symbolic meaning in engagements with nature. However, these authors measured only engagement in activities related to studying or 'finding out more' about living organisms, and how much participants valued this engagement, not how much they knew about nature. But ecological knowledge is cumulative and can be transmitted through various forms of interpersonal communication and engagement with nature (Almeida et al., 2018; Olsson & Folke, 2001) and does not have to correlate with science-inspired activities. Thus, there remains a gap in understanding the relationship between nature connection and levels of ecological knowledge.

1.3 | Drivers of nature connection and ecological knowledge

Ecological knowledge and nature connection are rarely examined together, and it is unclear whether they are influenced by the same factors. Nonetheless, both are theoretically and empirically recognised as rooted in people's unique personal experiences of nature (Clayton et al., 2017; Miller, 2005; Soga et al., 2016; Turvey et al., 2010). Drawing on the largely separate literatures on ecological knowledge and nature connection, we can identify groups of environmental, social and geographical factors that may shape them simultaneously. These groups include what we here refer to as ‘nature-contact’, ‘nature-reliance’ and ‘nature-access’ factors.

Nature-contact factors relate to the type and amount of nature experiences that people have and are key drivers identified in the nature connection literature. Research indicates positive associations between the frequency of past and present nature experiences and various measures of nature connection (e.g. Kals et al., 1999; Soga et al., 2016). There is also evidence of a positive feedback loop because people who visited natural spaces in childhood and those with higher nature connection are more likely to continue visiting natural areas in adulthood (Lin et al., 2014; Rosa et al., 2018). Formal education can also be classified as a nature-contact factor, emerging from the ecological knowledge literature. Education has been frequently (but not always) linked to losses of traditional ecological knowledge among indigenous populations (Aswani et al., 2018, p. 2) because it often reduces the time that children spend in natural areas, either alone or with knowledgeable elders (Demps et al., 2015). The effect of education on nature connection remains less explored.

Nature-reliance factors affect the extent of people's direct material reliance on nature to satisfy basic needs such as food, shelter and medicine. These factors relate to broad-scale socio-environmental transformations including modernisation (spread of technology, urbanisation, modern health services), market integration and growing wealth. These transformations are the principal candidate explanations for declining ecological knowledge in traditional populations (Aswani et al., 2018; Pilgrim et al., 2008), which act by changing people's lifestyles and by lowering people's direct reliance on natural ecosystems and thus the need for intimate knowledge of the local environment. Pilgrim et al. (2008) also suggested that increases in societal wealth are likely to similarly negatively affect whether people care about nature, but this hypothesis remains largely unexplored.

Nature-access factors relate to the accessibility of nature experiences. Declines in biodiversity, natural habitats and restrictions to accessing remaining natural areas, for example, former common lands, have all been linked to losses in ecological knowledge, presumably through decreased opportunities to interact with nature (Barreau et al., 2016; Kai et al., 2014; Miller, 2005). There is also evidence that the ‘extinction of experience’ resulting from physical separation from nature, most extreme in many cities, may lead to disconnection from nature among urban dwellers, especially children (Miller, 2005). For example, in Stockholm, children attending preschools located close to areas offering diverse nature experiences were more empathetic towards the natural world than children from preschools with lower access to such areas (Giusti et al., 2014).

Beyond factors related to contact, reliance and access to nature, differences in ecological knowledge and nature connection have been associated with socio-demographic factors such as gender, age and culture (e.g. Aswani et al., 2018; Luck et al., 2011), although the directions of these associations are context-dependent.

1.4 | Nature connection and ecological knowledge at deforestation frontiers

It is important to understand the relationship between nature connection and ecological knowledge in the Global South, particularly at tropical forest-farm frontiers where biodiversity loss is often most intense (Barlow et al., 2018). Many such frontiers are characterised by remoteness and relatively weak state presence and are inhabited by colonist farmers without traditional ties to the land, and whose individual decisions collectively shape the landscape and hence conservation outcomes (Fearnside, 2008). Farmers who care more about nature appear relatively more engaged in conservation (Gosling & Williams, 2010), for example, setting aside more forest for protection (Rueda et al., 2019). Local ecological knowledge can help the colonist farmers decide, for example, where to plant to get better yields, or to notice changes in the population of an animal species. But do farmers need to gain intimate knowledge of the local biodiversity before they feel compelled to protect it? Do farmers with better ecological knowledge care more about biodiversity? Understanding the knowledge-connection relationship could help answer these questions and inform conservation engagement programmes, many of which currently rely on promoting factual knowledge and awareness of biodiversity as a way of fostering pro-conservation views (e.g. Howe et al., 2012; Vieira et al., 2016).

1.5 | Study aim and research questions

Here we assess the relationship between ecological knowledge and nature connection in the Transamazon Highway region, a mature Amazonian forest-farm frontier. We address this main aim by asking two research questions. First, is there a positive relationship between ecological knowledge and nature connection among Transamazon colonist farmers? We achieve this by comparing two validated, independent measures of nature connection with two purposely developed measures of ecological knowledge based on the ability to identify local forest and non-forest bird species. Second, do ecological knowledge and nature connection share common drivers? This is answered by examining the roles of access to, contact with and reliance on nature. In addition, we assess how knowledge of birds and nature connection varies according to social and demographic characteristics including geographical origin, gender and age. Because we make use of observational data and cannot infer causality, we talk about predictors and associations rather than drivers and effects when discussing our results. We sample various farms across the region to capture diverse experiences of nature, which we expect to relate to high levels of variation in remaining forest cover, urban accessibility and household reliance on forest foods.

2 | METHODS

2.1 | Study site

Our study area is located around the Transamazon Highway, in the south-eastern Brazilian Amazon in Pará state (see Figure 1). The development of this deforestation frontier was initiated in the 1970s by Brazil's then-military government. Its purpose was to consolidate Brazil's geopolitical claim to the Amazon, connect the region with the rest of the country through road-construction, and to provide farming opportunities for smallholders displaced by agricultural mechanisation and natural disasters in the South and the North-East Regions of Brazil (Moran, 1981). Before the early 1970s, it was sparsely populated, mostly by indigenous peoples and *caboclo* rubber-tappers (traditional people of mixed European, indigenous and African origin), and almost completely covered with old-growth forest (see Moran, 1981 for historical background). Since road-based colonisation, the Transamazon Highway region has lost *c*. 30% of forest cover (INPE, 2018).

Nowadays, rural landscapes around the Transamazon Highway are a mosaic of agricultural land, forest fragments and forest reserves, inhabited by thousands of predominantly farming families (Figure 2). The region can be classified as a 'mature deforestation frontier'; after nearly five decades since road-based colonisation began, it has intermediate levels of market accessibility and forest

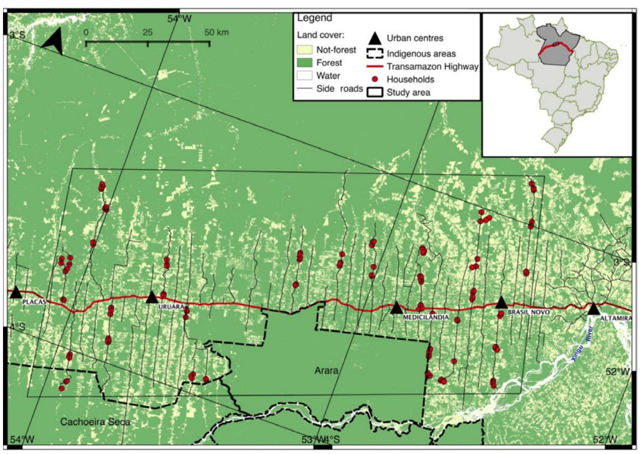

FIGURE 1 Study area. Inset map shows location within Brazil. The bounding box covers *c*. 17,838 km^2

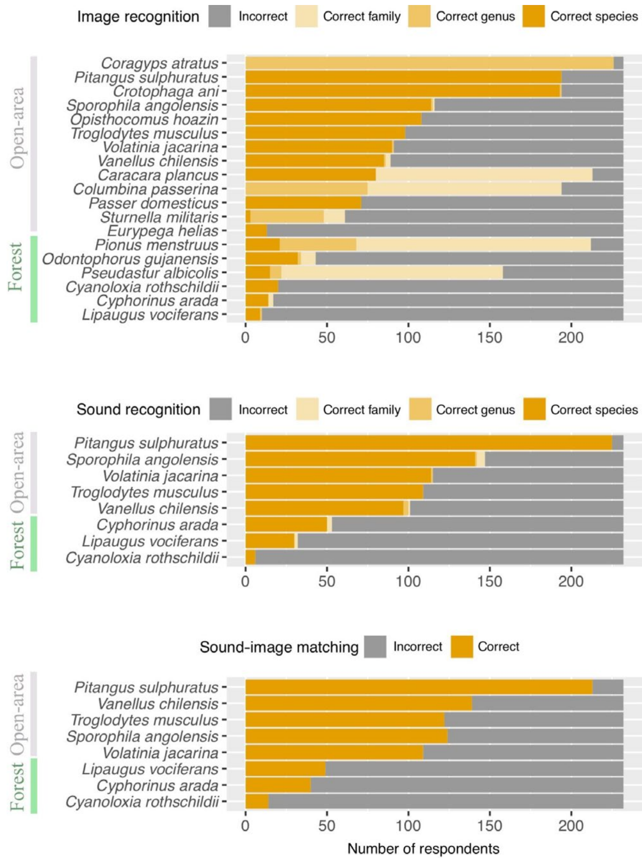

FIGURE 2 Species recognition based on images, sounds and sound–image matching. Species were ranked by whether they were non-forest or forest associated species, and then by the combined total of the correct genus- and species-level identifications

cover, relative to new frontiers and post-frontier areas (Schielein & Börner, 2018). Throughout this time, and despite strict federal forest-protection laws and hunting regulations (El Bizri et al., 2015; Soares-Filho et al., 2014), the apparatus of the state has been weak, with under-resourced enforcement and ineffective judicial system, leaving the region under ongoing pressure from forest loss, fragmentation degradation and defaunation. Recent relaxations of environmental and hunting regulations by President Bolsonaro's government are likely to further aggravate this situation (Abessa et al., 2019).

2.2 | Study design and questionnaire application

Sampling was stratified to capture variation in local forest cover and distances from the sub-regional urban centre Altamira (Table 2). In all, 45 sampling points were selected along 15 side-roads running perpendicular to the highway (details in Mikołajczak et al., 2019). Six points were abandoned due to accessibility issues or apparent lack of inhabitants. At each point, we aimed to interview the male and female heads of families owning four properties closest to the sampling point. Following prior, informed consent (written or verbal, depending on the preference of the respondent because some interviewees felt uncomfortable signing

TABLE 2 Descriptive statistics for the response and independent variables in the complete dataset ($n = 227$)

Variable group	Variable	*M*	*SD*	Median	Range
Response variables					
Ecological knowledge	Non-forest EK total score (max = 23)	12.02	5.00	12.00	1.00–22.00
	Forest EK total score (max = 11)	1.52	1.88	1.00	0.00–10.00
Nature connection	Inclusion of Nature in Self (INS) score (min = 1, max = 7)	5.19	1.47	5.00	1.00–7.00
	Love and Car for Nature—Rural (LCNR) score (min = 1, max = 5)	4.50	0.63	4.71	2.14–5.00
Independent variables					
Nature-contact factors	Current frequency of contact with nature (max = 8)	4.83	2.04	5.00	1.00–8.00
	Childhood frequency of contact with nature (max = 4)	2.74	1.15	3.00	1.00–4.00
	Years of education	5.05	3.90	4.00	0.00–19.00
Nature-reliance factors	Subsistence index (max 27)	5.84	5.16	5.00	0.00–24.00
	Distance to Altamira (km)	141.40	71.89	112.63	41.98–261.50
	Distance to closest town (km)	21.88	12.50	23.69	0.98–54.45
Nature-access factors	Forest cover (% within 500 m around household)	51.28	17.76	51.12	14.28–92.80
Socio-demographic factors	Age	46.85	13.00	48.00	18.00–75.00
	Gender	Female: 97 Male: 135			
	Origin	Amazonian: 123 Other: 109			

documents), questionnaires were completed in face-to-face interviews in Portuguese. Besides measures explored in this study, questionnaires included data on economic status and attitudes and beliefs regarding agriculture and nature conservation in the area. The research was approved by the Lancaster University Research Ethics Committee (RS2015/68).

2.3 | Ecological knowledge measures

Our ecological knowledge measures were based on the ability to recognise local bird species. We chose birds as they are ubiquitous, are commonly used in research on ecological knowledge of species, many are relatively easy to identify for non-specialists and most have little utilitarian value locally (few species are regularly hunted). Therefore, we consider bird identification skills a good proxy for general ecological knowledge of species identification. Additionally, based on our previous observations from the Amazon basin, we suspected that the colonist farmers will be more familiar with species commonly observed near human settlements and in heavily anthropogenically modified habitats than forests. To maximise the chances of identifying knowledgeable 'experts' but also differentiating between people at the lower end of knowledge levels about bird species, the species in our sample were chosen to (a) represent both forest and non-forest habitat, (b) be relatively common locally (Lees et al., 2013a, A. C. Lees unpublished abundance data for the neighbouring region of Santarém, Pará) and (c) be comparably easy to identify in the field without binoculars. The selected species are also not commonly hunted or persecuted, although some species are prized as cage birds.

Participants were asked to name species from two bespoke plates with photographs of 19 birds: 13 non-forest species that occupy agricultural areas and six forest-associated species (Table S2). To account for the possibility that some birds may be easier to recognise by sound than by sight, we then played calls of a sub-sample of eight species (five non-forest and three forest) with easily recognisable songs and calls and asked the participants to name the species. Lastly, to account for the possibility that respondents may recognise species but not necessarily know their common names, we asked the participants to match the recorded calls to the images. Thus, we obtained three complementary—but not fully independent—measures of bird recognition. Some names proffered by interviewees did not exactly match the target species but could be matched to closely related species or higher-level classifications, roughly corresponding to genus and family level. To account for this, names were scored for correctness at species and approximately genus and family level. See Supporting Information Section S3 for further details on ecological knowledge measures construction and scoring.

2.4 | Nature connection measures

Nature connection was scored by two independent methods. The cognitive nature connection (the extent to which one believes themselves to be part of nature) was measured with the Inclusion of Nature in Self scale (INS; Schultz, 2002) and the affective nature connection was measured using the Love and Care for Nature—Rural (LCNR) scale (Mikołajczak et al., 2019). The Inclusion of Nature in Self (INS) is a single-item graphic instrument depicting seven Venn-diagrams of two progressively overlapping circles representing 'self' and 'nature'. The INS was measured using the following instructions: '*The two circles indicate you and nature. Please indicate which of these drawings best represents your relationship with the natural environment. How connected are you with nature?*' The 'Love and Care for Nature—Rural' is a 5-item Likert-like scale, with responses measured from 1 = 'Completely disagree' to 5 = 'Completely Agree', aimed to capture feelings of love, caring, awe, and psychological well-being derived from nature. The same dataset on LCNR and INS scores that is used here has been previously used to validate these measures in our study area (Mikołajczak et al., 2019).

2.5 | Socio-demographic and nature-experience-related factors

The explanatory variables included a selection of nature-contact, nature-reliance and nature-access indicators, as well as socio-demographic factors. The measures of nature contact, reliance and access were focused on forests, rivers and lakes as exemplifying natural spaces. This was guided both by the disproportional conservation value of forest habitats (relatively few Amazonian species have managed to adapt to modern agriculture and deforestation practices), as well as by the local people's perceptions of 'naturalness'. Based on pre-study interviews (November 2015), animals and forests appeared uniformly regarded as parts of 'nature'. The terms 'forests' (port. 'mata', 'floresta') were frequently used interchangeably with 'nature' (port. 'natureza') and in opposition to pasture, which some even referred to as 'deserts'. Importantly, the term 'forest' appeared inclusive of both primary and regenerating forests, as well as agroforestry plantations.

Nature contact was indicated by years of formal education (negative indicator), current nature contact (indicated by the frequency of visits to natural habitats like forest, rivers and lakes) and frequency of nature contact in childhood (see Supporting Information). Indicators of direct reliance on nature included a forest-foods subsistence index (see Supporting Information), travel distance to sub-regional city (Altamira) and travel distance to the nearest market town. Nature access was indicated by per cent forest cover within a 500 m buffer around the house and calculated based on Global Forest Change maps (Hansen et al., 2013; see Supporting Information). Socio-demographic variables comprised age, gender and origin (whether participant grew up in an Amazonian state or elsewhere).

2.6 | Analysis

Data cleaning, checking for consistency and all the statistical analyses were conducted in R version 3.5.1. (R Core Team, 2018). The different ecological knowledge measurement methods and species name scoring methods were compared through Pearson correlations (details in Supporting Information). Correlation and multicollinearity of predictor variables were low and not considered to be an issue—Pearson correlations between pairs of continuous predictors were below 0.25 except for age and education ($r = -0.38$), and Variable Inflation Factors were below 2, as assessed using the imcdiag function in the MCTEST package ver 1.2 (Imdadullah et al., 2016). Relatedness between nature connection and ecological knowledge measures was assessed using Spearman correlations; significance was tested using t tests with Holm correction for multiple tests (alpha = 0.5).

Generalised linear models with beta-binomial error distribution and logit link were used to test the associations between socio-demographic and nature-related factors as predictors and LCNR, INS, forest bird ecological knowledge and non-forest bird ecological knowledge as outcome variables. The models were run on complete cases data ($n = 227$) using the package GAMLSS ver. 5.1 (Stasinopoulos & Rigby, 2007). Continuous predictors were standardised by centring and dividing by two standard deviations and the binary predictors (gender, origin) were centred (rescale function in package ARM). A predictor was considered significantly associated with an outcome variable if the 95% confidence interval of the estimated beta-coefficient did not contain 0.

Beta-binomial models are appropriate for modelling data in the form of a discrete number of successes in a fixed number of trials with unknown probabilities. In our models, each point that was 'scored' on a nature connection or an ecological knowledge scale counts as a single 'success' on that scale. For example, for the LCNR measure, respondents score their agreement with each of the seven items on a five-point ordinal scale, so when the lowest answers are counted as zeros, the respondent's total score can be interpreted as the number of successes out of 28 trials with unknown probabilities. The beta-coefficients can be interpreted in the same way as for the logistic regression: when all other terms in the model are held constant, the exponent of a beta-coefficient is the odds ratio of success (OR) for a one-unit change in the corresponding predictor. The OR for an x-unit change in a predictor is calculated by raising the beta-coefficient exponent to the power of x. For the standardised predictors in our models, ORs for a one-unit change on the original scales were calculated by diving the beta-coefficients by two standard deviations before taking the exponents.

Additionally, having found much inter-species variation in recognition rates, we ran a post-hoc mixed-effects logistic regression for the probability of recognising a bird species from an image ($n = 4,408$ observations), exploring the effects of species body mass (EltonTraits, Wilman et al., 2014), habitat (forest/non-forest), our subjective assessment of ease of visual detection (high, medium and low) and relative abundance (high/low) based on a survey in Santarem (Lees et al., 2013b, unpubl. results) which was separated for forest and non-forest species. We used the species ($n = 19$) and respondent id ($n = 232$) as random effects.

3 | RESULTS

3.1 | Participant characteristics

In all, 241 respondents from 147 properties participated in our study and our complete case data included 227 respondents. Participants were aged 18–75 (*M* 47.0, *SD* 13.4); 13% had no formal education, most (71%) had at least some primary schooling (median formal education was 4 years), 12% completed high school and 4% had at least started higher education (Table 2). No participants self-identified as indigenous. Smallholders (≤100 ha) represented 51% of interviewees, medium landholders (101–600 ha) 46% and large landholders (>600 ha) 3%—which, incidentally, corresponds closely to their regional frequency distribution (Godar et al., 2012).

3.2 | Bird identification knowledge

On average, respondents recognised 46%–61% of non-forest bird species and 12%–15% of forest species at the genus level (Figure 2; Table S2), depending on the method of recognition (by image, sound or sound–image matching). Knowledge of forest-associated birds was highly skewed, with most respondents, especially women, able to recognise very few species, while knowledge of non-forest birds was more normally distributed (Figures 3 and 5).

Different name scoring methods (correctness at family, genus or species level) were highly congruent with each other (r = 0.96–0.99). Different bird recognition methods (from image, sound, sound–image matching or combined score) were positively correlated (r = 0.41–0.83) but showed some differences (Figures S1 and S2). Therefore, for subsequent analysis, we used the sum of recognition scores for images, sounds and sound–image matching, with image and sound recognition scored at the genus level, separately for forest and non-forest species. This produced two ecological knowledge measures (one for each habitat) that were less biased towards any single recognition method, although more strongly weighted towards those species which were included in all three methods.

The post-hoc analysis of interspecific visual recognition rates revealed strong effects of habitat, body mass and relative abundance (Figure 4, see Table S3 for model statistics). All else held equal, the odds of correct identification were 9.53 times higher for the locally common versus rare species, 8.43 times higher for non-forest versus forest species and increased 1.17 times for a 100 g increase in body mass.

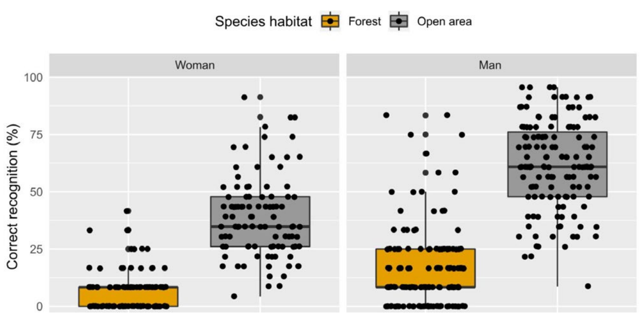

FIGURE 3 Tukey boxplots showing per cent recognition score of bird species based on combined scores for recognition from image, sound and sound–image matching, separated by respondent's gender and birds' habitat association

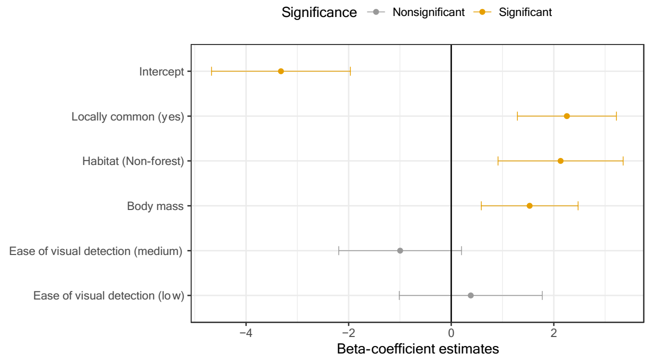

FIGURE 4 Results of a mixed-effects logistic regression modelling the probability of correct visual recognition of bird species, showing the standardised beta-coefficients of fixed-effect predictor variables with their 95% confidence intervals

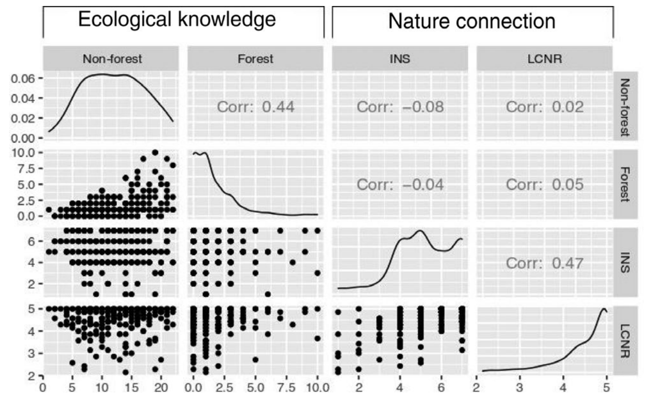

FIGURE 5 Pairs plots of ecological knowledge and nature connection measures. INS = Inclusion of Nature in Self (cognitive nature connection), LCNR = Love and Care for Nature—Rural (affective nature connection), Forest = number of forest-associated birds and Non-forest = number of non-forest bird species recognised by each participant. Panels along the diagonal display the distributions of the four variables with *y*-axis showing density and *x*-axis variable scores; panels to the right and above the diagonal show Spearman correlations between the four measure pairs; and panels to the left and below the diagonal show scatterplots between measure pairs, with units corresponding to variable scores

In summary, respondents generally held more knowledge of local non-forest bird species and poor knowledge of forest-associated species, with larger and more common species recognised more often than others.

3.3 | Nature connection

Nature connection levels for this sample, as measured with the INS and LCNR scales, were originally described in Mikołajczak et al. (2019). The distributions of nature connection measures showed a strong tendency towards high values in both scales, which was particularly pronounced in LCNR (Table 2; Figure 5), suggesting the possibility of a ceiling effect in the LCNR scores.

3.4 | The relationship between ecological knowledge and nature connection measures

The ecological knowledge measures and nature connection measures were not correlated ($r = -0.04$ to 0.05, all $p \geq 0.88$; Figure 5). By contrast, the two measures of nature connection—INS and LCNR—were moderately strongly correlated to each other (Spearman correlation = 0.47, $p < 0.01$), as were the two measures of ecological knowledge (Spearman correlation = 0. 44, $p < 0.01$).

3.5 | Associations with socio-demographic and nature-experience-related factors

There was no similarity between the correlates of ecological knowledge of birds and nature connection (Figure 6; see Tables S4 and S5. for model statistics). Ecological knowledge associated significantly only with socio-demographic factors, indicative of cultural and individual differences. Specifically, men were more knowledgeable than women (Figure 3); men's odds ratio of scoring a point were 2.33 times higher on the forest-birds knowledge scale and 2.72 times higher on the non-forest species knowledge scale. Additionally, knowledge of non-forest species was lower among older generations, with 0.90 times lower OR for a 10-year difference in age. Neither knowledge about the forest or non-forest birds was associated significantly with any of the nature-contact, nature-access or nature-reliance measures.

Both the cognitive and emotional connection measures increased with age (OR increased 1.45 times for LCNR and 1.26 for INS for an age difference of 10 years between the respondents), in contrast to ecological knowledge measures. The cognitive nature connection also showed the predicted associations with two nature-contact measures, namely, it associated positively with the current frequency of visits to natural areas (OR increased 1.11 times per one-unit increase), and negatively related to years of education (OR decreased 0.77 times for a difference of 5 years of schooling between the respondents). Additionally, emotional nature connection was significantly associated with origin; people raised in Amazonia felt more connected with nature than those who grew up elsewhere (OR 1.72 times higher). The only nature-reliance factor significantly associated with a nature connection measure was distance to the main sub-regional city Altamira; people living farther away from this city felt slightly less emotionally connected to nature than those living closer by (OR 0.67 times lower for a 100-km difference in household distance from Altamira).

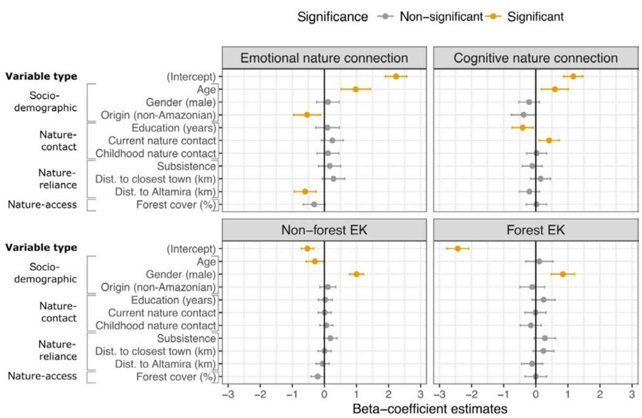

FIGURE 6 Generalised linear model results for nature connection and ecological knowledge of bird species, showing the standardised beta coefficients of predictor variables with their 95% confidence intervals

Knowledge of forest and non-forest bird species shared similar (though not identical) patterns of associations with explanatory variables; there were also similarities between the patterns of associations of the two nature connection measures. Conversely, none of the significant associations found between ecological knowledge and explanatory variables were also found for nature connection measures or vice versa. Four of the explanatory variables—the frequency of childhood visits to natural areas (a nature-contact measure), forest cover (the nature-access proxy), subsistence on forest foods and distance to Altamira (nature-reliance indicators)—had no significant association neither to nature connection nor ecological knowledge.

Taken together, the low correlations and contrasting sets of predictors indicate that ecological knowledge of birds and nature connection are unrelated in our study population and are linked to disparate factors related to nature experience.

4 | DISCUSSION

Contrary to a common conservationist discourse (Table 1), our survey of Amazonian colonist farmers across diverse landscapes at an Amazonian deforestation frontier found no evidence that people with greater ecological knowledge of species feel more strongly connected to nature. Moreover, knowledge and connection did not share any predictors in common, indicating that they are shaped by different social processes. These findings were consistent across the two measures of nature connection we employed (cognitive Inclusion of Nature in Self and emotional Love and Care for Nature—Rural scales) and across our two measures of ecological knowledge—one for non-forest species and other for forest-associated bird species. We also found that Transamazonian farmers tend to have high levels of nature connection, moderate ecological knowledge of non-forest bird species and very low ecological knowledge of forest bird species; they also recognise large and abundant birds more often than others.

Farm-forest landscapes are critical arenas in which tropical habitats and biodiversity are declining (Barlow et al., 2016), yet they have been largely overlooked by conservation psychology research (Mastrangelo et al., 2014). In these Amazonian settings, where traditional forest peoples have been largely pushed out to reserves, with much territory lost to agriculture expansion, colonists have come to be recognised as key ‘conservationist actors’ (Campos & Nepstad, 2006). We show that the colonist farmers can develop a relatively strong connection with nature, even without traditional ties to the land or detailed knowledge of local biodiversity. However, their capacity for protecting the local environment may be constrained by poor knowledge of forest taxa (Peterson et al., 2008), particularly in the case of small, rare and inconspicuous species which form the bulk of the forest-associated fauna. More generally, our findings, which contrast with previous studies from Europe and the United States, imply that the link between ecological knowledge of species and nature connection is context-dependent and highlight the need to better understand the specific mechanisms that shape each one of them.

4.1 | When is knowing nature related to caring about nature?

We show that the positive relationship between ecological knowledge and nature connection, found in the United States and the United Kingdom, is not universal. We found no correlation between knowledge and connection; most people felt strongly connected to nature, but their knowledge of bird species varied widely (Figure 5). Notably, even some of the few people who were expert at identifying birds had below-average nature connection. Although our ability to detect relationships may have been impaired by a possible ceiling effect (i.e. saturation) in the affective nature connection measure, the tendency for high scores on nature connection measures is not uncommon (e.g. Cox & Gaston, 2015). Moreover, the independently measured cognitive connection was also unrelated to either measures of bird identification knowledge, suggesting that the lack of significant relationship between ecological knowledge and nature connection is not merely a statistical artefact.

Our findings are congruent with recent psychological research exploring what types of nature experiences promote a holistic, committed relationship with nature among adults and children (Giusti et al., 2018; Lumber et al., 2017; Richardson & McEwan, 2018). This literature emphasises the role of experiences involving embodied interactions with natural spaces, exploration, contemplations of nature's beauty, play and compassion as effective pathways to generate nature connection; crucially, it attributes only a limited role to learning environmental facts. Yet, our results clash with other research showing that levels of knowing and caring about nature covary (Cox & Gaston, 2015; Hammond & Herron, 2012; White et al., 2018). Where does this discrepancy come from?

The association between ecological knowledge and nature connection is inevitably influenced by the choice of measures. Social psychology shows that behaviour-specific attitudes correlate with pro-environmental behaviour much more closely than general pro-environmental attitudes (St. John et al., 2010). Consequently, we might expect that object-specific measures of ecological knowledge (e.g. bird identification skills) will correlate more closely with measures indicating connection with specific elements of nature (e.g. attitudes towards birds) than with measures of general nature connection, such as those we used.

To assess nature connection across people with different levels of ecological knowledge, the choice of taxa used to estimate this knowledge also matters. We show that species with attributes such as large body size, high abundance and ease of observation are easier to identify than others, highlighting the importance of including species with diverse traits to distinguishing experts from less knowledgeable people. Our selection of birds was purposively skewed towards species that we expected to be easily recognised. It proved well suited for our study population, with good differentiation between people across the scale of ecological knowledge. In populations with higher average knowledge, the inclusion of 'harder' taxa, such as invertebrates and small mammals (Medin & Atran, 2004), could improve the ability to discriminate between individuals with high levels of ecological knowledge. Conversely, including 'easy' taxa like large mammals could extend the lower end of the scale where necessary.

The contrast between our research in rural Amazonia and the results from US- and UK-based studies suggest that the relationship between ecological knowledge and nature connection varies with the socio-cultural and ecological context. We cannot rule out that ecological knowledge and nature connection may in some conditions stimulate one another. However, our results also suggest that knowledge and connection are shaped by separate processes, shown by the apparent lack of common predictors and opposing associations with age: positive for connection and negative for knowledge. This conclusion is supported by the contrasting effects of modernisation and wealth in other studies. For example, in a cross-cultural study across India, Indonesia and UK, these factors associated with lower ecological knowledge and its concentration among a few specialists (Pilgrim et al., 2008), but in a longitudinal US study, these same drivers promoted an intergenerational shift towards seeing wildlife more as human-like and deserving of care (Manfredo et al., 2020). Hence, we caution against assuming that ecological knowledge and nature connection are co-dependent. Instead, we recommend focussing on understanding the mechanisms that drive them.

4.2 | Who is connected with nature?

Even though many Amazonian agriculturalists equate cultivation and conversion of natural land with progress and success (Hoelle, 2018), we found that most farmers in the Transamazon Highway region felt strongly connected to nature. Nature connection measures were related to a mix of socio-demographic factors, nature-contact and nature-reliance measures. Previous studies show a clear association of nature connection with nature contact (e.g. Soga et al., 2016); we only found this association for our cognitive measure of connection but not for the affective measure. This could be an artefact of our contact measures, which were based on the frequency of visits to natural habitats such as forests, rivers or lakes, whereas it is possible that strong emotional connection to nature can be built and sustained through nature experiences happening close to home, such as overflights by colourful birds like macaws in agricultural areas.

Furthermore, the apparent lack of a relationship between nature connection and forest cover suggests that the importance of physical access to nature is secondary to social factors that shape whether and how people interact with it.

We found nature connection increases during adulthood, supporting previous studies (Hughes et al., 2019). A possible explanation might be a gradual increase in the cognitive and emotional bond between a person and place (Baldwin et al., 2017). Older colonist farmers have typically lived in Amazonia and on their properties for longer than younger counterparts, providing greater opportunities for attaching to nature on their properties (Bogdon, 2016). We found no evidence of a nature-connection gender gap in Amazonia, contrasting with previous work in the United States and China (Schultz & Tabanico, 2007; Tam, 2013b). Those studies attributed higher nature connection among women to gendered forms of socialisation, including expectations of caring for others' welfare. We also found evidence that people who grew up in Amazonia as children have stronger emotional connection to nature than people who have migrated to Amazonia later in life. This may be due to cultural differences because farmers with Amazonian ancestry (e.g. descendants of rubber tappers, extractivists) typically have more favourable views of forest-based livelihoods and are less enthusiastic towards large-scale deforestation than farmers from other parts of the country (Hoelle, 2018; Oestreicher et al., 2014).

We did not find support for Pilgrim et al.'s (2008) assertion that nature connection is positively related to nature reliance. Neither the relative dependency on forest foods (low on average, Figure S3) nor distance to the nearest market town, presumed to indicate reliance on subsistence foods, related to nature connection. Unexpectedly, however, we found that people living nearby to the sub-regional city Altamira reported somewhat higher emotional nature connection than those living farther away. Perhaps this reflects a spatial gradient in the activity and influence of environmentalist NGOs, government regulatory bodies, academic researchers and agricultural extension services. These institutions generally champion the view of small and medium landholders as custodians of the local environment (Schwartzman et al., 2010; de Toledo et al., 2017) and most of them operate out of Altamira. Farmers may respond to these interactions over time with a change in their underlying nature connection, and/or changes in the way they talk about the environment with outsiders (i.e. a potential reporting bias for psychological surveys).

Overall, it appears that nearly 50 years of forest loss and socio-environmental transformation in eastern Amazonia have not resulted in any clear 'extinction of experience' and a resultant loss of nature connection, counter to the tendency in the Global North (Miller, 2005).

4.3 | Who knows about nature?

Transamazonian farmers appear to have low-to-moderate ecological knowledge, placing them somewhere on a spectrum between highly knowledgeable traditional peoples and the industrial societies where ecological knowledge is generally low but skewed by knowledgeable specialists (Medin & Atran, 2004; Pilgrim et al., 2008). Amazonian colonists arrived with little prior knowledge of the Amazonian environment (Moran, 1977). Some of the bird species living in the Amazon are the same or similar to species found in other parts of Brazil, so migrant farmers could have had pre-existing knowledge of them. However, in the case of Amazonian endemics, this knowledge is presumably built mainly through the farmers' own, sometimes inter-generational, experiences. Whereas shapes and behaviours can be learned from observation alone, names are harder to learn, given they are normally acquired from other knowledgeable people and sometimes media. Indeed, we found that for some birds, respondents could correctly match their images and sounds, but did not always know their names (Table S1).

The social basis of ecological knowledge acquisition was reinforced by our finding that knowledge of forest and non-forest birds was related only to socio-demographic factors, but not to nature-access or nature-contact measures. However, our contact measures focused only on the frequency of visits to natural habitats but did not account for time spent in agricultural areas, which could relate specifically to knowledge of non-forest birds, so this gap remains to be explored. The two factors that related to ecological knowledge were age and gender. Younger farmers were more knowledgeable about non-forest bird species than older respondents, resonating with a study of migrant farmers in Sumatra (Nyhus et al., 2003). We also found that men were far better than women at recognising bird species. This gendered gap in ecological knowledge is context-specific and has been found also in the United States, United Kingdom and the Narok region in Kenya (Huxham et al., 2006; Kassilly, 2006; Kellert et al., 1987), but not in the Netherlands (Hooykaas et al., 2019) or the Nkuru region in Kenya (Kassilly, 2006). The gendered differences in ecological knowledge are likely explained by the division of labour and resulting differences in exposure to nature, since men generally spend more time outside engaged in farming, agroforestry and occasionally hunting, whereas women traditionally tend to engage in home-bound activities (Oestreicher et al., 2014).

We did not find a positive linkage between reliance on nature and ecological knowledge, in contrast with previous work (Aswani et al., 2018; Pilgrim et al., 2008). Though most of our respondents reported some use of forest products, their livelihoods were rarely dependent on them (Figure S3). There were also no linkages of ecological knowledge with proximity to the nearest urban area or the regional town. Potentially, the associations with nature-reliance measures may have been stronger had we measured ecological knowledge of species of utilitarian value, such as that of medicinal plants or game species.

Some birds were much easier for the colonists to identify than others. Larger and more abundant species were better known than smaller and rare species, resonating with previous studies from Germany and China (Kai et al., 2014; Randler et al., 2007). Another important factor influencing recognition was habitat. Consistent with the results of Nyhus et al. (2003) on mammals, people were much better at recognising non-forest species than the forest ones. This is unsurprising because most of the non-forest species in our sample are widespread throughout Brazil, so migrant farmers could learn to identify them even before coming to Amazonia and could pass this knowledge to their children. Second, in the case of species novel to them, the colonists likely learn to recognise non-forest species first. Farmers tend to spend more time in pastures and plantations than in old-growth forests, and visually detecting elusive forest species is often impossible without binoculars. Nonetheless, poor recognition of forest species implies that farmers may underestimate forest biodiversity and the damage resulting from forest conversion and disturbance, potentially constraining their capacity for conservation (Peterson et al., 2008; Pollock et al., 2015).

5 | CONCLUSIONS

We show that colonist farmers living along a farm-forest frontier in the Brazilian Amazon tend to be strongly connected to nature, but their knowledge of local forest biodiversity remains limited. Contrasting with studies from the Global North, we found no evidence that ecological knowledge and nature connection are related to each other or shaped by the same socio-demographic and nature-experience-related factors. Therefore, we caution against the common assumption of co-dependence between ecological knowledge and nature connection. Where they are considered important for conservation, we recommend focussing on understanding the context-specific mechanisms that drive each one of them. Although willingness and knowledge are both important for nature protection, we must remember that farmers' decisions are also shaped by wider systemic forces, including markets, social norms and the law. To achieve effective and just conservation, the relevant policies, norms and regulations must be harmonised to incentivise pro-conservation practices both socially and economically so that people may feel capable of protecting the environment and maintaining other opportunities to lead lives they have reason to value.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

K.M., A.C.L., J.B. and L.P. conceived the ideas; K.M., A.C.L., J.B., O.T.d.A. and L.P. designed the methodology; K.M., A.C.S. and F.S. collected the data; K.M. analysed the data and lead the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

DATA AVAILABILITY STATEMENT

Anonymous data supporting the conclusions of this manuscript have been archived in the publicly available Dryad archive, available at https://doi.org/10.5061/dryad.08kprr520 (Mikołajczak et al., 2021).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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