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RESEARCH ARTICLE

Application and attitudes: active restoration in the context of biodiversity offsetting

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The global trend in offsetting for no-net-loss (NNL) is increasing, focusing on protecting high-condition habitats and restoring degraded ones. Australia's New South Wales (NSW) Biodiversity Offset Scheme (BOS) promotes active restoration (AR; reconstruction of missing ecosystem properties, AR) on offset sites. We examined (1) the adoption of AR under the BOS, and (2) practical constraints and attitudes toward AR. Records of management actions on 138 proposed offset sites revealed that AR was proposed for 19.3% (12,180 ha) of the total offset area (67,310 ha). For areas with a low-moderate condition score (26,528 ha), AR was proposed for only 27.3% (7248 ha), despite these being the areas where it would be most likely to be necessary. A survey of 111 individuals involved in offsetting policy and restoration revealed that while 76% agreed AR was necessary for NNL, financial constraints were seen as a major barrier. A structural equation model indicated that positive attitudes toward AR rules and AR as a social imperative were strongly linked to agreement on the necessity of AR for NNL outcomes. Our results indicate that attitudes could influence the adoption of AR on offset sites, even in cases where policies are explicitly designed to provide financial incentives for AR, as exemplified in the context of NSW.

Key words: active restoration, attitudes, biodiversity offsetting, no-net-loss, structural equation modeling

Implications for Practice

- Offset policies in New South Wales aim to encourage active restoration (AR), but the actual adoption of AR is limited.
- Challenges to AR go beyond practical issues like costs and seed supply; they also include individual attitudes toward offsetting policies and AR practices.
- Insight into the practical constraints and attitudes surrounding AR is crucial for shaping the design of offset policies and regulations.
- Attitudes toward metrics in offsetting, especially those promoting AR, can influence the decision to carry out restoration on offset sites.

Introduction

Globally, biodiversity offsets are increasingly used as a policy tool to compensate for negative biodiversity impacts incurred through development activities, such as habitat loss, fragmentation, and degradation (Bennett et al. 2017; Droste et al. 2022). Offsets represent the final step in the mitigation hierarchy, compensating for losses that cannot be avoided or minimized (Bull & Strange 2018). Typically, offsetting aims to achieve "no-net-loss" (NNL) or "net gain" of comparable ecological features. This goal is assessed by accounting for the losses and gains in habitat extent and quality or target species occurrence both with and without the offset (Mayfield et al. 2022). These NNL or net gain goals are essential for ensuring that development activities do not compromise the long-term health of ecosystems and the species that depend on them (Rainey et al. 2015).

Under most offset schemes, biodiversity gains are achieved through protecting existing habitats, managing threats, and pressures to encourage natural recovery (passive or assisted regeneration), or actively restoring degraded areas by reconstructing missing ecosystem components (active restoration [AR]) (Maron et al. 2013; Pope et al. 2021). Gains from the protection of good-condition habitats are primarily generated from

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"avoided loss," compared to a counterfactual scenario (i.e. the likelihood of loss in the absence of an offset). However, "avoided loss" metrics have been criticized because of significant uncertainties associated with estimating future losses and a tendency to overestimate the "avoided loss" baselines (Maron et al. 2015; Miller et al. 2015). Management of threats and pressures results in additional gains from improvements in ecological condition from the dispersal, establishment, and growth of native species and populations. While the greatest potential for biodiversity improvements occurs in degraded or low-condition habitats, managing threats and pressures alone may be insufficient to support recovery and AR may be needed (Hannis & Sian 2012; Maron et al. 2018). Consequently, AR is increasingly viewed as necessary to produce NNL and in particular, net gain of biodiversity in the context of offsets (Meli et al. 2017; Jones et al. 2018; Moilanen & Kotiaho 2021).

Gains achieved through offsetting are converted into economic units, which serve as financial incentives intended to encourage landholders to implement land management activities on their properties to improve biodiversity. While many offset schemes incentivize the protection of existing habitats (Hannis & Sian 2012; Miller et al. 2015), others explicitly encourage AR (Maron et al. 2012; Gibbons et al. 2016) by maximizing improvements in biodiversity through degraded habitats. In general, if an offset scheme incentivizes protection and avoided losses, more offset sites will occur in areas of relatively good condition (Fig. 1). However, if incentives are maximized by managing threats and pressures and encouraging assisted natural regeneration, then habitats in moderate condition are more likely to be preferred. Schemes that prioritize AR would more likely target degraded habitats (Oliver et al. 2021). Therefore, an evaluation of the degree to which a specific offset scheme incentivizes AR, natural regeneration, avoided loss, or a combination of these approaches could be achieved by assessing the distribution of offset sites with respect to their initial habitat conditions (Fig. 1). However, even in cases where specific policy settings are intended to favor AR, other externalities, including access to resources or the attitudes of individuals involved in a scheme could influence the uptake of restoration in practice.

Biodiversity offsetting often elicits strong and diverging views. On the one hand, it has been proposed as a pragmatic and systematic approach to ensure accountability for development that negatively impacts biodiversity (Tucker et al. 2018), yet it has also been viewed as facilitating and legitimizing biodiversity loss (Spash 2015). Adverse attitudes toward offsetting could contribute to negative views toward AR on offset sites (Sullivan & Hannis 2015). In addition, there may be concerns over the legitimacy of the rules and policies underpinning an offset scheme's functioning. For example, offset schemes measure NNL and net gain after converting biodiversity into transactable units. Individuals may oppose the construct of biodiversity as a commodity, the resolution or scale by which those units are measured, or the metrics through which the units are calculated. As a result of these concerns, a landholder or the intermediaries who advise them may be willing to undertake restoration but disagree with the principles or rules of an offsetting scheme (Plant & Ruoso 2023) and therefore, choose to engage in an alternative conservation agreement (Selinske et al. 2022).

Even if individuals are motivated to undertake AR and receive financial compensation through programs such as offsetting, they may have insufficient access to the resources needed to undertake restoration work (Gibson-Roy 2018; Cortina-Segarra et al. 2021). Previous studies have emphasized that both uptake and success of AR depend on access to various forms of capital including adequate financial, physical (e.g. seed supply, tube stock, and machinery) (Gibson-Roy et al. 2021*a*), information (e.g. knowledge of restoration practices), and human capital (e.g. skilled and available people to complete the restoration work) (Ntshotsho et al. 2015). When access to these resources is limited, restoration projects may become difficult, costly, or unfeasible (Fisher et al. 2019). A further impediment to AR is the risks and uncertainty of outcomes when applying AR (Bidaud et al. 2017). The literature on AR contains ongoing debates regarding the feasibility of restoration under certain conditions. Key points include a lack of knowledge about the ecosystem and appropriate management interventions (Brudvig & Catano 2021); the viability and affordability of fully restoring highly degraded land (Holl & Aide 2011); or whether the impacts of ongoing disturbances can be effectively managed (Jentsch 2007; Suding 2011). Additional debates around restoration exist, including the definition of restoration (Martin 2017), the acceptability of creating novel ecosystems through restoration efforts (Miller and Bestelmeyer 2016), and the identification of appropriate target states (Hallett et al. 2013). All of the aforementioned contribute to uncertainty in the outcomes of AR.

Offsetting policies may incentivize AR through increased compensation in low-moderate condition habitats. This can be tested by exploring the range of habitat conditions on offset sites. If the policy does not result in the expected outcomes, it may be due to cognitive factors such as attitudes toward offsetting or attitudes toward AR, notably regarding potential risks and likelihood of success. Trends may also be explained by access to practical constraints (forms of capital) to conduct AR. Collectively, these factors may contribute to an individual's perspective on the use of AR to achieve NNL outcomes.

We examined the adoption of and attitudes toward ecological restoration within the New South Wales (NSW) Biodiversity Offsets Scheme (hereafter, the "scheme"), Australia. The scheme was established under the NSW Biodiversity Conservation Act, 2016 and applies to most development projects that require approval under the Environmental Planning and Assessment Act 1979 (Supplement S1). Under the scheme, offsets can be delivered by avoiding loss (habitat protection), improving vegetation conditions through management practices that manage threats and pressures and encourage natural regeneration, and undertaking AR. However, gains are assumed to primarily accrue through assisted natural regeneration on offset sites of moderate condition and through the AR of degraded sites (NSW Department of Planning and Environment 2021; Oliver et al. 2021) and are therefore an ideal case study for understanding how policy settings influence the uptake of AR.

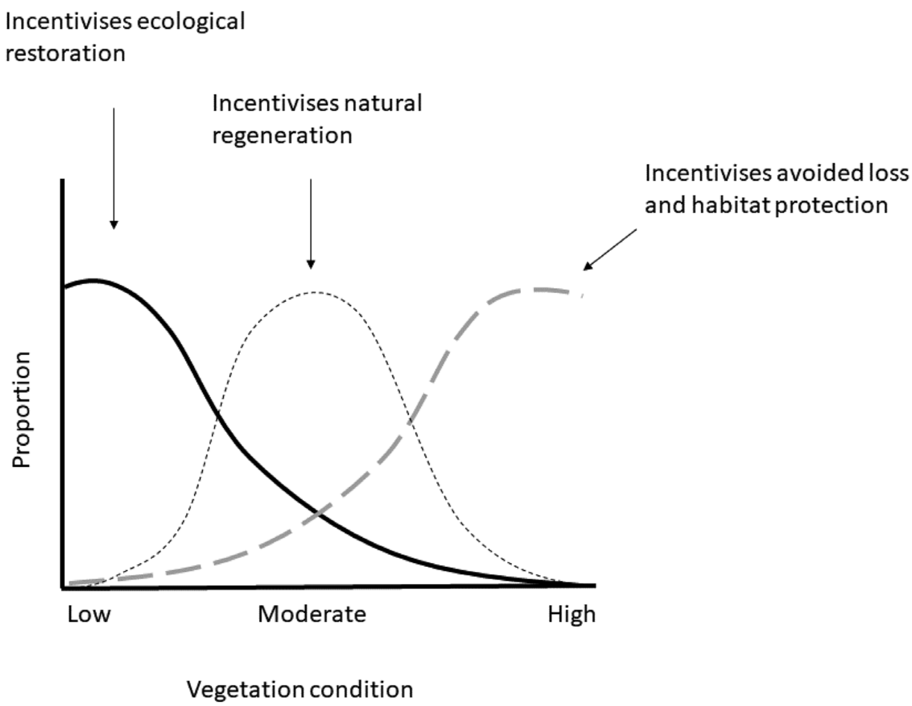

Figure 1. Theoretical distribution of offset according to policy settings that: incentivize active restoration, incentivize avoided loss, or incentivize neither active restoration or avoided loss.

Our study aims to address three broad questions: (1) does the scheme encourage the uptake of AR in degraded habitats? (2) what are the general trends in survey responses exploring attitudes toward potential? constraints to AR generally as well as under the scheme; and (3) what is the importance of attitudes for determining an individual's agreement that AR contributes to meeting NNL of biodiversity? To answer the first aim, we analyzed a dataset describing the adoption of AR and habitat condition within biodiversity offset sites in NSW. To answer the second and third aims, we analyzed a dataset containing responses to an online survey of restoration practitioners and individuals involved with the NSW scheme.

Methods

Data Collection

Practice of Active Restoration on Offset Sites. We obtained data for finalized offset (Biodiversity Stewardship Agreements) sites stored within the NSW Biodiversity Offsets and Agreement Management System database (accessed 27 Jul 2022). The database stores records of vegetation field assessments and proposed AR management actions for finalized Biodiversity Stewardship Areas (offset sites) undertaken between 2017 and August 2022. This data does not include sites established under previous offsetting policies. It provides details on finalized agreements but also unfinalized sites (cases that are proposed but may not continue). We focus on finalized sites as these have been reviewed by government officers responsible for approving the agreement and are, therefore, considered unlikely to change. We consulted with government staff to identify cases that were errors, not proceeding or superseding, resulting in the removal of 18 offset sites.

We assessed the total area (ha), the starting Vegetation Integrity Score (the condition of the vegetation relative to a reference state benchmark; scores range from 0 to 100), and the proposed adoption of AR in each Vegetation Management Zone within an offset site. Vegetation Management Zones (Zones) define broadly mapped areas with similar vegetation types, conditions, and proposed future management actions. Zones with Vegetation Integrity Scores greater than 60 are generally considered in good condition (Environment Energy & Science 2020; Oliver et al. 2021).

Attitudes Toward Active Restoration. Our survey elicited attitudes concerning various factors that may influence both the general adoption of AR and the attitude toward AR as contributing (or not) to NNL under the scheme and were informed by the scientific literature, submissions to a NSW Parliamentary Inquiry concerning the scheme (Legislative Council 2021) and research team knowledge (Table 1). Survey responses were recorded on a 7-point ordinal Likert agreement scale ranging from strongly disagree to strongly agree (Joshi et al. 2015), which were re-coded to a numeric integer scale (−3:3) for all analyses.

The target audience for our survey consisted of individuals who were engaged in biodiversity offsetting within one or more of the following areas: (1) employees of the NSW government who were involved in the policy and governance of offsetting;

Table 1. Questions from the online survey were grouped by variable type (Response, Observed, or Composite) and one of six themes: attitudes toward access to capital (capital constraints), attitudes toward active restoration, the social imperative of active restoration, and attitudes toward the rules that govern the Scheme. Mean, median, and standard deviation (SD) of the 7-point Likert scale ratings (scale = −3, strongly disagree to 3, strongly agree). These are indicative of the survey response direction and variability within responses. Composite factors were obtained as the first axis of each principal component analysis. Factor loading is for the first axis; [a]indicates a moderate correlation (>0.3) between the variable and the factor. $N = 111$ [b]Values represent an inversion (multiplied by −1) from the original data. Questions were inverted to ensure the positive or negative framing of the questions matched the framing of others within the theme. The inverted questions should be interpreted as follows: current scientific knowledge is inadequate to support active restoration design. Active restoration does not recreate similar biodiversity and environmental values to reference state vegetation. Restoration (both passive natural regeneration and active) is adopted because other land uses are less profitable.

Type	*Theme*	*Question*	*References*	*Interpretation*	*Mean*	*Median*	*SD*	*%n/a*	*Factor loading*
Response		Active restoration is necessary to meet no-net-loss of biodiversity.	Hilderbrand et al. (2005)		1.31	2.0	1.74	17	N/A
Observed	Attitude toward offsetting	Biodiversity offsetting is an effective mechanism for avoiding the loss of biodiversity.	Walker et al. (2009); Karlsson and Edvardsson Björnberg (2021)		−0.494	−1	1.96	13	N/A
Composite	Capital constraints	Implementation of active restoration is constrained by native tube stock availability.[a]	Greet et al. (2020)	Seed and tubestock constrain the implementation of AR	0.564	1.0	1.73	3	0.919
		Implementation of active restoration is constrained by native seed availability.[a]	Merritt and Dixon (2014)		0.984	1.0	1.63	15	0.939
		Access to equipment and machinery (e.g. direct seeding machinery, weed spraying, machinery for scalping) is insufficient to support the implementation of active restoration.[a]	DonTigny et al. (2017)		0.247	0.0	1.73	16	0.311
		Implementation of active restoration is constrained by financial feasibility.	Manning et al. (2006), Cortina-Segarra et al. (2021)		2.01	2.0	1.21	10	0
		There is insufficient technical and practical knowledge to support active restoration efforts.	Hagger et al. (2017)		0.26	1.0	1.76	10	0
		Current scientific knowledge is adequate to support the design of active restoration.[b]	Ntshotsho et al. (2015)		−0.66	−1.0	1.64	3	0
Composite	Attitudes to active restoration	Active restoration recreates similar biodiversity and environmental values to reference state vegetation.[b]	Marchand et al. (2021)	Preference for natural regeneration rather than active restoration.	−0.69	−1	1.57	0	0.199
		Managing land for assisted regeneration is less risky than active restoration.[a]	Atkinson and Bonser (2020); Hariharan and Raman (2022)		1.06	1	1.62	3	0.815
			Crouzeilles et al. (2020)		−0.94	−1	1.63	9	0.836

Table 1. Continued

Type	Theme	Question	References	Interpretation	Mean	Median	SD	%n/a	Factor loading
		Active restoration is not necessary due to the natural recovery potential of most sites.[a]							
		Post-establishment management of threats to restored vegetation can be managed adequately.	Atkinson and Bonser (2020)		0.61	1	1.62	10	0.177
Composite	Social imperative	My colleagues consider active restoration to be an adequate mechanism to ameliorate threats to biodiversity.[a]	Ceccon et al. (2015)	There is a social expectation for active restoration.	0.168	0.0	1.8	4	0.800
		Restoration (both passive natural regeneration and active) is not adopted because other land uses are perceived as more profitable.[b]	Bullock et al. (2011)		−1.85	−2.0	1.32	11	0
		There is an obligation to actively restore degraded habitats.[a]	Parrillo (2005)		1.13	2.0	1.93	3	0.725
Composite	Attitudes to the rules that govern the BOS	I understand the required administrative process to recommend active restoration under the Biodiversity Offset Scheme.	Legislative Council (2021)	The rules and metrics underpinning the Scheme accurately measure and prioritize gains.	1	1	1.53	24	0
		The Biodiversity Assessment Method incentivizes active restoration in the most needed places.[a]	Legislative Council (2021)		−0.48	0.0	1.69	23	0.781
		The Biodiversity Assessment Method (BAM) Calculator provides reasonable predictions of biodiversity gains at stewardship sites.[a]	Legislative Council (2021)		−0.352	0.0	1.67	21	0.850

(2) restoration practitioners who implement management actions at restoration sites; (3) accredited assessors who were individuals certified to assess a site's current and predicted future biodiversity values and advise landholders on management actions; and (4) local government employees who were involved in the assessment of development applications (which may generate offset obligations) and in some circumstances, management of offset sites. Participants represent a range of perspectives from individuals directly involved in offsetting and restoration but did not include private landholders, although many participants are intermediaries who provide advice to private landholders about AR and biodiversity offset areas.

We recruited participants using direct invitations via professional email list servers, professional group memberships, and subsequent snowball sampling (Wolf et al. 2016). Participants received a pre-notification email outlining the survey context and the date the survey would be distributed, an email invitation to participate in the online survey, and two email reminders (Sammut et al. 2021). The online survey was available for 4 weeks between March and April 2022. We obtained Human Ethics approval through the University of Technology Sydney, Human Research Ethics Committee (Approval for Project Number: 21169).

Data Analysis

Practice of Active Restoration on Offset Sites. We summarized the finalized offset site data according to (1) the total area proposed for restoration and (2) the condition of offset sites with and without restoration proposals. To estimate the proposed adoption of AR, we calculated the proportional area of Vegetation Management Zones with and without restoration within 10 groupings of condition classes.

Attitudes Toward Active Restoration. Survey responses were summarized and plotted using the Likert package (Bryer et al. 2016). We then used a structural equation model to test the relationships in the a priori framework described in Figure 2. Structural equation modeling (SEM) is a multivariate statistical technique used to estimate a priori relationships (MacCallum & Austin 2000) and is advantageous over traditional approaches (such as multiple regressions) because of its ability to examine direct and indirect relationships between composite (unobserved or latent) factors, observed factors, and the outcome of interest (Cheng 2001; Jeon 2015). We used an SEM to estimate the relationships shown in Figure 2 using a four-step process.

Step 1. Create Composite Factors. Using a principal component analysis (PCA), we created four composite factors to achieve model parsimony and prevent overfitting. Composites are the unobserved causal or formative latent factors directly influencing one or more observed factors (Weng & Young 2017). Specifically, each composite variable relates to attitudes toward: (1) AR; (2) the social imperative of AR; (3) the rules or governance of the scheme; and (4) the capital required to implement AR. Each composite variable comprised between 3 and 6 survey questions (Table 1). PCAs were conducted using the psych package in R to derive the composite factors (Table 1) (Revelle & Revelle 2015). The analyses were performed with a two-factor solution and a varimax rotation to examine the underlying factor structure of the survey data. The varimax rotation was chosen to maximize the independence between factors and simplify the interpretation of the factor structure. The factor loadings were examined to identify items that were highly correlated with each factor and to ensure that each item loaded predominantly on one factor. We extracted factor loadings for the first axis. When interpreting the composite variable, we focused on factors with factor loadings greater than 0.3, which are those most strongly associated with the factor (Black & Babin 2019) (see also Supplement S2).

Step 2. Accommodate Missing Data. In surveys, missing data is expected, as respondents may skip or refuse to answer questions. Imputation methods are frequently used to address missing data within social surveys (Rubin 1988; Penn 2007; Mirzaei et al. 2022) and here we used multiple imputations (Little & Rubin 2019) with the Hmisc package. This involved building a regression model that included the response, composite factors (derived from step 1), and the observed variable listed in Table 1. Multiple imputations allow us to account for the uncertainty caused by missing data by creating plausible values for the missing responses based on their relationship with other factors in the dataset. The imputed values were extracted using the mice package (Van Buuren & Groothuis-Oudshoorn 2011) to create 1000 complete datasets. We considered factors with missing values below 25% as acceptable for imputation.

Step 3. Develop a Conceptual Model and Test With a Structural Equation Model. To understand the various factors explaining the uptake of AR on offset sites, we developed a conceptual model for understanding the relationships between survey questions and the positive attitude toward AR in meeting NNL (Fig. 2): We expected the following:

- Broadly positive attitudes toward restoration (Walker et al. 2009) (H1).
- Agreement that AR is an individual or social imperative (H2).
- Positive attitudes toward the rules and policies underpinning offset schemes (Ferraro & Pressey 2015) (H3).
- Positive attitudes toward the role of offsetting policy (in general) in avoiding biodiversity loss (Maron et al. 2016) (H4).
- Ready access to capitals required for AR (Hagger et al. 2017) (H5).

We also expected a relationship between the perception of offsetting rules and policies and the role of offsetting in avoiding biodiversity loss (H6) (Maron et al. 2016).

We used the lavaan package (Rosseel 2012) to fit an SEM to each imputed dataset using a weighted least squares mean and variance adjusted estimator (Li 2016). The response variable in our SEM was measured in agreement with the statement, "*Active Restoration is necessary to meet no-net-loss of biodiversity*." We summarized the path coefficients from the replicate models

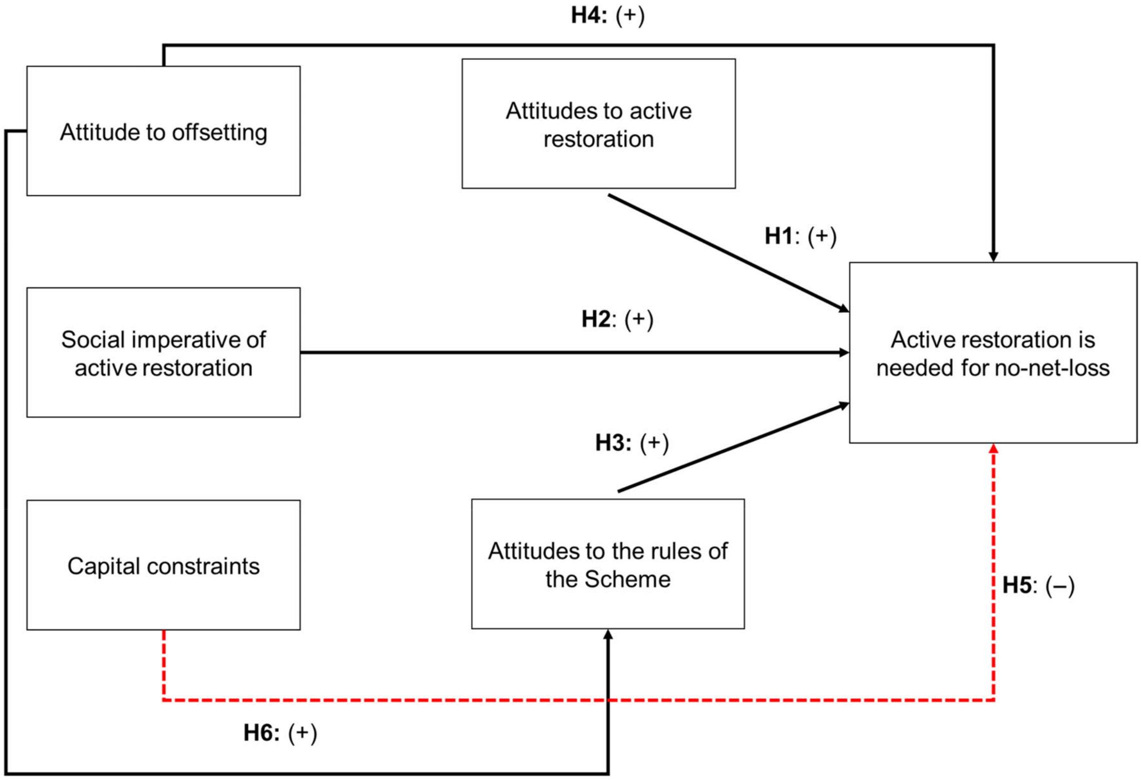

Figure 2. Conceptual model depicting the hypothesized relationships among factors thought to potentially influence the attitude that AR is needed to meet no-net-loss objectives under biodiversity offsetting. These were tested using structural equation modeling of survey responses. Attitudes are measured using a 7-point Likert scale of agreement (−3:3; strongly disagree–strongly agree).

as the mean upper (95th) and lower (5th) points of the distribution of coefficient estimates from all 1000 simulations.

The profitability of alternative land use and the financial costs associated with AR are both expected to be major factors influencing the adoption of AR (Cortina-Segarra et al. 2021). However, these survey questions did not load onto their respective composite factors (Table 1). We included them as independent factors in a preliminary SEM to test whether they were associated with the level of agreement toward "*Active Restoration is necessary to meet no-net-loss of biodiversity*." Results indicated that associations were weak and uncertain (Table S2) and so they were excluded from the final SEM.

Step 4. Evaluate the Model Fit. To evaluate the fit of the SEMs, five model fit statistics were calculated and compared to recommended benchmarks. All fit measures indicate good fit and we present the results for the Tucker-Lewis Index (TLI) and root mean square error of approximation (RMSEA).

All data were analyzed in R v4.2.1 (R Core Team 2019).

Results

Practice of Active Restoration on Offset Sites

Between 2017 and 2022, 135 offset agreements covering an area of 63,103 ha were finalized. These were divided into 1033 vegetation management zones. AR was proposed for 51.8% of these agreements ($n = 70$) and 27.8% of Vegetation Management Zones ($n = 287$) or approximately 19.3% of the offset area (12,180 ha).

Half of the total proposed area was in good condition (Vegetation Integrity score >60, 57.9%, 36,576 ha, Fig. 3), of which a quarter (26.1%, 16,500 ha) had a VI between 60 and 70. AR was proposed for 27.3% (7248 ha) of the offset area in moderate to low condition (VI <60, 26,528 ha). Over a third of the total proposed offset site had a VI between 40 and 60 (17,477 ha). Of the 3462 ha with very low condition (VI <20), AR was not proposed for 20.1% (697 ha, Fig. 3).

Attitudes Toward Active Restoration

One hundred and eleven individuals participated in the online survey. Of these, 95 completed all questions (85.6%). Most respondents had postgraduate qualifications (48%), identified as male ($n = 65$, 58%) and were between 41 and 50 years of age ($n = 34$, 31%) (participant demographics are provided in Table S1). Overall, most respondents agreed that AR is necessary to meet NNL (76%).

Most respondents agreed that financial capital is a barrier to AR (93%). At the same time, attitudes to limited access to physical capital, in the form of seed and tube stock availability and equipment and machinery, were mixed (46–65% agreed). Overall, 65% of respondents agreed that scientific knowledge is

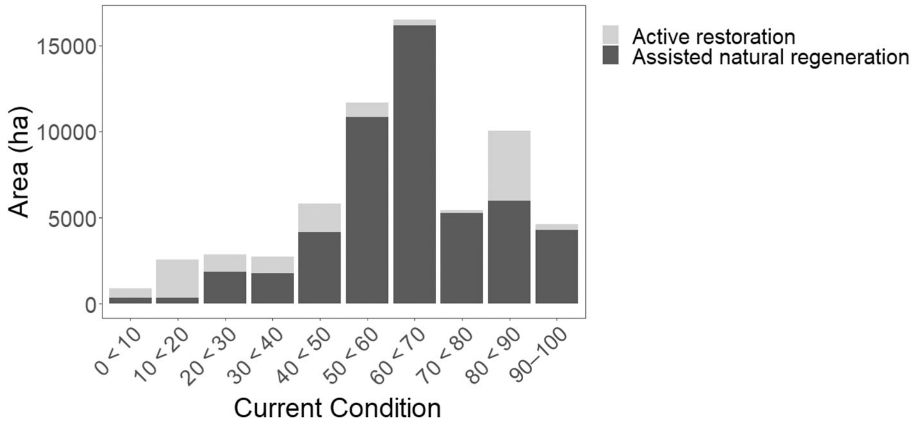

Figure 3. The offset area given the current condition (0–100) with active restoration and without active restoration (assisted natural regeneration). Data were extracted from the Biodiversity Offsets and Agreement Management System BOAMs in July 2022.

adequate to support AR. More than half of the respondents (66%) agreed that AR is an obligation. However, responses regarding whether their colleagues think AR ameliorates threats to biodiversity were mixed. Most respondents (88%) agreed that restoration (both passive and active) is often not adopted because other land uses are perceived to be more profitable. While just a quarter of respondents (24%) agreed that AR is unnecessary because sites have natural recovery potential, most tended to agree that passive approaches to restoration are less risky than AR (69%). Most respondents also agreed that AR can recreate biodiversity values consistent with a reference site (69%), and once sites are established, 65% of respondents agreed that ongoing threats can be managed.

Concerning restoration within the context of the scheme, most respondents agreed that they understand how to recommend AR in the context of the scheme (71%). However, there were mixed views on the effectiveness of the scheme's methods (Fig. 4).

Structural Equation Modeling

Replicate SEMs were well fitted to the imputed data (TLI median of 0.97, 56.9% and RMSEA <0.05 in 60.2% of replicates), indicating a supported model (Table S3).

H1: There was a negative relationship between the composite variable representing attitudes to AR and the belief that AR is necessary to achieve (NNL) ($\beta = -0.378$). The composite variable comprised attitudes that AR is not necessary and assisted regeneration is less risky (Table 1). Hence, respondents who perceived AR as risky and unnecessary were less likely to agree that AR was necessary to meet NNL (Fig. 5).

H2: The composite variable for the social imperative of AR was positively associated with the attitude that AR is necessary to achieve NNL ($\beta = 0.478$). The social imperative composite variable comprised attitudes that there is an obligation to restore and agreement that colleagues see AR as an adequate mechanism to ameliorate threats to biodiversity. This indicates that respondents who perceive AR as an individual and social imperative are more likely to agree that AR is necessary to meet NNL (Fig. 5).

H3: The composite variable for attitudes to the rules of the scheme was positively associated with the attitude that AR is necessary to achieve NNL ($\beta = 0.426$). This composite was comprised of an agreement with the statements that the rules incentivize AR where needed, and that the metrics make reasonable predictions of the biodiversity gains associated with AR (Table 1). This indicates a positive association between those who believe that the rules and metrics supporting the scheme perform well and an attitude that AR is needed to meet NNL (Fig. 5).

H4: Although we predicted a positive association between the attitude that offsetting is an effective mechanism for reducing threats to biodiversity and that AR is needed to meet NNL, our analysis revealed no relationship ($\beta = -0.059$) (Fig. 5).

H5: The relationship between the capital constraints composite variable and agreement that AR is necessary for NNL was weak ($\beta = 0.173$) and uncertain, suggesting access to capital was not negatively associated with the participant's agreement that AR is needed to meet NNL (Fig. 5). The capital constraint composite was comprised of agreement with statements that asked if practical constraints (tube stock, seeds, and machinery) limited the adoption of AR (Table 1).

H6: The relationship between attitudes to offsetting and attitudes to the rules underpinning offsetting scheme was supported ($\beta = 0.671$). This suggests that those individuals who agree offsetting is an effective mechanism for avoiding the loss of biodiversity are more likely to agree that the metrics used to assess NNL are accurate and prioritize AR correctly (Fig. 5).

Covariance paths estimate relationships among factors. We had no a priori assumptions concerning directional effects. Overall, covariance paths were generally weak, and the direction

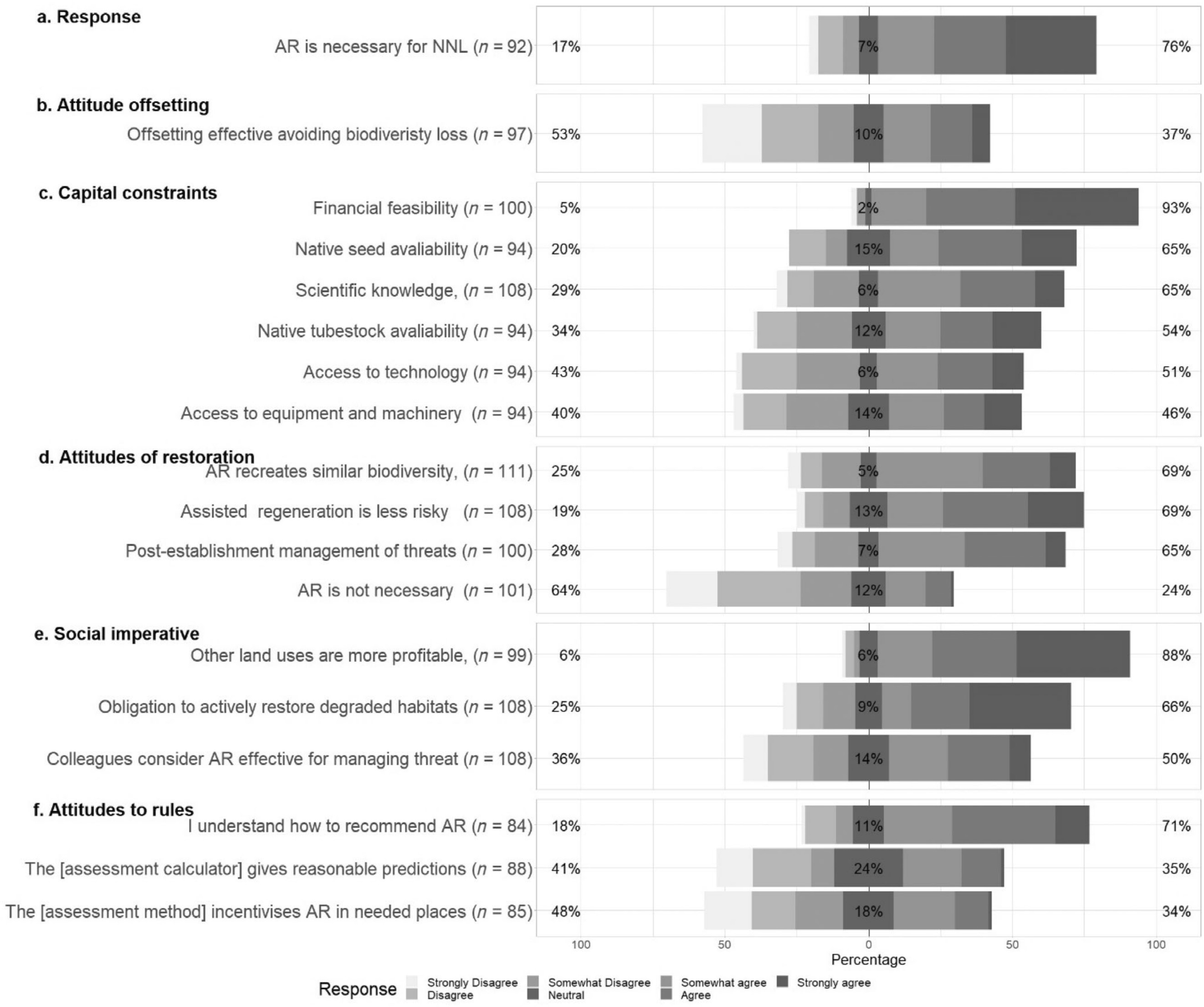

Figure 4. Seven-point Likert scale for the survey responses used in subsequent analysis. For all panels, AR = active restoration. In this figure, "offsetting" refers to the New South Wales Biodiversity Offsetting Scheme; "assessment calculator" refers to the Biodiversity Assessment Method Calculator (NSW Department of Planning and Environment 2021); "assessment method" refers to the Biodiversity Assessment Method (NSW Department of Planning and Environment 2020). Percentages on the left of the panel are the sum of slightly disagree, disagree, and strongly disagree. Percentages on the right panel of the plot are the sum of somewhat agree, agreem and strongly agree.

of their relationship was often uncertain, indicating the indirect relationships between composite factors are minor (Fig. S1).

Discussion

Biodiversity offsets are being increasingly adopted globally as a policy response to manage and compensate for these biodiversity impacts. AR addresses biodiversity impacts by improving habitats through the reconstruction of missing ecosystem properties. Under the Biodiversity Offsets Scheme in NSW, AR is undertaken through in-perpetuity conservation covenants. Financing is included within these covenants to enable implementation and ongoing monitoring. Under previous policies in NSW, offsets primarily occurred in areas that were, on average, of higher condition than the sites approved for clearing and relied mainly on avoided losses to meet NNL objectives (Gibbons et al. 2018). The current NSW offset scheme intends to incentivize gains through AR and natural regeneration, rather than avoided losses, hence we expected that most offset sites would be of low to moderate condition. Still, we found that 36,576 ha (nearly 60%) of offset sites were in good condition suggesting that the scheme is currently relying on avoided loss to deliver biodiversity gains. Our results also indicate that the scheme is also relying on natural regeneration (rather than AR), with just over 27% of moderate to low condition sites having AR management actions.

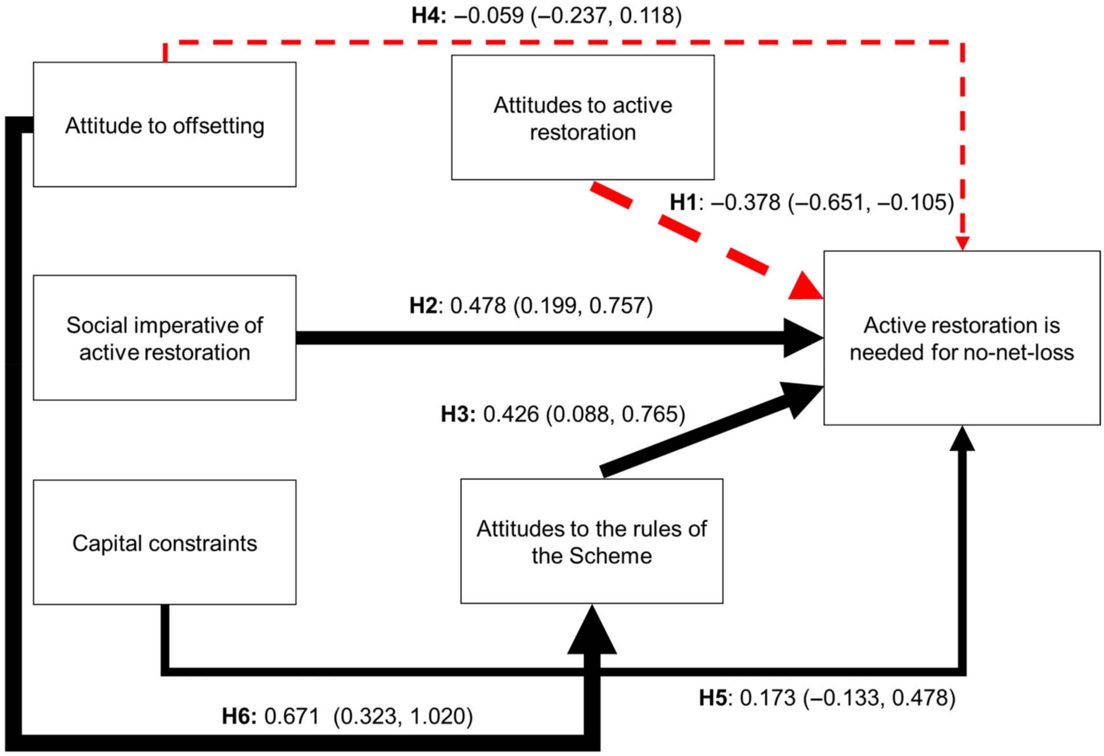

Figure 5. Path diagram of structural equation model (SEM) showing hypothetical factors influencing the agreement that active restoration is necessary to meet NNL objectives. Black solid lines between factors represent positive and red dashed lines represent negative predictive relationships (i.e. paths). The importance of each linkage (i.e. path) in contributing to the whole network is represented by regression coefficients derived from the average estimates across the 1000 replicated SEMs. The mean confidence interval (upper [95th] and lower [fifth]) across all 1000 simulations are shown in brackets.

These findings suggest there may be constraints to AR limiting its adoption on offset sites.

Our analysis sheds light on the complex constraints to AR on offset sites that extend beyond the policy settings of the scheme. We found that the relationship between overall attitudes toward AR, and the risks and costs of AR are not unidirectional but rather divergent and complex. We explain our findings in terms of attitudes toward AR under the scheme and attitudes to AR more generally.

We found the attitudes toward the rules used to estimate biodiversity gains and incentivize AR are important determinants of participants agreeing that AR contributes to meeting NNL. Disagreement with the rules to estimate biodiversity gains may be attributable to attitudes toward the reliability of metrics used to calculate gains (including the scale of units of biodiversity considered transactable under the scheme) or, more practically, the on-ground reality of gains achieved. Indeed, several studies have criticized the trade-off between uncertain biodiversity gains made on offset sites and an inevitable loss of biodiversity from development (Weissgerber et al. 2019) with this uncertainty ultimately influencing landholder choice to participate in offsetting schemes (Le Coent et al. 2017). Likewise, the often polarized views on market-based environmental policy have also received criticism (Sullivan & Hannis 2015). Overall, this highlights the importance of perceived legitimacy for environmental policies (Bennett 2016) and supports the need for effective, well-tested, and accepted metrics of biodiversity gain to support AR efforts under offsetting policy. Positive association may indicate that those who generally agree with the metrics used by the scheme also tend to agree that AR is necessary for achieving NNL. Still, further research will be needed to examine how stakeholders' attitudes toward the rules of the scheme are influenced by other factors such as accountability and transparency, as other studies have raised these criticisms in the past (Ruoso & Plant 2021; Kujala et al. 2022).

Low adoption of AR on offset sites may also be explained by individual attitudes to AR. As previous authors have suggested, diverging attitudes may lead to disputes about the value of AR (Hobbs et al. 2004). The attitudes to AR composite variable were comprised of agreement with questions about whether or not assisted natural regeneration is less risky than AR and if most sites will naturally recover without AR. Hence, these questions measure participants' preference for, rather than actions toward, assisted natural regeneration. While most respondents agreed that assisted natural regeneration was less risky than AR, the majority also disagreed that most sites would naturally recover. Our analysis reveals that those who prefer assisted natural regeneration would be less likely to believe that AR contributes to NNL. While studies have found that restoration (in general) is an effective mechanism for increasing biodiversity and ecosystem services (Benayas et al. 2009), ecological restoration, is viewed as uncertain and difficult to forecast

(Brudvig & Catano 2021). This may be because of the site-specific context and risks associated with both the outcomes and practice of ecological restoration (Tian et al. 2023). Such considerations may lead to reluctance to adopt AR in the context of offsetting. Further research could identify which factors contribute most to the perceived riskiness of AR. Designing approaches that consider and account for risks to the restoration project could be effective strategies for encouraging support for AR initiatives both within and outside of offsetting contexts (Tupala et al. 2022).

Our results also underscore the importance of general expectations regarding AR, particularly in the context of offsetting. We found a strong positive association between those who generally agree that AR is a social imperative and that AR is necessary for achieving NNL. The social imperative variable measured agreement that restoring degraded habitats is an obligation and that participants believe their colleagues perceive AR as effective for managing threats to biodiversity. A divergence of attitudes toward AR as an obligation potentially manifests as opposing views that promoting AR reduces the incentive to protect intact habitats or that incentivizing AR more than protection accelerates progress toward NNL. Concerning the role of AR in managing threats, we observed mixed views. This result suggests that some participants believe that those within their professional network doubt the effectiveness of restoration. The underlying causes of variation among participants are unknown but may be affected by differences in perceptions about the major drivers of biodiversity loss as well as the extent to which AR or other conservation strategies (e.g. habitat protection) can address these. Together, these views may be influenced by differences in the perceived riskiness and necessity of AR (Miller & Hobbs 2007).

Previous research has found that funding availability is a significant barrier to AR (Cortina-Segarra et al. 2021). Indeed, recent audits of restoration projects in Australia found that restoration is rarely undertaken voluntarily and depends on government grants with accompanying investment from private donations, non-governmental organizations, and the involvement of volunteers (Mcneill et al. 2022). Corresponding to such studies, respondents widely acknowledged that financial feasibility and the profitability of alternative land uses (opportunity costs) pose significant barriers to the adoption of AR. This constraint is particularly crucial for offset sites, where financial compensation is offered for management actions and yet our findings indicate a limited uptake of AR. Still, this question did not load onto the capital constraints composite variable, along with other capital-related questions. However, not loading and exclusion from subsequent analysis does not mean that financial and land use considerations are not critical factors influencing either the perceived role or the uptake of AR. Indeed, the opportunity costs relative to the financial gain from undertaking AR on offset sites are likely to influence the uptake of AR strongly but may not influence attitudes toward the role of AR in NNL. It remains uncertain whether the provided financial compensation is inadequate or if the opportunity costs are indeed prohibitive. Consequently, we present our findings here, but caution that further research is needed to explore the financial obstacles preventing landholders from entering agreements, including the extent to which financial incentives facilitate the inclusion of AR in such agreements (Plant & Ruoso 2023).

Our survey results suggest that participants' attitudes toward the availability of seed and tubestock varied with more participants agreeing that seed supply is limiting whereas tubestock was often not. surprisingly, however, the association between access to capital (comprising perceived access to seed supply, tube stock, and machinery) was only weakly associated with respondents' attitudes about the role of AR in meeting NNL. The lack of association between capital constraints and levels of agreement that AR is needed to meet NNL objectives may appear to contradict previous research exploring barriers to AR more generally (Gibson-Roy et al. 2021*b*) as such factors are thought to constraint restoration activities (Broadhurst et al. 2017). While access to capital is important in a broader restoration context, this factor appears to hold less significance for understanding variation in attitudes toward restoration in meeting NNL objectives.

Our study highlights the importance of attitudes toward restoration for those involved in offsetting policy design, management, and site. Individual attitudes to the rules underpinning offset policy, whether AR is considered a social imperative and the perceived necessity and riskiness of AR are important determinants in whether individuals consider AR necessary to achieve NNL. Because such attitudes play an important role in the general acceptance of offset policies, policy design seeking to encourage the uptake of AR on offset sites should be directed toward overcoming rather than reinforcing diverging attitudes. For example, while policymakers may consider adjusting gain metrics to encourage AR, caution is needed as such adjustments may affect attitudes toward the scheme, including perceived legitimacy. Empirical testing of metric assumptions and transparently communicating the outcomes of robust monitoring may ensure the effectiveness of AR and associated gains, ultimately ensuring AR on offsets is perceived as a valid approach. Still, even with such measures, some individuals may prefer natural regeneration and avoided loss as cost-effective and less risky approaches. In such cases, adopting sophisticated adaptive management approaches (such as encouraging AR in areas where natural regeneration is not achieving gains) on offset sites and encouraging management flexibility may help to achieve NNL policy objectives.

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Supporting Information

The following information may be found in the online version of this article:

Table S1. Socio-demographic characteristics of survey participants (total completed, $n = 95$ partial completed $= 111$).

Table S2. Estimates from an additional SEM model which analyzed the relationship between the response and financial factors.

Table S3. Fit measures for the 1000 replicated structural equation models.

Supplement S1. Further details on the NSW Biodiversity Offsets Scheme and Agreement Management System (BOAMS) database.

Supplement S2. Principle component analysis and composite variables.

Figure S1. Covariance Path diagram of structural equation model (SEM) showing relationship between hypothetical factors influencing the agreement that active restoration is necessary to meet NNL objectives.

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