Received: 7 April 2020 | Revised: 8 February 2021 | Accepted: 2 April 2021

DOI: 10.1111/csp2.431

CONTRIBUTED PAPER

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access

WILEY

Uncovering opportunities for effective species conservation banking requires navigating technical and practical complexities

Thomas B. White[1,2] | **Joseph W. Bull**[3] | **Theodore P. Toombs**[4] | **Andrew T. Knight**[1,5,6]

[1]Department of Life Sciences, Imperial College London, Berkshire, UK

[2]Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge, UK

[3]Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, UK

[4]Environmental Defense Fund, Boulder, Colorado

[5]School of Biological Sciences, The University of Western Australia (UWA), Perth, Western Australia, Australia

[6]BlueAnt Consulting, Fremantle, Western Australia, Australia

Correspondence
Thomas B. White, Conservation Science Group, Department of Zoology, University of Cambridge, The David Attenborough Building, Downing Street, Cambridge CB3 3QZ, UK.
Email: tbw27@cam.ac.uk

Abstract

In the USA, Species Conservation Banking is a prominent example of compensatory biodiversity impact mitigation, with an annual market value estimated at US$354.2 million. Species Conservation Banking represents a useful case study of a well-established program that can provide empirical insights into the practicalities of implementing quantitative compensatory biodiversity mitigation on-the-ground. Using semi-structured key-informant interviews structured around well-established technical challenges to compensatory mitigation, this study aimed to understand (i) how and why these challenges are or are not addressed in practice; and (ii) how these challenges relate to practical challenges faced by conservation banking stakeholders on-the-ground. Challenges identified included: (i) defining trading currencies and equivalence, (ii) regulatory and political uncertainty, (iii) regulatory agency capacity, will and knowledge, (iv) lack of policies, standards, and competition with other mitigation mechanisms, (v) long-term uncertainty/longevity, and (vi) lack of species knowledge and data transparency. These challenges are numerous, diverse, interlinked and transdisciplinary, and collectively inhibit the ability of practitioners to resolve underlying technical challenges—a finding likely applicable to related biodiversity offset programs. To help address challenges and navigate this complexity, we formulate several recommendations for conservation banking stakeholders to improve the chances of beneficial biodiversity outcomes being achieved.

KEYWORDS

biodiversity offsets, compensatory mitigation, endangered species act, listed species, mitigation hierarchy, no net loss

1 | INTRODUCTION

Compensatory biodiversity mitigation is a mechanism designed to reduce the conflict between development and conservation goals by compensating for a development's residual impacts on species and habitats, and is increasingly applied world-wide. In the United States of America (USA), a biodiversity banking industry worth approximately US$3.6 billion per annum has emerged, focused mainly on wetland mitigation driven by the Clean Water Act 1972 (Bennett, Gallant, & Ten Kate, 2017). "Species Conservation Banking" or "Conservation Banking" has evolved from this concept and is one of multiple authorized mitigation mechanisms in the USA for mitigating impacts to species listed under the Endangered Species Act 1973 (ESA), with an annual market worth US$354.2 million (Bennett et al., 2017).

Species Conservation Banking in the US is a mechanism by which a third party provides compensatory mitigation for impacts regulated by the US Endangered Species Act. An individual who owns land where an endangered species is present can establish a Species Conservation Bank (SCB) for the species, for which they are granted credits by either the U.S. Fish and Wildlife Service (USFWS) or the National Oceanic and Atmospheric Administration (NOAA). Once credits are granted, the land becomes a conservation bank, but credits are only granted on the condition that the land is managed for the conservation of the endangered species in perpetuity (Carroll, Fox, & Bayon, 2008; Fox & Nino-Murcia, 2005). Credits can be purchased by developers who are required to offset impacts on a specific ESA-listed species (Figure 1). There are 154 SCBs registered in the US Regulatory In-lieu fee and Bank Information Tracking System (RIBITs) database, 72% of which are in California, but with others distributed across the USA focused on a limited, but expanding set of listed species (Gamarra & Toombs, 2017). No ecological assessment of the effects of the conservation banking program on target species has been conducted, although habitat-level analysis shows Californian SCBs have significantly averted levels of natural habitat conversion that have occurred outside of banks. However, the same study showed banks prevented the passive restoration of degraded habitats which has occurred outside banks—a finding potentially indicating perverse outcomes (Sonter, Barnes, Matthews, & Maron, 2019).

Species Conservation Banking is often perceived as a species-focused form of biodiversity offsetting (Bennett et al., 2017; McKenney & Kiesecker, 2010) as it bears much resemblance to the offsetting approach practiced in other countries. For example, it relies upon the same basic policy machinery which requires quantifiable and genuinely additional compensatory conservation benefits in response to specific development impacts. However Species Conservation Banking differs from offsetting in

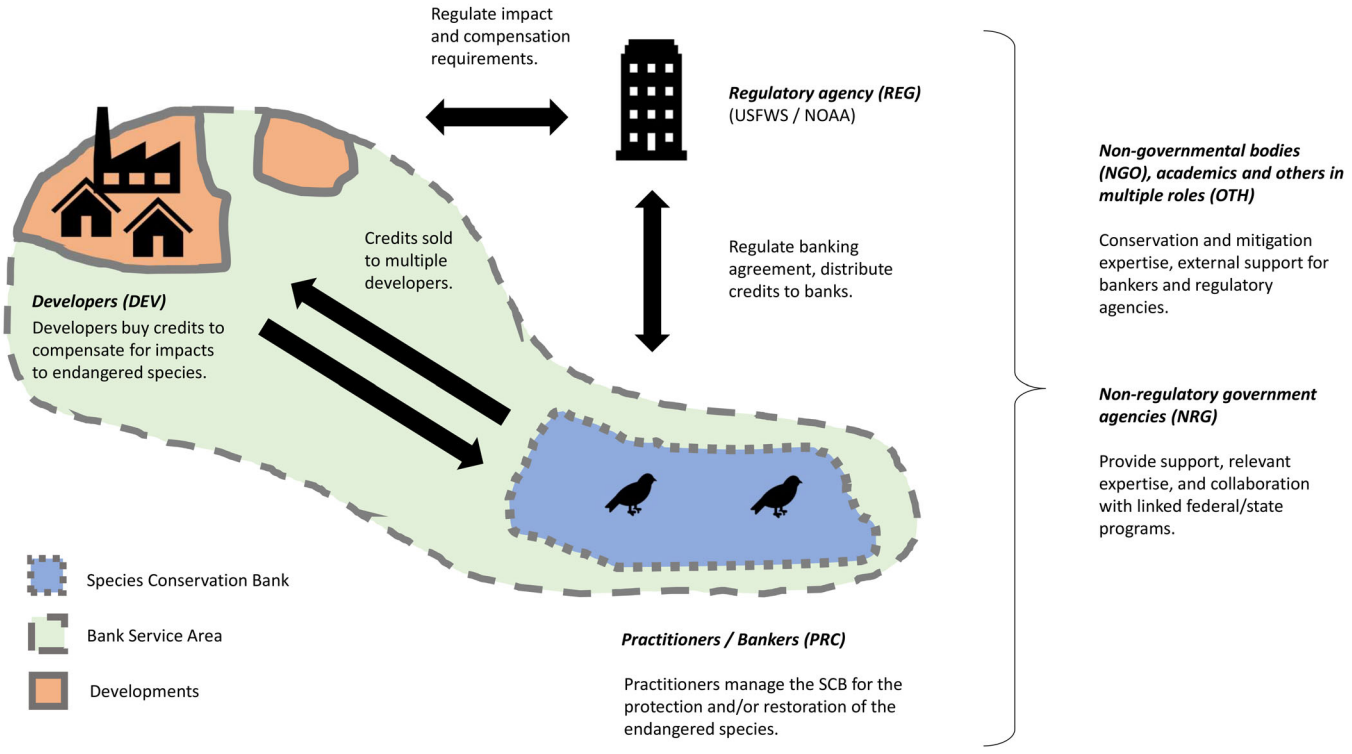

FIGURE 1 A conceptual model of a Species Conservation Bank showing the interrelationships between different stakeholder groups

that (a) there is no overall requirement for no-net-loss or net gain, as part of the broader mitigation hierarchy, and (b) it is focused entirely on endangered species protected by law, rather than using species or habitats as a proxy for biodiversity in a broader sense. Protecting species does not necessarily result in protecting biodiversity more generally, but they are widely used in policy and legislation as a proxy for biodiversity as their protection requires the conservation of functioning ecosystems and the associated species and habitats.

Despite the increased global application and several documented short-term successes of biodiversity offsetting (Rainey et al., 2015; zu Ermgassen et al., 2019), there are both technical and practical challenges associated with the approach (Bull, Suttle, Gordon, Singh, & Milner-Gulland, 2013; Maron et al., 2016), raising concerns about its ecological and social consequences (Bidaud et al., 2017; Walker, Brower, Stephens, & Lee, 2009). Technical challenges have been well documented and exemplified in the literature including difficulties quantifying biodiversity for trading, ensuring additionality or defining limits for what can be offset (e.g., Pilgrim et al., 2013; Sullivan, 2013; Walker et al., 2009). For example, biodiversity offsetting in France requires demonstrated NNL of biodiversity, however data suggest that success has been limited (Bezombes, Kerbiriou, & Spiegelberger, 2019), and a range of technical and practical challenges have influenced this outcome (Dauguet, 2015; Guillet & Semal, 2018).

Due to the similarities to other offsetting programs, similar technical challenges are also faced by SCBs (Table 1; McKenney & Kiesecker, 2010; Gamarra & Toombs, 2017). Gamarra and Toombs (2017) found that although national standards are met well by SCBs (USFWS, 2003), the same banks failed to meet many of the Business and Biodiversity Offsets Programme (BBOP) offsetting principles. For example, as many of the banks set up are preservation banks (i.e., they preserve existing habitat), the additionality of gains is brought into question (Pawliczek & Sullivan, 2011). It is important to note that banks are not legally required to meet these principles, but as these principles are often seen as best practice, failing to meet them risks negative ecological outcomes.

A diverse and linked set of practical challenges faced by SCBs have been identified, which may hinder a banks'

TABLE 1 Technical challenges of offsetting and how they are addressed by Species Conservation Banks

Technical challenge	Description (Bull et al., 2013)	Reported practice
Measuring biodiversity	Choosing a currency for measuring biodiversity. In the case of SCBs, these are the metrics used for the calculation of species' credits and debits.	70% of conservation banks reported using a 1 credit = 1 acre approach, and only 13% included a measure of habitat quality in credit calculation (Gamarra & Toombs, 2017).
Equivalency	Ensuring equivalence in biodiversity value between the credit and debit sites.	None of the conservation banks reported on the quantification of losses and gains of biodiversity (Gamarra & Toombs, 2017).
NNL	A requirement to demonstrate no net loss of biodiversity occurs overall.	No net loss is not an objective of the program, but no net loss/net gain is included in 6% of banking agreements (Gamarra & Toombs, 2017).
Long-term	Management of the site in perpetuity for the endangered species being protected.	All conservation banks are established in perpetuity through a legal mechanism, all require monitoring of the offset area in banking agreements, and most have endowment funds for long-term financing (Carroll et al., 2008; Gamarra & Toombs, 2017). A recent habitat level analysis indicated potential perverse ecological outcomes (Sonter et al., 2019).
Uncertainties	Managing for uncertainties throughout the compensation process.	12% of banks reported using mitigation ratios; performance standards are used that must be met in order to obtain credits; 74% reported the use of adaptive management procedures (Gamarra & Toombs, 2017).
Limits/thresholds	Defining limits to what can be offset through the conservation banking process.	Limits are considered by 18% of conservation banks documentation (Gamarra & Toombs, 2017).
Monitoring	Monitoring the transaction and progress of the conservation bank.	In conservation banking agreements, all (bar three) required the conservation bank site to be monitored (Gamarra & Toombs, 2017).

intended implementation and functioning. These include: a lack of resources at regulatory agencies to set up conservation banking programs; high upfront costs to establish banks; difficulties with law enforcement of required mitigation; lack of empirical evidence supporting management of endangered species; the creation of a thin market for credits due to the species-specific focus of conservation banks; and the reliance of future funding (e.g., credit sales, interest on endowments) on economic conditions (e.g., Bruggeman, Jones, Lupi, & Scribner, 2005; DOI, 2016; Ferreira & Ferreira, 2018; Fox & Nino-Murcia, 2005; Pawliczek & Sullivan, 2011; Wilcove & Lee, 2004). Similar practical challenges are often faced by biodiversity offsets making it difficult to transition offsetting programs from policy to implementation. Some programs have remained nascent with few transactions (Bennett et al., 2017), while for others practical challenges during implementation (e.g., politics, market factors, and stakeholder values) have complicated the efforts to compensate for impacts (Brownlie et al., 2017; Carver & Sullivan, 2017; Robertson, 2009). For example, in the UK the use of biodiversity metrics was hindered by stakeholder pressure to save money and decrease the value of calculations (Carver & Sullivan, 2017). In the USA wetland mitigation banking is highly influenced by changes in the regulatory setting which drives credit demand, and where project delays can result from differing viewpoints on risks and income (Robertson, 2009).

Practical challenges are often linked, transdisciplinary and formed as a result of conservation interventions being implemented in dynamic social-ecological systems where stakeholders have diverse perspectives and values. This is exemplified by Pawliczek and Sullivan (2011) who describe the enabling policies and governance frameworks that have allowed SCBs in the USA to proliferate, but also describe some of the linked challenges that have emerged. Such situations present high levels of uncertainty in decision-making, which can hinder efforts to achieve positive conservation outcomes in practice (Knight et al., 2019; Regan, Colyvan, & Burgman, 2002).

Although there is currently no formal requirement for NNL to be achieved by SCBs (Bunn, Moyle, & Johnson, 2014), the USFWS Mitigation Policy (USFWS, 2016) looked likely to introduce an overall mitigation planning goal of a "net conservation gain" into regulation. However, this was rescinded by the USFWS in July 2018, returning the former regulations and guidance back into force (USFWS, 2018). On top of these policy movements, multiple actors are working to improve SCBs, or develop new mitigation mechanisms for endangered species (e.g., Chiavacci & Pindilli, 2018; Kreuter, Wolfe, Hays, & Conner, 2017) aiming to tackle some of the challenges faced by the offsetting approach. To achieve net gain, or a similar target, would require many of the challenges of offsetting (Table 1) and practical challenges faced on the ground to be tackled.

Conservation banking provides a useful case study of a well-established mechanism that can provide insights into the practical challenges of designing, implementing and seeking to improve biodiversity impact mitigation on the ground. Using similar interview and thematic analysis methodologies used to investigate other offsetting programs (e.g., Maestre-Andrés, Corbera, Robertson, & Lave, 2020; Sullivan & Hannis, 2015), we reviewed the implementation of SCBs and interviewed stakeholders to understand their perspectives on the technical and practical challenges faced by SCBs including:

1. How and why identified technical challenges in biodiversity offsetting (Table 1) are, or are not, addressed and overcome by SCBs; and
2. Further challenges perceived to prevent the functioning and implementation of effective SCBs in practice.

Doing so, will help advance an understanding of conservation banking as a mechanism for ensuring the persistence of biodiversity, and of the situations and broader systemic contexts that promote practical and technical challenges in designing, implementing and improving conservation banking. This study also helps to identify points of intervention where challenges are yet to be tackled. Overcoming and tackling these challenges has potential to advance the effectiveness, cost-efficiency and equity of SCBs for delivering positive conservation outcomes for endangered species.

2 | METHODS

2.1 | Developing an interview protocol

An interview protocol was developed to guide semi-structured interviews with individuals involved in SCBs (Supporting information S1). The questionnaire comprised three sections addressing: (1) the SCB process and the participant's role; (2) how, why and where identified technical challenges in offsetting processes are, or are not, addressed by SCBs (Table 1); and (3) challenges that exist in practice. As SCBs encounter many similar challenges to biodiversity offsetting, and may one day be required to incorporate a NNL or better objective (a key component of offsetting programs), Section 2 of the protocol was framed around commonly identified challenges of offsetting (Table 1) and promoted discussion as to how and why each of these challenges were addressed. Section 3 allowed scope for participants to raise other

challenges or topics important to them in practice. The protocol was reviewed by all authors and trialed with colleagues familiar with the conservation banking approach before the commencement of interviews. Participants were encouraged to speak openly about their experiences, knowledge, and perspectives.

2.2 | Identifying and interviewing participants

To be included as a "key-informant", individuals had to have had multiple years' experience working on SCBs at multiple sites within the USA, and/or oversight of the mechanism at a national scale, be over the age of 18 and English-speaking. The first four key-informants were identified through recommendations from T.P.T. In small, well-connected social networks, such as the SCB industry, snowball sampling can create exhaustive sampling frames, and we used this approach to identify the subsequent key-informants (Bernard, 2006). Within the sampling frame identified (41 individuals), we contacted 37 individuals using purposive sampling to ensure representation of different stakeholder groups (Figure 1).

Between June and August 2018, T.B.W. conducted and audio recorded 19 initial interviews using online audio or video call software (Stage 1), with two further interviews conducted in September 2018 due to the participant's availability (Stage 2). Interviews lasted between 36 and 105 min with an average duration of 62 min. Participants comprised six regulatory agency staff, four practitioners, three nonregulatory government staff, two developers, two NGO staff, and four individuals having experience in multiple roles including research. Participants were based in nine different states, including states with and without SCBs (Figure 2). The majority of interviews covered all topics in the interview guide, although some interviews were limited by time constraints. The number of interviews was limited by the available research timeframe. During the latter interviews many of the same participants were recommended and convergence emerged on several themes.

Recordings were transcribed utilizing the transcription tool "*Temi*" (https://www.temi.com). Transcripts were manually reviewed by T.B.W. to ensure transcription accuracy.

2.3 | Thematic analysis

Data from Stage 1 interviews were analyzed following The Framework Approach (Gale, Heath, Cameron, Rashid, & Redwood, 2013; Ritchie & Spencer, 1994), a thematic analysis comprising five main steps: familiarization with the data, development of a thematic framework, coding of the data using this framework, organizing the coded data into charts, and finally interpretation. Firstly, a random subset of seven transcripts (38%) were selected from which an understanding of participants perspectives could be derived. Recurring themes and sub-themes were identified and used for development of a thematic framework which was used to code the transcripts from all interviews in "*Nvivo 12 Pro*" (QSR International Pty Ltd.). To ensure validity of the thematic framework and coding, an external researcher reviewed the framework and transcripts (Supporting information S1).

For the thematic framework, seven themes were predefined based on the technical challenges of offsetting outlined in Table 1, allowing us to tackle our first research question (Bull et al., 2013). An inductive approach was used to identify both sub-themes within these themes, and all other broad themes that emerged from the data (Gale et al., 2013). This inductive approach was important as it allowed us to identify those challenges raised as important by the interviewees without biasing results by defining all themes prior to the analysis (e.g., Sullivan & Hannis, 2015). To synthesize key findings, we identified a subset of all themes, based on (i) the quantity of coded data, and (ii) relevance to the research questions, to take forward for charting. Charting involved separating the coded data by theme and displaying data on each theme categorized by stakeholder groups and sub-themes. These charts present the data analyzed for this study. Data from Stage 2 interviews were coded using the thematic framework developed from Stage 1, and any new themes or sub-themes identified added to the thematic framework. To acknowledge the subjectivity of this method, an observational standpoint (Clark, 2002) was undertaken (Supporting information S1).

3 | RESULTS

3.1 | Themes and codes

Twenty-one themes were identified from the Stage 1 interview transcripts. Seven of these themes were classified as "challenges to offsetting" (following the challenges shown in Table 1), the remaining 12 were identified as practical challenges and uncertainties. Seven priority themes were selected for charting and are reported here. Coding of transcripts from Stage 2 of the interview process revealed no new themes to add to the framework. Direct quotes from participants which are representative of themes are presented in Table 2. A complete list of

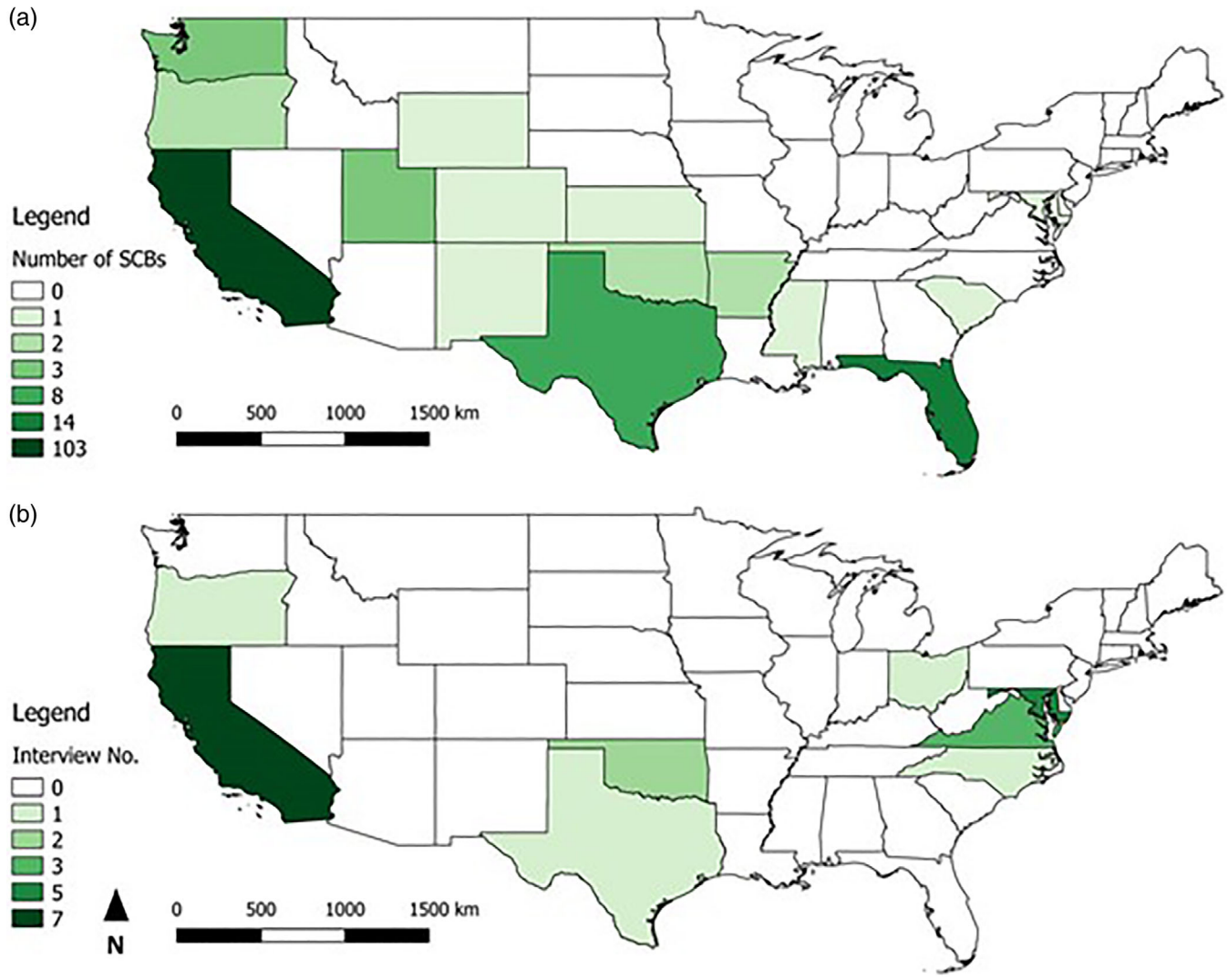

FIGURE 2 The number of (a) Species Conservation Banks; and (b) participants in this study, as defined by their primary work location, per state in the USA. The number of Species Conservation Banks totaled 144 and participants 21. Note that although an individual was identified as based in a specific state, many had experience on a multi-state or national level, hence the large number of participants based in Washington, D.C. and Maryland. Data downloaded from RIBITS (Data downloaded: May, 2018). Projection: EPSG:4269

themes, two example thematic charts, and an expanded table of quotes are provided in Supporting infomation S1.

3.2 | Addressing offsetting challenges

3.2.1 | Currency and equivalence

Participants across the stakeholder groups stated that most banks use an acre-based approach for credit calculation. The interviews highlighted a difference in opinion regarding the adequacy of these measures. Practitioners and some agency staff advocated for the use of these relatively simple and easy-to-use metrics (Quote 1A). Other agency staff, NGOs and some non-regulatory agency staff would have liked to see more ecologically-meaningful metrics incorporating habitat quality and other aspects of endangered species ecology, to increase the likelihood of positive conservation outcomes and equivalence being achieved (Quote 1B). This difference of opinion was underlain by a broad appreciation of the need to trade-off the complexity of the crediting approaches against the practicality of being able to apply the survey methods in the field. Most practitioners, and some participants in multiple roles, perceived that methods deemed too complex caused delays in bank approvals, greater perceived financial risk and ultimately reduced investment (Quote 1C).

Perceptions varied regarding achieving equivalence between impact and credit sites. Many regulatory agency staff and participants with multiple roles stated that methods used for determining credits and debits were the

TABLE 2 Representative quotes from key-informants

Theme[a]:			
(1) Currency and equivalence	**(2) Longevity**	**(3) Regulatory and political uncertainty**	**(4) Regulatory agency capacity, will and knowledge**
1A, PRC "It is a topic of spirited debate amongst many conservation stakeholders and I believe that the key thing is to have something that's simple, functional, repeatable—that can deliver a benefit to the species." 1B, NGO "With the amount of data collection possible today, I think that banks could do a much better job of including functional metrics of habitats and some are, but I think that is an opportunity that must be pursued." 1C, REG "I've seen them go way too complicated trying to, you know, know every single little part of the life history of the species into a credit methodology that does not, that may not work. I've seen way too simple or it's just like so many acres is a credit and not really paying too much attention to the quality behind those."	2A, REG "it's important to me to keep in mind or maybe helps me sleep at night, you know, to, to consider whether conservation banks do a better job of that than the other mitigation options do. It's hard to do a perfect job of that. You know, how you ensure that something's going to be a particular way forever is kind of an impossible job to begin with. We do it the best we can. The best we know how, and I think conservation banks do it better than just about any other mitigation approach does." 2B, PRC "those [long term] requirements start to swing the financial feasibility of the bank projects." 2C, NRG "If you put a bank on the ground there may not be any development encroaching on that bank right now. But ... in, 20, 30 years that bank might be threatened with encroachment by nonsuitable habitat. Some species might not be adversely affected by that. Other ones that are really sensitive to things happening in the landscape scale might be. My understanding is I do not know how that is incorporated in banking and I do not think it is."	3A, OTH "From the point of view of the banker the key uncertainty is whether there will be buyers for credits. The banker is totally dependent on enforcement of the regulatory program to generate demand for credits. And in the US at least, enforcement of the Endangered Species Act has been episodic, irregular, unpredictable, not as rigorous as bankers might wish it to be in order for their investments to be relatively secure." 3B, REG "I think there's a lot of uncertainty in the banking world about what, um, the federal government's view of conservation banking and mitigation offsets is going to be in this administration, the level of support, the level of staff involvement. I think that's been creating some uncertainty as well." 3C, OTH "I worked very hard in the state of [specific state], which is extremely conservative, trying to push off, push off as banks in the state where there's been this interface between the need to develop and need to conserve. But again, some states just do not have the regulatory side of It to help push federal regulation along."	4A, REG "our funding has remained flat for—relatively flat—for a long time, and we are one of the smaller federal agencies and one of the less funded. So it does make it difficult." 4B, OTH "Well, why not conservation banks? Well, when we called up one particular agency in [specific state] and they said, well, we already have an established in lieu fee program and we would not be interested in approving a conservation bank at this time." 4C, PRC "There is tremendous variability within field offices and tremendous variability within regions. (1) determining mitigation, (2) coming up with methodologies, and then (3) coming up with approaches on land tenureship."
Theme:			
(5) Policies, standards and competition	**(6) Species knowledge & data transparency**	**(7) Complex system**	
5A, PRC "without that document that says if you are going to use mitigation for species x, it has to have these things, no exceptions. Without that then you have conservation stakeholders often fighting against each other instead of working	6A, NGO "the USFWS does not have a really strong track record of proactively issuing mitigation guidance for individual species... [if such guidance is available (e.g., in mitigation banking)], you get a pretty clear sense of how	7A, PRC "details matter in these programs and there's very few people on planet earth that understand how to connect all these details. If you do not connect just one detail in your design... You get outcomes that are unintended, unintended consequences in conservation." 7B, PRC "And a lot of people who run these, who create these systems do not have the experience. And they may have money behind them. They may be really great biologists. You have to have all these different skillsets, business, conservation biology,	

(Continues)

TABLE 2 (Continued)

Theme[a]:			
(1) Currency and equivalence	**(2) Longevity**	**(3) Regulatory and political uncertainty**	**(4) Regulatory agency capacity, will and knowledge**
collaborative with each other." 5B, NGO "The other challenge that I see, is the competition that banks face from even less rigorous mitigation standards, or forms of mitigation. The in-lieu fee programs that you can basically buy credits from an in-lieu fee program before any mitigation is done on the ground." 5C, OTH "there can be what some of the mitigation bankers call leaky demand meaning the entire business model is based on having regulatory demand for a product—a unit of restoration of habitat. But if the regulators do not accept that. And instead say, you know, "this company can do a little restoration on their own land" instead of getting a credit in the mitigation bank or "this company can, you know what, just pay to have the agency do some research", then you, you are weakening the demand, for doing entrepreneurial or larger scale restoration."	credits and debits are going to be assessed." 6B, OTH "I think wetland banking is a little different because it's relatively similar across the country, but for each species they have their own unique threats, habitat needs and life cycles and things like that. So they are each going to have a unique set of activities that can, kind of, create that ecological uplift. But figuring out what it is and how you do it. You know, that's, that's a challenge..." 6C, NGO "I was shocked by how little transparency there is and how the overall program works. And, um, you know, there's not even a basic understanding of how prevalent impacts are, how prevalent it is that compensatory mitigation happens, just that basic level understanding... the agencies just do not have the tracking tools that they need."	industry, legal, and there's just literally, there's very few people on this whole planet who could have done this and that's why you keep having these failures of these new ideas." 7C, PRC "I'm not opposed to having more complex systems if they can be proven to be functional and deliver real outputs on the ground and all the things I'm talking about. The challenge I see with them is that today I do not see the complexity creating any additional value or conservation on the ground or to attract private investors into the space or to get industry change."	

Abbreviations: NGO, nongovernment organization; NRG, non-regulatory government department; OTH, individuals with experience in multiple roles, or research; PRC, practitioner; REG, regulatory agency.

[a]Text in square brackets has removed the participants original wording to remove sources of identification, or wording been changed to allow the quote to be understood standalone.

same. However, other regulatory agency staff outlined this wasn't always achieved in practice. Some practitioners and NGO staff highlighted the difference between credit and debit methodologies as a key challenge for SCBs.

3.2.2 | Longevity

Through a combination of land use restrictions (i.e., conservation easements), long-term management plans and financial instruments (i.e., endowment funds), participants generally agreed that the long-term commitments required by the USFWS are adequate, or at least better than alternative mitigation mechanisms, for ensuring the persistence of endangered species in perpetuity (Quote 2A). However, some participants across stakeholder groups perceived the high and uncertain costs of perpetual management as a challenge (e.g., endowments; Quote 2B). Most nonregulatory government participants, some regulatory agency staff, a developer and a practitioner expressed concern that the system does not

account for events outside of the banker's control, such as climate change-driven habitat changes within bank boundaries and shifts in species distributions, or force-majeure events (Quote 2C). For example, climate change may render a bank unsuitable for its endangered species, and therefore, remove a bank's credit generation potential.

3.3 | Practical challenges and uncertainties

3.3.1 | Regulatory and political uncertainty

The dependence of the market for SCB credits on regulatory drivers was a challenge perceived by most participants (Quote 3A). Future demand for credits is influenced by changes in policy, legislation, regulations and guidance, and the interpretation and enforcement of these by regulatory agencies. Participants across all stakeholder groups identified the current US political context, specifically the weakening of environmental laws and potential changes in the requirements for mitigation, as leading to increased uncertainty in the market, and hence reduced demand for species credits (Quote 3B).

Many government employees, practitioners and developers outlined the importance of: (i) state legislation and policy in driving SCBs and (ii) the importance of an accepting political context for their proliferation. Both conditions were perceived as present in California, but not in other states, creating a barrier to the implementation of SCBs (Quote 3C).

3.3.2 | Regulatory agency capacity, will and knowledge

The capacity of regulatory agencies to implement conservation banking programs was identified as challenging. Many agency staff and developers suggested that a lack of staff, time and financial resources led to difficulties maintaining oversight of banks and delays in bank approval times (Quote 4A). Some practitioners, agency staff, developers and NGO staff perceived a lack of knowledge within some sections of regulating agencies, specifically regarding how to establish banks, and also a lack of will to do so in some regions where regulatory agency staff did not feel comfortable with the approach, or did not have the resources to implement it. A lack of knowledge of conservation banking, and willingness to implement them, was perceived as a primary reason why banks are more common in some states than in others (Quotes 4B). A few participants, including researcher and non-regulatory government individuals, highlighted that knowledge and the drive for innovation to set up banks was often driven by one or a few key individuals in a specific state.

Some participants from across the stakeholder groups outlined that ambiguous interpretations of policies and guidance by different regulatory agency offices created inconsistencies in perceived mitigation requirements, inconsistencies in how mitigation was conducted, which was perceived to drive uncertainty in demand for credits. This was identified by both practitioners and agency staff as a reason for the variable number of banks between states and regions (Quote 4C).

3.3.3 | Policies, standards, and competition

Participants across several stakeholder groups, apart from developers, perceived that uncertainty in future demand and in how conservation banking is implemented is increased by the absence of policies and standards applicable to conservation banks (Quote 5A). A broader challenge was a perceived lack of standards applicable to all types of mitigation (Quote 5B). Some participants perceived that banks were often held to a higher standard than other mitigation mechanisms (e.g., permittee responsible mitigation), and regulatory agencies did not show preference for the advance mitigation offered by SCBs, allowing it to be undercut by other mitigation mechanisms perceived as less stringent and delivering fewer positive conservation outcomes. This was referred to as "leaky demand" and created uncertainty in the future demand for credits (Quote 5C).

3.3.4 | Species knowledge and data transparency

Several government staff, NGOs, practitioners and researchers, were concerned about a lack of biological information and knowledge of endangered species targeted by conservation banks, which made managing habitat for those species difficult and uncertain, as actions could not be founded upon evidence. Several agency staff, NGOs and practitioners expressed concern about the absence of species mitigation guidelines for species not previously addressed through banks, where a difficulty in the design and implementation of banks was not knowing how to create and manage a bank for a specific species (Quote 6A). These challenges were underlain by the innate complexity of the suite of species targeted

by SCBs, each of which had specific habitat requirements and threats, making the application of general rules and guidance difficult (Quote 6B).

A small number of participants, from across stakeholder groups, identified the lack of transparency in much of the data collected by banks, and the inadequacy of the available information, hindered research to determine the ecological and economic outcomes of conservation banking (Quote 6C).

3.3.5 | Complex systems

An overarching challenge identified by several participants, particularly practitioners, is that SCBs and the social-ecological systems in which they operate are complex, dynamic and diverse, which produces multiple sources of uncertainty (Quotes 7A, 7B).

Participants in all stakeholder groups, recognized that this complexity necessitates repeated trade-offs between practicality and comprehensiveness. On the one hand, participants realized an easy to use, simple, operational approach facilitates implementation of banks, but on the other, an approach needs to be sufficiently comprehensive to encompass the requirements of endangered species being targeted and the intricacies of the socio-economic context that manifests pressure on these species. This trade-off was identified for crediting techniques, with monitoring requirements, adequate levels of science and in the development of bank implementation guidelines (Quote 7C).

4 | DISCUSSION

Few studies have investigated the functioning of, and perceived challenges faced by, SCBs (e.g., DOI, 2013, 2016; Fox & Nino-Murcia, 2005; Gamarra & Toombs, 2017; Sonter et al., 2019) and this is the first study to have examined the practical experiences of a diverse range of SCB stakeholders. We found Species Conservation Banks present as complex systems, being highly dynamic, comprising diverse and ever-changing ecological and socio-political situations typically involving multiple species, and stakeholders with diverse values, perspectives, attitudes and behaviors which interact in often unpredictable ways (Brownlee, 2007; DeFries & Nagendra, 2017). This complexity was identified as a challenge by participants and is perhaps the most fundamental challenge facing those designing and implementing SCBs (e.g., Miller, 2013) as it leads to a diverse, transdisciplinary set of challenges manifesting high uncertainty whilst attempting to navigate trade-offs between practicality and comprehensiveness—a state common to many conservation programs (see Catalano, Lyons-White, Mills, & Knight, 2019 for a review). Similar findings have been observed for wetland mitigation banking in the USA which needed to align various economic, ecological and regulatory agendas, navigate trade-offs between comprehensiveness and practicality (Robertson, 2004, 2009) and ensure that "policy must attend to, rather than ignore, contingency, complexity and unpredictability in the application of market-based policy principles" (Robertson, 2009). Given this complexity, a clear typology of the institutional and social challenges facing SCB, as we have presented here, is essential for designing and implementing effective programs.

4.1 | Challenges and uncertainties

Complexity presents a set of practical challenges perceived by participants to inhibit the design, implementation, effectiveness and proliferation of SCBs. These challenges include: (1) the reliance of the market on enforced, stable regulatory structures; (2) heterogenous levels of access to information and knowledge about, and management requirements of, endangered species; (3) lack of regulatory agency capacity; (4) lack of data for evaluation; and (5) regular trade-offs between comprehensiveness and practicality. These findings align with previous studies (e.g., Bowers, 2017; Fox & Nino-Murcia, 2005; Gamarra & Toombs, 2017; Mills, 2003; Pawliczek & Sullivan, 2011), but this study provides greater resolution of these perceived challenges, notably the different values, perspectives and attitudes across diverse stakeholder groups whose ability and willingness to collaborate underpins the effectiveness of SCBs (as it does with many conservation projects; Catalano et al., 2019).

There are well characterized technical challenges facing offsetting programs (Bull et al., 2013), some of which participants perceived to be well addressed by their programs, including managing sites for conservation in perpetuity and monitoring and evaluation requirements (not reported in this study), which is consistent with a recent review (Gamarra & Toombs, 2017). However, regarding long-term positive conservation outcomes, there is a broadly perceived uncertainty in funding for management, and uncertainty about how banks meet their responsibilities when events beyond their control pose challenges. These challenges may be common for SCBs generally (e.g., Whipps, 2015) as they are thought to be with other site-specific conservation mechanisms, such as protected areas (Mascia et al., 2014) and Integrated Conservation and Development Projects (Wells & Brandon, 1992).

Conversely, the use of appropriate currencies for calculating the credit numbers was perceived to be less effectively

addressed. Similar to findings for wetland mitigation banking (Robertson, 2004), opinions differed as to the most effective methods, which was complicated by an appreciation of the need to trade-off a method's comprehensiveness (which recognizes the situational complexity; sensu Tinbergen, 1952; Young et al., 1996) against the need for pragmatism (where practicality and simplicity are essential for effective implementation; Peirce, 1878; Knight, Rodrigues, Strange, Tew, & Wilson, 2013). Area based metrics are most frequently used but raise challenges regarding equivalence (Pawliczek & Sullivan, 2011). Several crediting methods are now available (Chiavacci & Pindilli, 2018), with some attempting to more meaningfully address the ecological characteristics of SCB sites (e.g., Bruggeman et al., 2005; Searcy & Shaffer, 2008). However, without agreement between developers, practitioners, researchers and agency and NGO staff as to the level of comprehensiveness required to address social-ecological complexity, and acknowledgement that pragmatic processes will be fundamental for SCBs to operate effectively, new metrics may have limited effectiveness.

Efforts to address the technical challenges of offsetting, such as determining meaningful biodiversity metrics, or ensuring longevity of outcomes, are linked to the practical challenges of implementing mitigation on-the-ground, which are dependent on the economic, political and social context of individual banks. Without a detailed and nuanced understanding of social-ecological context, and effectively addressing practical design and implementation challenges, the market may struggle to grow, and the many technical challenges, such as those identified by Bull et al. (2013), remain insoluble.

For example, addressing deficiencies in crediting methods may increase the likelihood of NNL being achieved, but this will achieve little if a bank cannot sell credits, which may depend on regulatory agency staff opinions, policy reform, economic growth rates, species ecology, climate change predictions, monitoring and evaluation effectiveness, endowment fund growth, and competition from other mitigation mechanisms. Poor understanding of the social-ecological context, and the associated linked practical challenges, runs the risks of generating unintended ecological consequences, perhaps similar to the prevention of natural habitat gains recently identified (Sonter et al., 2019), or unexpected social impacts such as the accumulation of conservation-related wealth by large land-owners (Pawliczek & Sullivan, 2011).

Participants identified the reliance of the markets on regulation and policy and the uncertainty generated by political changes as a key challenge. In 2018, the political context in the USA was perceived as posing difficulties for the conservation banking industry, where weakening of the ESA mitigation requirements could cause a decline in the demand for endangered species credits. As US banks are largely privately owned, their profit depends on the stable regulatory context, perhaps making the program's success more vulnerable to shifts in regulation or policy than in programs where banks are publicly owned. Part way through this research, the 2016 Compensatory Mitigation Policy was rescinded by the USFWS (USFWS, 2018). The 2016 policy would have established a goal of "net gain" for endangered species mitigation initiatives. Previous studies found practitioners generally supported: (1) the introduction of equivalent standards for different permitted mitigation mechanisms; (2) a policy preference for conservation banks; and (3) formal conservation banking regulations. Agency staff were, however, opposed to a stated preference for banks over other forms of mitigation (DOI, 2013, 2016). In this study, not all participants expressed support for the introduction of a conservation banking policy, but many sought certainty in the regulatory context, which would likely have been compromised by proposed changes to environmental legislation and the lack of consistent guidelines for implementing endangered species mitigation, be it through conservation banking or other mechanisms. Our study aligns with previous ones that highlighted the influence of economic, political and social context and uncertainty on the effectiveness and proliferation of biodiversity banking (Calvet, Napoléone, & Salles, 2015; Robertson, 2004). These factors possibly obstruct the proliferation of conservation banks.

4.2 | Implications for offsetting

In the offsetting literature, there is a push towards addressing the many technical challenges posed by the offsetting approach (Gamarra & Toombs, 2017; Maron et al., 2016). We have found that whilst some of the technical challenges of offsetting are well addressed by conservation banking, in practice, they are underlain by a diverse set of practical challenges which themselves are difficult to solve, and whose solving precedes the effective implementation of technical matters. This finding may be applicable to offsetting programs more generally.

For example in the United Kingdom, a pilot biodiversity offsetting initiative was met by vocal opposition, diverse value positions, delays in implementation, and a perception that socio-economic factors compromised the technical specifications of the offsets (e.g., metrics, equivalent gains) (Carver & Sullivan, 2017; Sullivan & Hannis, 2015). Similar practical challenges were faced by the French offsetting program, limiting success in achieving NNL (Bezombes et al., 2019; Guillet & Semal, 2018). In South Africa, offsetting has been integrated into the environmental impact assessment process but faces a

diverse range of implementation challenges including inconsistent offset requirements due to an absence of clear policy, limited government capacity, information and knowledge, and inconsistent decision-making and enforcement of offset decisions (Brownlie et al., 2017). In Spain disagreements over the concept of NNL, concerns over government capacity, data availability and metrics have led to large delays in the production of habitat banking guidance (Maestre-Andrés et al., 2020).

4.3 | Future opportunities for navigating complexity

Compensatory mitigation programs present a diverse set of challenges, varying in their tractability (Maron et al., 2016), creating situations with high levels of uncertainty and complexity where there are often no clear solutions to achieving intended ecological outcomes. In these situations, refinements to, and creation of new mixes of, mechanisms may produce unintended negative outcomes (Rittel & Webber, 1973). The design, implementation and adaptive improvement of compensatory mitigation programs need to address both practical and technical challenges, whilst being mindful of social-ecological context and the system's complexity.

Our study highlighted differences in values between groups of stakeholders on key challenges faced by offsetting programs, which must be navigated for effective implementation of compensatory mitigation. Stakeholders with a common interest in functional, effective and profitable SCB initiatives can collectively undertake a boundary critique (Ulrich & Reynolds, 2010) ahead of designing an SCB program to generate a common understanding (e.g., mental model; Biggs et al., 2011) of the situation in which a SCB is to be established. This common understanding will be useful when developing conservation banks, policies, conservation banking and species mitigation guidance, to design and change programs in a mutually agreeable direction. Accounting for confounding complexity during implementation necessitates rapid learning, which may be most profitably undertaken as small, incremental improvements to SCBs, where there are risks with oversimplifying a solution (DeFries & Nagendra, 2017; McCarthy & Possingham, 2007), and by grappling with, and learning from, the failures that will inevitably occur. This requires implementing simple systems within organizations and teams that are designed cognizant of stakeholder's mindsets (Catalano, Redford, Margoluis, & Knight, 2018).

The tools and principles from the transdisciplines of evaluation and systems thinking (e.g., boundary critiques, multi-criteria decision analysis) may be particularly relevant to establishing effective SCBs, as both could help design solutions that can address the complexity and linked set of technical and practical challenges that arise (see Knight et al., 2019). By understanding system complexity, one could make changes to SCB that "fit" more effectively within the economic, political and social contexts to allow beneficial outcomes for endangered species to be secured.

Second, provision of a policy, or at least strengthened guidelines for the compensatory mitigation of individual species, may increase certainty in the market and address some of the practical challenges identified. This could help establish greater clarity of policy and requirements for banks, reduce uncertainty in demand, and ensure different types of mitigation are held to the same standards. Lastly, the collection and better centralization of ecological (including baselines and counterfactuals) and economic data, information and knowledge on SCBs and impact sites may facilitate decision-making and research into the ecological and economic outcomes of conservation banking (Gamarra & Toombs, 2017; Sonter et al., 2019).

5 | CONCLUSION

Over the last 40 years, SCBs have developed a suite of concepts, tools, methods and mechanisms to more effectively manage the economic, ecological, political, social and regulatory components of these systems (Fox & Nino-Murcia, 2005; Gamarra & Toombs, 2017). Despite struggling to gather momentum in some states and challenges with the current approach, SCB is a highly developed compensatory mitigation mechanism, increasingly used across the USA, providing private landowners with an incentive to conserve endangered species on their properties. As the new administration promises sweeping changes to environmental protections in the US, addressing the practical challenges identified in this study will likely help minimize uncertainties in these complex systems, and ultimately assist these programs to more effectively mitigate impacts to endangered species in the USA.

The challenges identified here, are complex, diverse, dynamic and generating high uncertainty—making them difficult to address in practice, and necessitating regular trade-offs between comprehensiveness and pragmatism. This is a likely characteristic of offsetting strategies generally, noticeable where practical challenges have often left programs struggling to gain momentum, even in the USA where these approaches have been developing for over 30 years. Embracing this complexity, as well as the challenges associated with it, may provide us with better ways of designing and addressing offsetting programs in the future.

ACKNOWLEDGMENTS

We would like to thank K Bracy Knight and W McDow at the EDF, and M Mills and J Lyons-White at Imperial College London for helpful discussions during the project's conception. Thanks also to: M Manfredo for help with logistical arrangements, E Muench for reviewing the thematic analysis, A Sharp for assisting with interview methods, and L Bennun for providing comments on and suggestions to improve the manuscript. We also thank two anonymous reviewers for constructive feedback which greatly improved the manuscript. The research presented here was completed by the lead author whilst completing the Masters in Conservation Science programme at Imperial College London.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Thomas B. White, Joseph W. Bull, Theodore P. Toombs, and Andrew T. Knight all contributed to the design of the study. Data collection and analysis was conducted by Thomas B. White. The manuscript was drafted by Thomas B. White, with input from Theodore P. Toombs, Joseph W. Bull and Andrew T. Knight.

ETHICS STATEMENT

The study was conducted in accordance with the Society for Conservation Biology ethical guidelines (Society for Conservation Biology, 2018) and the ethics procedures of the Department of Life Sciences at Imperial College London. Participants were fully informed of the research goals and approach and gave informed consent before interviews commenced.

ORCID

Thomas B. White https://orcid.org/0000-0002-0536-6162
Joseph W. Bull https://orcid.org/0000-0001-7337-8977
Andrew T. Knight https://orcid.org/0000-0002-6563-0500

REFERENCES

Bennett, G., Gallant, M., & ten Kate, K. (2017). *State of biodiversity mitigation 2017 markets and compensation for global infrastructure development*. Washington, DC: Forest Trends.

Bernard, H. R. (2006). *Research methods in anthropology: Qualitative and quantitative approaches* (fourth ed.). Lanham: Rowman & Littlefield.

Bezombes, L., Kerbiriou, C., & Spiegelberger, T. (2019). Do biodiversity offsets achieve no net loss? An evaluation of offsets in a French department. *Biological Conservation*, *231*, 24–29.

Bidaud, C., Schreckenberg, K., Rabeharison, M., Ranjatson, P., Gibbons, J., & Jones, J. G. (2017). The sweet and the bitter: Intertwined positive and negative social impacts of a biodiversity offset. *Conservation and Society*, *15*, 1–13.

Biggs, D., Abel, N., Knight, A. T., Leitch, A., Langston, A., & Ban, N. C. (2011). The implementation crisis in conservation planning: Could "mental models" help? *Conservation Letters*, *4*, 169–183.

Bowers B. (2017). Feasibility of establishing a conservation bank to benefit greater sage-grouse in Montana. Available at: https://www.americanprairie.org/sites/default/files/SageBankingFinalReport_unsigned.pdf.

Brownlee J. (2007). Complex adaptive systems, CIS technical report 070302A. 1-6.Retrieved from: https://pdfs.semanticscholar.org/44de/012ccf9ff522ab6ed6dfb66c75e39e986be1.pdf.

Brownlie, S., von Hase, A., Botha, M., Manuel, J., Balmforth, Z., & Jenner, N. (2017). Biodiversity offsets in South Africa: challenges and potential solutions. *Impact Assess. Proj. Apprais.*, *35*, 248–256.

Bruggeman, D. J., Jones, M. L., Lupi, F., & Scribner, K. T. (2005). Landscape equivalency analysis: Methodology for estimating spatially explicit biodiversity credits. *Environmental Management*, *36*, 518–534.

Bull, J. W., Suttle, K. B., Gordon, A., Singh, N. J., & Milner-Gulland, E. J. (2013). Biodiversity offsets in theory and practice. *Oryx*, *47*, 369–380.

Bunn, D. A., Moyle, P. B., & Johnson, C. K. (2014). Maximizing the ecological contribution of conservation banks. *Wildlife Society Bulletin*, *38*, 377–385.

Calvet, C., Napoléone, C., & Salles, J.-M. (2015). The biodiversity offsetting dilemma: Between economic rationales and ecological dynamics. *Sustainability*, *7*, 7357–7378.

Carroll, N., Fox, J., & Bayon, R. (2008). *Conservation and biodiversity banking: A guide to setting up and running biodiversity credit trading systems. Page environmental markets insight series*. London: Earthscan.

Carver, L., & Sullivan, S. (2017). How economic contexts shape calculations of yield in biodiversity offsetting. *Conservation Biology*, *31*, 1053–1065.

Catalano, A. S., Redford, K., Margoluis, R., & Knight, A. T. (2018). Black swans, cognition, and the power of learning from failure. *Conservation Biology*, *32*(3), 584–596.

Catalano, A. S., Lyons-White, J., Mills, M. M., & Knight, A. T. (2019). Learning from published project failures in conservation. *Biological Conservation*, *238*, 108223.

Chiavacci SJ, Pindilli EJ. (2018). *A database of biodiversity and habitat quantification tools used in market-based conservation*. U.S. Geological Survey, Reston. Available from: https://www.sciencebase.gov/catalog/item/5aa94672e4b0b1c392f14b17.

Clark, T. W. (2002). *The policy process: A practical guide for natural resource professionals*. New Haven: Yale University Press.

Dauguet, B. (2015). Biodiversity offsetting as a commodification process: A French case study as a concrete example. *Biological Conservation*, *192*, 533–540.

DeFries, R., & Nagendra, H. (2017). Ecosystem management as a wicked problem. *Science*, *356*, 265–270.

DOI (2013). A preliminary analysis of the conservation banking program and results from a survey of USFWS staff. In *United States Department of the interior*. Washington: DC.

DOI (2016). Results from a survey of conservation banking sponsors and managers. In *United States Department of the Interior*. Washington: DC.

Ferreira, C., & Ferreira, J. (2018). Political markets? Politics and economics in the emergence of markets for biodiversity offsets. *Review of Social Economy*, *76*, 335–351.

Fox, J., & Nino-Murcia, A. (2005). Status of species conservation banking in the United States. *Conservation Biology*, *19*, 996–1007.

Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology*, *13*(1), 1–8.

Gamarra, M. J. C., & Toombs, T. P. (2017). Thirty years of species conservation banking in the US: Comparing policy to practice. *Biological Conservation*, *214*, 6–12.

Guillet, F., & Semal, L. (2018). Policy flaws of biodiversity offsetting as a conservation strategy. *Biological Conservation*, *221*, 86–90.

Knight, A. T., Rodrigues, A. S. L., Strange, N., Tew, T., & Wilson, K. A. (2013). Designing effective solutions to conservation planning problems. In D. Macdonald & K. Service (Eds.), *Key topics in conservation biology* (2nd ed., pp. 362–383). UK: Wiley-Blackwell, Cambridge.

Knight, A. T., Cook, C. N., Redford, K. H., Biggs, D., Romero, C., Ortega-Argueta, A., ... Keene, M. (2019). Improving conservation practice with principles and tools from systems thinking and evaluation. *Sustainability Science*, *14*(6), 1531–1548.

Kreuter, U. P., Wolfe, D. W., Hays, K. B., & Conner, J. R. (2017). Conservation credits: Evolution of a market-oriented approach to recovery of species of concern on private land. *Rangeland Ecology & Management*, *70*, 264–272.

Maestre-Andrés, S., Corbera, E., Robertson, M., & Lave, R. (2020). Habitat banking at a standstill: The case of Spain. *Environmental Science & Policy*, *109*, 54–63.

Maron, M., Ives, C. D., Kujala, H., Bull, J. W., Maseyk, F. J., Bekessy, S., ... Possingham, H. P. (2016). Taming a wicked problem: Resolving controversies in biodiversity offsetting. *Bioscience*, *66*, 489–498.

Mascia, M. B., Pailler, S., Krithivasan, R., Roshchanka, V., Burns, D., Mlotha, M. J., ... Peng, N. (2014). Protected area downgrading, downsizing, and degazettement (PADDD) in Africa, Asia, and Latin America and the Caribbean, 1900-2010. *Biological Conservation*, *169*, 355–361.

McCarthy, M. A., & Possingham, H. P. (2007). Active adaptive management for conservation. *Conservation Biology*, *21*, 956–963.

McKenney, B. A., & Kiesecker, J. M. (2010). Policy development for biodiversity offsets: A review of offset frameworks. *Environmental Management*, *45*, 165–176.

Miller, B. (2013). *False identity: Conservation banking, a program analysis. Mercatus Graduate Policy Essay No 13*. Fairfax: George Mason University.

Mills, C. S. (2003). Incentives and the ESA: Can conservation banking live up to potential. *Duke Environmental Law & Policy Forum*, *14*, 523–561.

Pawliczek, J., & Sullivan, S. (2011). Conservation and concealment in SpeciesBanking.com, USA: An analysis of neoliberal performance in the species offsetting industry. *Environmental Conservation*, *38*, 435–444.

Peirce, C. S. (1878). How to make our ideas clear. In L. Menand (Ed.), *1997, pragmatism: A reader* (pp. 26–48). New York: Vintage Books.

Pilgrim, J. D., Brownlie, S., Ekstrom, J. M. M., Gardner, T. A., von Hase, A., ten Kate, K., ... Ward, G. (2013). A process for assessing the offsetability of biodiversity impacts. *Conservation Letters*, *6*, 376–384.

Rainey, H. J., Pollard, E. H. B., Dutson, G., Ekstrom, J. M. M., Livingstone, S. R., Temple, H. J., & Pilgrim, J. D. (2015). A review of corporate goals of no net loss and net positive impact on biodiversity. *Oryx*, *49*, 232–238.

Regan, H. M., Colyvan, M., & Burgman, M. A. (2002). A taxonomy and treatment of uncertainty for ecology and conservation biology. *Ecological Applications*, *12*, 618–628.

Ritchie, J., & Spencer, L. (1994). Qualitative data analysis for applied policy research. In A. Bryman & R. E. Burgess (Eds.), *Analyzing qualitative data* (pp. 173–194). London: Routledge Taylor and Francis Group.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*, 155–169.

Robertson, M. (2009). The work of wetland credit markets: Two cases in entrepreneurial wetland banking. *Wetlands Ecology and Management*, *17*, 35–51.

Robertson, M. M. (2004). The neoliberalization of ecosystem services: Wetland mitigation banking and problems in environmental governance. *Geoforum*, *35*, 361–373.

Searcy, C. A., & Shaffer, H. B. (2008). Calculating biologically accurate mitigation credits: Insights from the California tiger salamander. *Conservation Biology*, *22*, 997–1005.

Society for Conservation Biology. (2018). *Code of ethics*. Society of Conservation Biology, Washington DC. Retrieved from https://conbio.org/about-scb/who-we-are/code-of-ethics.

Sonter, L. J., Barnes, M., Matthews, J. W., & Maron, M. (2019). Quantifying habitat losses and gains made by US species conservation banks to improve compensation policies and avoid perverse outcomes. *Conservation Letters*, *12*(3), e12629.

Sullivan, S. (2013). After the green rush? Biodiversity offsets, uranium power and the 'calculus of casualties' in greening growth. *Human Geography*, *6*, 80–101.

Sullivan, S., & Hannis, M. (2015). Nets and frames, losses and gains: Value struggles in engagements with biodiversity offsetting policy in England. *Ecosystem Services*, *15*, 162–173.

Tinbergen, J. (1952). *On the theory of economic policy*. North Holland: Elsevier.

Ulrich W, Reynolds M. (2010). Critical systems heuristics. In: *Systems approaches to managing change*. Reynolds M, Holwell S. Springer, London, 243–292

USFWS. (2003). Guidance related to the general characteristics and the establishment, function and operation of Conservation Banks. U.S. Fish and Wildlife Service, Washington, DC.

USFWS. (2016). Endangered and Threatened Wildlife and Plants; Endangered Species Act Compensatory Mitigation Policy: Announcement of draft policy. U.S. Fish and Wildlife Service. Federal Register Vol. 81, 61031.

USFWS. (2018). Endangered and threatened wildlife and plants; endangered species act compensatory mitigation policy: withdrawal. U.S. Fish and Wildlife Service. Federal Register Vol. 83, 36469.

Walker, S., Brower, A. L., Stephens, R. T. T., & Lee, W. G. (2009). Why bartering biodiversity fails. *Conservation Letters*, *2*, 149–157.

Wells, M., & Brandon, K. (1992). *People and parks: Linking protected area management with local communities*. Washington, DC: World Bank.

Whipps, N. (2015). What happens when species move but reserves do not: Creating climate adaptive solutions to climate change. *Hastings Law Journal*, *66*, 557–589.

Wilcove, D. S., & Lee, J. (2004). Using economic and regulatory incentives to restore endangered species: Lessons learned from three new programs. *Conservation Biology*, *18*, 639–645.

Young, M. D., Gunningham, N., Elix, J., Lambert, J., Howard, B., Grabosky, P., & McCrone, E. (1996). *Reimbursing the future: An evaluation of motivational, voluntary, price-based, property-right and regulatory incentives for the conservation of biodiversity*. Sport and Territories, Canberra, Australia: Department of the Environment.

zu Ermgassen, S. O. S. E., Baker, J., Griffiths, R. A., Strange, N., Struebig, M. J., & Bull, J. W. (2019). The ecological outcomes of biodiversity offsets under "no net loss" policies: A global review. *Conservation Letters*, *12*(6), e12664.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: White TB, Bull JW, Toombs TP, Knight AT. Uncovering opportunities for effective species conservation banking requires navigating technical and practical complexities. *Conservation Science and Practice*. 2021;e431. https://doi.org/10.1111/csp2.431