CSIRO PUBLISHING

Pacific Conservation Biology, 2020, **26**, 269–281
https://doi.org/10.1071/PC19038

A case study of environmental offsets for the endangered Carnaby's cockatoo (*Calyptorhynchus latirostris*)

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Abstract. Environmental offsets are applied in Western Australia (WA) as a management tool to compensate for residual significant impacts of clearing and development of habitat for the endangered Carnaby's cockatoo (*Calyptorhynchus latirostris*). In the past 20 years many offsets have been established for the species. This research investigated whether environmental offsets were effective for conserving Carnaby's cockatoo habitat. The research was conducted as a case study describing offset implementation in WA based on 45 state-approved development proposals (2011–16) and 20 federally approved development proposals (2013–15). Land acquisition offsets were the most common type used for both WA- and federally approved developments. Only one offset that contributed to the 25 364 ha acquired has been vested as conservation estate. Land acquisition offsets allow development to occur without significant time delays, as developers have been able to use the transfer of funds for land purchase to fulfil most, or all, of their offset obligation(s). Those lands purchased by the Department of Biodiversity, Conservation and Attractions (and its predecessors) in fulfilment of offset conditions have been strategically acquired to either extend existing conservation estate, or to create a significant contiguous corridor of habitat suitable for Carnaby's cockatoos. Other offset types such as research and education were rarely used to fulfil offset obligations. There was free and easy access to online primary documentation associated with the granting of offsets, but secondary documentation was mostly unavailable and prevented in-depth investigation. Overall, mitigation of impacts on Carnaby's cockatoos from development of key habitat through environmental offsets shows promise, but thus far has resulted in a net loss of habitat for Carnaby's cockatoo.

Additional keywords: conservation outcome.

Received 27 September 2019, accepted 13 March 2020, published online 30 April 2020

Introduction

An environmental offset is a management technique that allows clearing or removal of native vegetation for development to occur without an overall or residual negative effect on an impacted 'biodiversity value' or 'matter of national environmental significance' (MNES) under specific legislation (McKenney and Kiesecker 2010; Bull *et al.* 2013; Vanderduys *et al.* 2016). Biodiversity values that are typically offset can include endangered species, threatened ecological communities or biodiversity as a whole, but can also include broader values such as air or water quality. Environmental offsets are also termed 'biodiversity offsets' or 'compensatory mitigation' (Gardner *et al.* 2013). Offsets are intended to prevent a net loss by balancing an impact on a biodiversity value and associated habitat loss with positive actions, including acquisition of habitat, funding of research, and direct on-ground measures such as land rehabilitation (Middle and Middle 2010; Miller *et al.* 2015). As such, environmental offsets are becoming widely recognised as a tool to help achieve conservation objectives (Potdar *et al.* 2016) while supporting ongoing development.

Local policies govern the use of offsets in the USA, Brazil, South Africa, and most states and territories of Australia (McKenney and Kiesecker 2010). In order to provide a framework for international consistency the International Union for Conservation of Nature (IUCN) has produced a policy on Biodiversity Offsets (IUCN 2016). It aims to provide a global framework for consistency amongst governments and non-government organisations who may develop offset policies in the future (IUCN 2015). The goal of offsets under the IUCN policy is to ensure a 'no net loss' with preference for a 'net gain' for the biodiversity values impacted. The purpose of creating these internationally applicable guidelines is to shape emerging and future offset policy creation, leading to best practice worldwide (IUCN 2015).

Two of the Australian offset policies in place that are relevant to this study are the federal *Environment Protection Biodiversity*

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Conservation Act (*1999*) (*EPBC Act 1999*) Environmental Offsets Policy (DSEWPC 2012) and the Western Australian *Environmental Protection Act 1986* (*EP Act 1986*) Environmental Offsets Policy (Government of WA 2011). Both the federal and Western Australian policies have a variation of a 'no net loss' requirement. The federal offsets policy states that offsets should 'improve or maintain' the biodiversity values experiencing a negative impact (DSEWPC 2012) while the Western Australian offset policy aims for 'offsets that are similar, but not identical, value' (Government of WA 2011). Federal and state offsets are classified into direct and indirect categories and both recognise land acquisition offsets, creation or improvement of habitat, research funding and educational activity as offsets.

Application of environmental offsets in Australia

The IUCN, federal and state offset policies all feature a type of mitigation hierarchy. The mitigation hierarchy is a process that proponents follow to reduce, as much as possible, the impact that development will have on the biodiversity value (Kiesecker *et al.* 2010; McKenney and Kiesecker 2010). In the case of the IUCN, all possible avoidance, mitigation and rehabilitation actions must be taken at the project site in order for the project to proceed. The two Australian policies mention avoidance and mitigation measures, but not rehabilitation at the development site which is usually addressed in associated or supplementary policy documents. Any environmental impact remaining after mitigation measures have been taken is called the 'residual impact' (McKenney and Kiesecker 2010; Quétier and Lavorel 2011). Ideally, avoidance and mitigation measures would be large enough to result in no residual impact and negate the need for offset application. However, for large developments, including roads, schools, housing or hospital construction, mining and farming, this is often not the case.

A lengthy process is in place that leads to the development of offsets and the specification of offset conditions by regulatory authorities. In Western Australia, developments can be approved with a clearing permit (Part V of the *EP Act 1986*) or by a ministerial statement (Part IV of the *EP Act 1986*). Project proposals must outline what environmental impact the proposed development action(s) will have. A decision is made regarding whether the proposal will be formally assessed. If it has been decided to formally assess the proposal, the EPA conducts an environmental impact assessment (EIA). EIA is a tool used to systematically evaluate the environmental impact of a proposed development and ways in which the impact could be reduced through avoidance and mitigation measures (EPA 2016). The Western Australian Department of Water and Environmental Regulation assesses the proposal in accordance with the clearing principles (DER 2014). Suggested offset types include establishing and maintaining vegetation or providing funding to do so (DER 2014) and funding to support research on impacted species (EPA 2016). An assessment bilateral agreement exists between the Commonwealth and Western Australian governments under the *EPBC Act 1999*, allowing Western Australia to assess proponent project proposals referred under both Part IV and Part V of the *EP Act 1986* on behalf of the Commonwealth if approved (DoE 2014). If not applied for under the bilateral agreement, both the Department of Environment and Energy and the Western Australian Environmental Protection Authority will assess the referrals. The proponent of a project can either undertake ministerial or clearing permit approval condition actions or transfer the responsibility to a third party.

Carnaby's cockatoo

An example of Western Australian biodiversity threatened by development and other pressures is Carnaby's cockatoo (*Calyptorhynchus latirostris*), an endemic species formerly distributed across the south-west corner of Western Australia, which overlaps heavily with areas of human agricultural and urban land use. Carnaby's cockatoo is a long-lived (Saunders and Dawson 2009), obligate hollow-nesting species with low reproductive output (Saunders *et al.* 2014*a*; Saunders and Dawson 2018). It is a seasonal migrant, moving from inland breeding areas to coastal locations in early summer, including urban and periurban parts of metropolitan Perth (Groom *et al.* 2014; Groom *et al.* 2017). It feeds on the seeds of proteaceous species and introduced *Pinus* spp. (Stock *et al.* 2013; Johnston *et al.* 2016, 2020). Habitat on the Swan Coastal Plain is regularly the focus of development opportunities (Ramalho 2012; DPaW 2013). The species is listed as endangered under Western Australian and Australian conservation legislation, and in the IUCN Red List (IUCN 2019).

Challenges of using offsets

Bull *et al.* (2013) divided offset implications into two categories: practical and theoretical. Practical implications included proponent compliance with offset requirements, as well as measuring and monitoring ecological outcomes during the period following the establishment of the offset. Theoretical implications included longevity of offset actions, suitability of metrics for measuring biodiversity to ensure 'no net loss', time lag between project impact and offset benefit, and defining what, according to policy, is a suitable offset. These challenges to implementing offsets have the capacity to undermine, or significantly delay any potential benefits offsets could provide and create uncertainty in offset outcomes.

A 'temporal gap' or 'time lag' may exist between an environmental impact and the benefits from compensation actions arising. Unless offset completion occurs before the development impact is incurred, there will be a gap before no net loss or gain is achieved (BBOP 2012; Bull *et al.* 2013). Any time lag experienced with revegetation offsets for Carnaby's cockatoos is likely to be challenging for the species given the large differences in regeneration time for different key plant species. For example, *Banksia* woodland can be grown to maturity in 12–16 years (Witkowski *et al.* 1991), but eucalypt woodlands necessary for nesting take more than 100 years. The final impact of any time lag is also influenced by the spatial arrangement of any new habitat relative to existing food and nesting resources and the capacity for the cockatoos to locate those new resources (Saunders and Ingram 1998; Saunders *et al.* 2014*b*).

Another important aspect in offset construction is the longevity of the offset (ten Kate *et al.* 2004). Environmental impact assessment considers the reversibility of the environmental impact and the length of time that the impact is experienced

(ten Kate *et al.* 2004). When the impact sustained is unable to be reversed, an offset lasting 'in perpetuity' may be considered a suitable offset (ten Kate *et al.* 2004). For example, the federal offsets policy states that direct offsets should be sustained for at least as long as the impact occurs (DSEWPC 2012). However, this is a large commitment for companies, some of which intentionally have a finite life related to the duration of a specific development project. A similar problem arises if the company undertaking the development is dissolved or ceases to trade. Protection against this type of risk would require trust funds or another plan to be put in place to ensure adequate funds are available for offsets to achieve their intended goals (Guerin-McManus 2001).

The IUCN offset policy requires baseline data to be obtained to compare the impact site before and after clearing/development, as well as monitoring of the offset area to assess whether the goal of the offset was achieved (IUCN 2014). There has been broad discussion in the literature regarding the measurement of biodiversity to determine offset outcomes, with no consensus on the best approach having been identified (ten Kate *et al.* 2004; Gordon *et al.* 2011; Quétier and Lavorel 2011; BBOP 2012; Bull *et al.* 2013). There is no universal metric or 'currency' to measure biodiversity, so each project often requires multiple metrics to be employed (Quétier and Lavorel 2011; Bull *et al.* 2013). In practice, often only the number of hectares impacted is used as a measure (Bull *et al.* 2013). Acceptable offset implementation relies heavily on enforcement (IUCN 2014), which can be difficult to achieve if there is a lack of clarity regarding who is responsible for offsets before and after implementation (particularly when a third party is involved) (Hayes and Morrison-Saunders 2007; Bull *et al.* 2013).

Monitoring of offsets is often inconsistent, making results unreliable (Quétier and Lavorel 2011). Inconsistent monitoring and a lack of monitoring have been attributed to uncertainty regarding who has the responsibility of offsets, in addition to any problems associated with how offsets are to be measured (Hayes and Morrison-Saunders 2007; Bull *et al.* 2013). Monitoring and reporting are essential for the evaluation of success of offsets. Without monitoring and reporting to the offset regulator, omissions and oversights cannot be identified and it will be difficult for offsets to be improved for the future.

The biodiversity of Perth, Western Australia, is threatened by a need to clear more land to support the growing human population. The current population of over 1.8 million is set to expand to 3.5 million by 2050. Environmental offsets that compensate for loss of habitat will play an important role in determining the future of species, including Carnaby's cockatoos (Morris *et al.* 2006; Miller *et al.* 2015). Environmental offset policy demonstrates political intent to conserve biodiversity and provides hope that the relationship between development and environmental MNES does not have to be a negative one. It also gives an economic incentive for avoiding biodiversity loss by placing a dollar value on biodiversity (Santos *et al.* 2015). However, theoretical studies maintain that offset foundational concepts and application of the offset process are ambiguous, which leads to unclear outcomes for the impacted biodiversity values. To date, there is little real-world research concerning effectiveness of current offset processes, application and outcomes and it is unknown if environmental offsets are adequately compensating serious habitat loss for Carnaby's cockatoo (Gardner *et al.* 2013; May *et al.* 2017). A recent study of a single offset project for Carnaby's cockatoo found that the offset habitat was of lesser quality compared with the development site (Thorn *et al.* 2018), while another study of Western Australian offsets found that many offsets are not meeting their goals (May *et al.* 2017). The research reported here expands on these studies by exploring whether state and federal offsets are delivering on the stated goals defined within offset policies, and specifically addresses the research question: how have offsets for Carnaby's cockatoo been applied by both Western Australia and the federal government? By virtue of the number of offsets created to mitigate development impacts on Carnaby's cockatoo, this case study allows inferences to be made regarding the offset process as a whole.

Methods

More offsets have been developed for Carnaby's cockatoo than for any other species in Western Australia; therefore, a substantial dataset is available to be utilised for this project. As such, a case study investigation of offsets was undertaken. Case studies (Denzin and Lincoln 2000; Baxter and Jack 2008) are not a methodology but a choice of what is to be studied (Denzin and Lincoln 2000). This study took a collective case study approach (Scheib 2003), where multiple offset cases were analysed against what a 'suitable' offset is, informed by offset policy and a search of the literature. To address the overall research question, a series of specific questions were formulated (see Table S1 available as Supplementary Material to this paper). Data were analysed in relation to these specific questions. Multiple data sources were obtained, and multiple methodologies utilised, allowing triangulation of the overall research question (Denzin and Lincoln 2000; Bekhet and Zauszniewski 2012).

Data and sample size

To explore how Carnaby's cockatoo offsets had been applied and how they have contributed to the species' conservation, data were obtained from government agency databases, university theses and reports available from non-government organisations. Themes identified in the policy review regarding offset qualities were used as a framework to guide the investigation of offsets.

The Western Australian Environmental Offsets Register is a publicly available database used to access offsets arising from Western Australian offset approvals (Government of WA 2016). This register contains details regarding offsets prescribed to compensate for a development, milestones required for completion of the offsets, a milestone timeframe, and a statement as to whether the milestones have been completed. The register allows searches to be customised in a variety of ways. The search term 'Carnaby's cockatoo' was used to create a list of projects that directly impacted the case study species. Other terms were trialled to ensure that all projects were captured within the primary output from the first search. These included: the species name '*Calyptorhynchus latirostris*' as well as 'short-billed black cockatoo' and other iterations. For consistency of data, only those offsets established between 2011 and 2016 were used, as the state policy was only released in 2011. Some offsets were excluded from analysis because although they made reference to Carnaby's

Table 1. Category criteria for offset classification by type

Category	Criteria
Land acquisition	Land with a level of protection into the future
On-ground management (rehabilitation/restoration/revegetation)	Creating habitat through revegetation of a degraded site
Other on-ground management	Other conservation management actions including: dieback disease control, fence installation, weed management, feral animal control
Research	Funding for scientific research addressing knowledge gaps in ecology of Carnaby's cockatoo
Education	Raising awareness through educational media about Carnaby's cockatoo and its habitat

Table 2. Data types and sources utilised to indicate usefulness of land acquisition offsets for Carnaby's cockatoo, current to 2016
DBCA, Department of Biodiversity, Conservation and Attractions; DPIRD, Department of Primary Industries and Regional Development; WA, Western Australia

Data type	Format	Source	Count
Great Cocky Count roost sites	Excel	BirdLife WA	263
Offset land parcels purchased	Shapefile	DBCA	44
Conservation covenant offsets	Shapefile	DPIRD	4
Carnaby's cockatoo known breeding habitat and adjacent feeding habitat	Shapefile	DBCA	–
National map colour base map	Shapefile	Geoscience Australia	–

cockatoo, on closer examination it was determined that the habitat was not suitable for this species and they were therefore removed from the list. A final sample size of 45 development projects and their associated offsets were examined.

The Australian Department of the Environment and Energy provided a list of federally approved development projects that had environmental offsets compensating for impact to Carnaby's cockatoos. This list provided the framework by which projects were searched via the Department of the Environment and Energy's Referrals List website (Department of the Environment and Energy 2016). Through this database, projects approved from 2013 through to 2015 were collated for analysis, resulting in a sample size of 20 project approvals. These 20 approval documents were the most recent and also those that could be analysed with the time available for this study.

The state and federal approved offset documents often referred to secondary documents (e.g. an offset management plan or a revegetation plan). These documents were searched for; however, accessibility depended on it being published online. Documents were searched for on regulatory authority websites and databases, development project proponent websites, as well as directly through search engines such as Google. Availability of these documents was used as a metric for transparency of the offset process. With a content analysis approach, offset documents obtained were investigated with a series of specific questions in mind and quantified with descriptive statistics (Supplementary Table).

Content analysis

A systematic, quantitative content analysis method of investigating the offset document text data was conducted. This process allowed collation of information based on a series of identified themes to put together a picture of offset use and implementation in Australia and Western Australia. Often used in the health sciences, it is unusual to see content analysis used in the field of conservation. However, content analysis is a commonly used methodology for examining policy and other text documentation (Kiesecker *et al.* 2007; Zardo and Collie 2014). There has been debate amongst social scientists regarding types of content analysis, and many different content analysis methods have been constructed over time (Hsieh and Shannon 2005). Systematic, quantitative content analysis has been described as the 'scientific approach to social science' (Franzosi 2008). This process gave descriptive frequency data and was chosen as it facilitated analysis of large amounts of text, was flexible in nature and enabled data to be systematically collated against the investigative questions and uncovered policy themes.

Offsets were categorised by type using definitions obtained from the offset policies, as well as the categories that Western Australian offsets were already placed into on the online Environmental Offsets Register (Table 1).

GIS and land acquisition

To further investigate specific offset types, more datasets were obtained and analysed (Table 2) in order to identify the location of offsets and overlay them with known Carnaby's cockatoo habitat types to identify the level of overlap, and if offsets were placed in areas of use for the birds.

Using the Model Builder tool of GIS program ESRI, spatial analyst tools and techniques were utilised to model multiple data sources (Table 2) and investigate land acquisition offsets acquired for Carnaby's cockatoo. Land parcels purchased by the Department of Biodiversity, Conservation and Attractions (DBCA) and covenants established by the Department of Primary Industries and Regional Development (DPIRD) under the provision of the Western Australian *Soil and Land Conservation Act 1945* were included in this analysis. It is likely that not all land acquisition offset locations were captured in the dataset

as covenants can be established through two other programs for which data could not be obtained.

The Great Cocky Count (GCC) is an annual citizen science survey conducted on the same night each year (Peck *et al.* 2016). Data are based on the number of black cockatoos that arrive at known roost sites at dusk and are used to provide population estimates. GCC data were received in Excel format. One GPS coordinate record within the GCC dataset was excluded and assumed to be an incorrect entry, as it was located in Indonesia.

Useful and important habitat to conserve for Carnaby's cockatoo could be characterised into breeding, foraging or roosting habitat (DPaW 2013). A recent study completed in 2015 fitted satellite tracking devices to 23 rehabilitated Carnaby's cockatoos and monitored their movement and use of habitat types across their distribution on the Swan Coastal Plain (Groom *et al.* 2017). The results indicated that, on average, the birds travelled 5.5 ± 3.8 km to and from roost sites on the Swan Coastal Plain each day. Therefore, any Carnaby's cockatoo habitat around roost sites that fell within a 5.5-km radius was used as an indication of 'usefulness' of offsets as they would be likely to either use the roost or foraging habitat surrounding it (useable area). Known breeding habitat site GIS data were obtained from the DBCA, which collated records from multiple sources into one dataset. Any used breeding habitat is considered important and therefore useful due to a decline in suitable breeding habitat.

Research offsets

Research offsets were explored with a content analysis approach, where text document data in the form of postgraduate research progress reports were examined to answer the research questions (Supplementary Table). These investigative questions were structured to indicate whether research was a successful offset type and how the products from the research contributed to the conservation of Carnaby's cockatoos. The research update reports were obtained from research students whose projects were funded through offsets (as well as by the DBCA). Two research students have been funded from offsets compensating clearing of Carnaby's cockatoo habitat. These two offsets, where research was a condition of approval, were not captured in the offset sample size initially investigated, with the developments having commenced before 2011, and so they were extracted for separate appraisal. Both research offsets were products of federal approvals. Approximately AU$275 000 was provided for a M.Sc. study by research based at Edith Cowan University. Funding this research was a condition of approval for the Fiona Stanley Hospital development approved in 2008. Multiple offsets funded the research conducted during a Ph.D. study based at the University of Western Australia.

Results

Offset analysis

A sample size of 45 development projects, including 93 offsets, were approved by Western Australian regulatory authorities. Of the 45 Western Australian–approved projects, 42 were approved via a clearing permit and three were approved via a ministerial statement. Federally, 20 approved projects produced 29 offsets.

Table 3. Percentage of different types of offsets for Carnaby's cockatoo habitat resulting from (a) Western Australian, and (b) Australian federal development approvals

	Western Australian development offset ($n = 93$)	Australian federal development offset ($n = 29$)
Land acquisition	71.0	62.1
Habitat rehabilitation	22.6	24.1
Other on-ground management	5.4	13.8
Education	1.1	0.0
Research	0.0	0.0

Offsets, when classified by type, revealed that land acquisition offsets were the most common type arising from both Western Australian and federally approved developments (Table 3). Less frequently encountered offset types were rehabilitation, other on-ground management and educational offsets. No research offsets were captured within the time frame of the sample size examined (see Methods section, above).

Land acquisition offsets

Land acquisition offsets were further classified by the method used to secure the area of land into the future (Table 4). Purchased areas of land constituted the most common acquisition type, both federally and for Western Australia. For Western Australian offsets, a total of at least AU$5 347 006 has, or will be, provided to the Department of Water and Environmental Regulation for the purchase of land acquisition offsets.

GIS and land acquisition

GIS analysis revealed that more breeding (plus the adjacent foraging) habitat has been protected than foraging and roosting habitat on the Swan Coastal Plain from both purchased land and land with a conservation covenant placed on it (Table 5). The data presented in Table 5 includes all land purchases, including those that predated the period used in this study, and the data presented in Table 4 relates only to the sample of offsets used in the analyses above.

Landscape-level planning has been undertaken in regard to the location of purchased land acquisition offset parcels (Fig. 1). The parcels (shown in red) are not randomly distributed across the distribution of Carnaby's cockatoo. Instead they are aggregated, and close to other lands already managed and protected (shown in dark green). It appears that the purchased parcels are converting unprotected areas between the already protected and managed lands, to provide linking corridors. Some parcels have been strategically obtained and directly adjoin existing protected areas. Most of these land parcels are on the Swan Coastal Plain to the north of Perth.

Research offsets

Results from the research offsets were published in reputable, peer-reviewed scientific journals and thesis downloads from university repositories are high (Table 6). There is a time lag for the M.Sc. research study, where publication did not occur until

Table 4. Number and area (ha) of Western Australian (WA) and Australian federally approved land acquisition offsets categorised according to the method used to secure the lands using the Western Australian Environmental Offsets Register and development approval documents from the Department of the Environment and Energy's Referrals List website

	Purchase	Cede	Conservation Covenant	Reserve management amendment	Binding agreement[A]	Not Specified	Total
No. of WA land acquisition offsets	43[B]	11[B]	5	2[B]	5	–	66
No. of federal land acquisition offsets	11[B]	–	3	–	–	4[B]	18
Area (ha) of WA land acquisition offsets	3505.9	2711.6	2706.1	5.6	353.09	0	9282.2
Area (ha) of federal land acquisition offsets	1905.8	–	708.3	–	–	886	3500.1

[A]A binding agreement condition gave proponents a choice of how to protect the land acquired. Options included conservation covenants, agreement to reserve or a ceding of land to the Crown.
[B]One land acquisition offset in each category did not specify the land area (ha) to be offset.

Table 5. Overlap between non-breeding useable area and known breeding habitat with the location of current state- and federal-approved land acquisition offsets

Non-breeding habitat comprises roost sites and potential foraging habitat surrounding it. DPIRD, Department of Primary Industries and Regional Development

Data type	Habitat type	Overlap (ha)	Total offset area (ha)	Purchased offset area within areas useful for birds (%)	No. of offset parcels
Purchased land parcel offsets	Useable area (non-breeding habitat)	1215.3	25 364.45	4.8	44
	Known breeding habitat	8655.3	25 364.45	34.1	44
DPIRD conservation covenants placed	Useable area (non-breeding habitat)	0	967.0	0	4
	Known breeding habitats	410.7	967.0	42.5	4

three years after thesis completion. This was not the case for the Ph.D. thesis, where publications were consistently generated throughout the student's enrolment.

Transparency

Of the Western Australian–approved projects, project approval documents that specified conditions relating to offsets were mostly publicly unavailable. Projects approved by ministerial statement had the approval document available; however, those approved by clearing permit (42 of 45; 93.3%) did not at the time this study was conducted. Therefore, it is unknown whether the Western Australian clearing permit approval documents had conditions similar to federal project approval documents requiring applicants to publish offset compliance reports or secondary documents. All secondary documents referred to in the Environmental Offsets Register (e.g. rehabilitation plans, weed control plans) were searched for online. For each offset, most secondary documents referred to were not found (60.5%). Only 8.6% of extra documentation referred to was found online. The remaining 30.9% of offsets did not refer to other documentation at all.

Of the 20 federal project approvals, 18 (90%) had a condition to publish a compliance report on the project proponent's website. Sixteen (80%) of the approvals specifically required the publishing of a compliance report annually. Of the approvals with a condition to publish a report, one stated that the reports must stay on the proponent's website for the life of the project approval, seven stated that the reports remain on the website for a minimum of 12 months, and 10 did not specify the duration that the compliance reports had to be available online.

Timeliness

Of the 238 implementation actions from all Western Australian–approved offsets, 24 of those actions had to be completed before clearing occurred. Considering these 24 actions required to be completed before clearing for a development took place, the transfer of funds ($n = 15$) was the most common action required, followed by land protection ($n = 7$) and approval of the offset proposal ($n = 2$). Data on the timeline of implementation actions were not available for federal offsets, as it was for Western Australian offsets.

The proportion of actions from Western Australian–approved offsets that had been completed at the time of this study, and those that were yet to be completed are shown in Fig. 2. This demonstrates the time lag between funds transfer for land purchase and the actual purchase of the land. Equivalent data for federally approved offsets were not available.

Discussion

Land acquisition

Land acquisition offsets are the most common of the offset types used in Western Australia (May *et al.* 2017). The IUCN policy recognises that land acquisition offsets (also known as averted loss offsets) are a useful way to protect biodiversity from impacts that would have occurred had protection not been given to it; however, these offsets should only be applied in addition to other offsets that 'improve the state or condition of the target biodiversity' (IUCN 2015). Replacing what is lost is key to achieving a neutral relationship between development

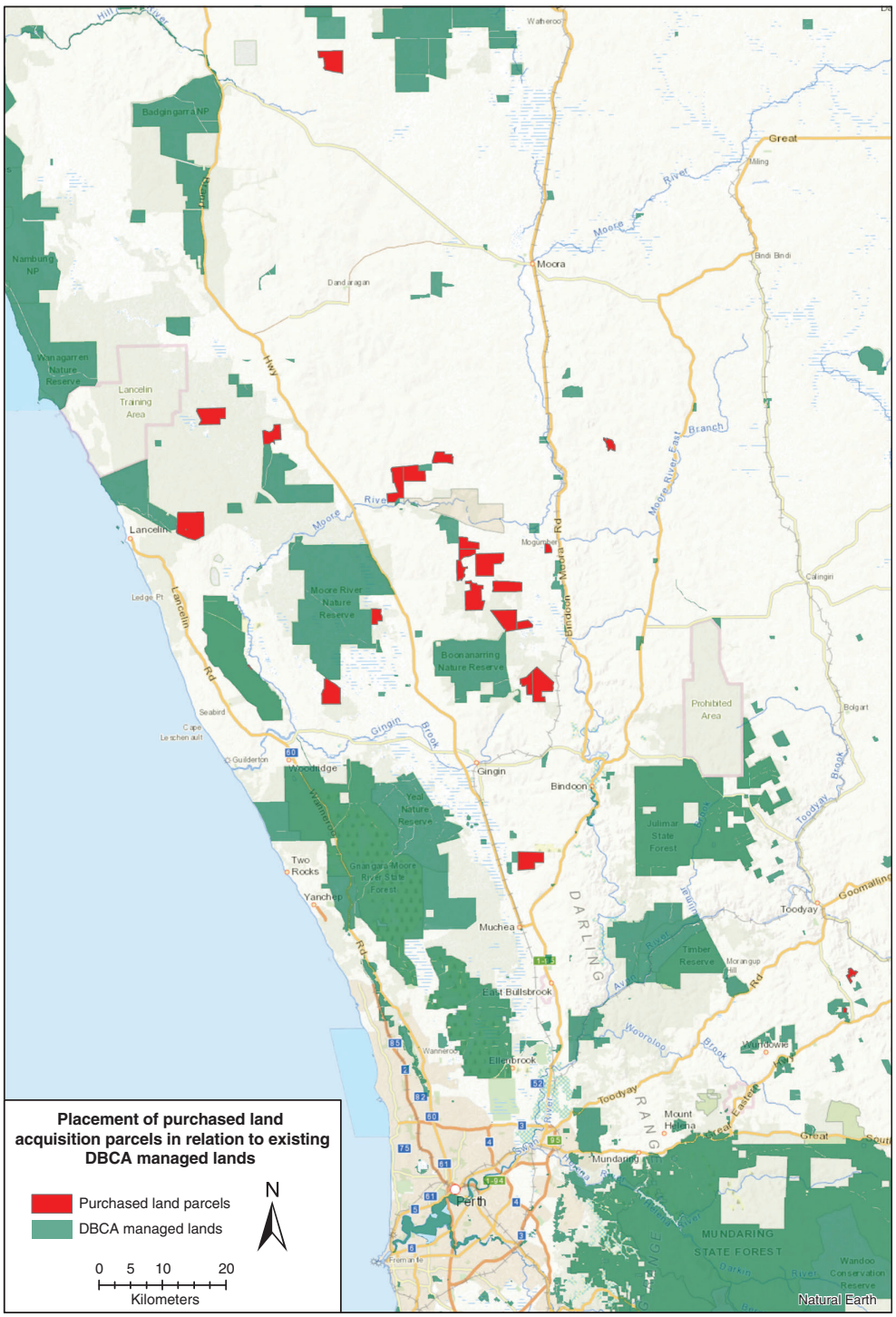

Fig. 1. Mapped location of purchased land acquisition parcels in relation to land managed by the Western Australian Department of Biodiversity, Conservation and Attractions for conservation, current to 2016.

and biodiversity. Land acquisition offsets do not create habitat. For Carnaby's cockatoo, loss of all habitat types is an acknowledged contributor to population decline (DPaW 2013). Habitat rehabilitation offsets are likely to be the most beneficial for the species in the future as resources provided by this type of offset mature. As both Western Australian and federally approved offsets most frequently specify land acquisition, and for many projects this is the only type of offset specified, a net loss of Carnaby's cockatoo habitat is almost a guaranteed outcome.

Table 6. Metrics to demonstrate success of two research offset theses addressing knowledge gaps needing to be filled as prescribed in the Carnaby's Cockatoo Recovery Plan (DPaW 2013)

Thesis title	Roost site fidelity and resource use by Carnaby's cockatoo, *Calyptorhynchus latirostris*, on the Swan Coastal Plain, Western Australia	Food resource availability for Carnaby's cockatoo *Calyptorhynchus latirostris* on the Swan Coastal Plain
Author and date	Groom (2015)	Johnston (2013)
Enrolment type	Ph.D.	M.Sc.
Thesis completed	Yes	Yes
Thesis completed on time	Yes	Yes
Pass/fail	Pass	Pass
No. of peer-reviewed papers arising from research	5	2
No. of thesis downloads (as of 12.vii.2019)	1097	1043
No. of conference presentations/documents/newsletters	2 (conference papers)	1 (newsletter)
Recovery plan actions addressed	Yes	Yes
Average time lag to publication (years) following submission of thesis	−1	3

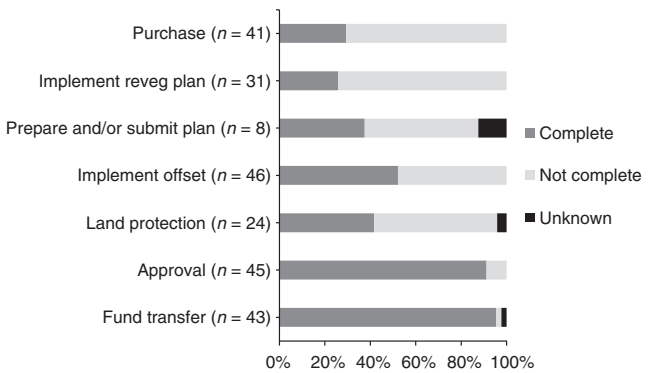

Fig. 2. Western Australian offset condition completion performance categorised according to implementation action type ($n = 238$ actions).

Most land acquisition offsets were purchased, ceded or had a conservation covenant placed on the title of land. Purchased and ceded land was to be vested with the Western Australian Conservation and Parks Commission, with the land to be managed by DBCA. Offset funds are expended obtaining the land; however, there is seldom any extra funding provided for managing that land after purchase. Without an increase in funding from alternative sources, the capacity for DBCA to manage lands given to them may be reduced as the amount of land they are required to manage increases.

All three offset policies agree that offset outcomes should endure for the long term, with federal and IUCN policy agreeing that 'long term' refers to the duration of the impact, where impact refers to the consequences to biodiversity arising from clearing. However, there is no guarantee that purchased land will be untouched in perpetuity. Until it is converted to conservation estate, purchased land is vulnerable to being used for future development.

Conservation estate in Western Australia includes nature reserves, national parks and conservation reserves. Conservation estate has legislative protection under the *Lands Administration Act 1997* and the *Conservation and Land Management Act 1984*. Conservation estate classified as a Class A nature reserve or national park is more difficult to develop as approval needs to be obtained from both Houses of Parliament. However, to become conservation estate the relevant minister needs to seek and obtain the approval from government authorities including the Department of Mines, Industry Regulation and Safety (DMIRS) (Conservation Commission of WA 2011). Proposals for new conservation estate are often not supported by the DMIRS, which has meant that creation of conservation estate is delayed indefinitely, as has been the case for most proposals to convert purchased offset land (Conservation Commission of WA 2011).

Since land acquisition offsets are the most common type of offset applied, it was important to investigate the location and quality of acquired land and how useful it may be to Carnaby's cockatoos (Thorn *et al.* 2018). Acquired land has been predominantly located in the northern part of the Swan Coastal Plain, suggesting that offset location was considered at a landscape level, as opposed to a project level. Some offset parcels that have been purchased shared a common boundary with existing conservation estate. Other individual offset parcels are located close together, or are adjoining, providing a more-or-less contiguous corridor running from just north of the Moore River, southwards to the southern margin of the Perth metropolitan area. This new aggregation of purchased land parcels is situated roughly midway between two already managed north–south corridors, strongly suggesting a strategic construction of a wildlife corridor. Although not a completely continuous habitat corridor, this is not a large issue for Carnaby's cockatoo as it is a highly mobile species and can fly between fragments of habitat (Groom *et al.* 2014). Protecting land strategically with a corridor for Carnaby's cockatoo indirectly benefits ecosystems in the area by offering protection into the future, if converted to conservation estate.

When consideration is given to the overlap of purchased land with known habitat used by Carnaby's cockatoos, offset land overlapped with breeding habitat (and associated foraging habitat) more than non-breeding habitat, which may be a function of the value of land on the Swan Coastal Plain in

comparison to land further away from the city. Given a set budget with which to purchase land, a greater number of hectares will be able to be purchased further away from Perth than closer to Perth, providing better value for money for project proponents. The difference in overlap with habitat types may simply reflect the availability of suitable habitat to purchase at the time the offset is being established, or it may reflect current limitations on knowledge of habitat use by Carnaby's cockatoos in areas beyond the coastal plain. As Perth's urban sprawl continues to expand, remaining native vegetation remnants are becoming increasingly scarce. The vegetation community '*Banksia* woodlands of the Swan Coastal Plain ecological community', which contains critical food resources for Carnaby's cockatoo, has recently been federally listed as a threatened ecological community (effective 16 September 2016).

Research

While research is not recognised by the IUCN policy as an offset since it does not produce a direct measurable outcome, the two research offsets examined provided examples of successful and useful research specific to Carnaby's cockatoo conservation. Both research projects addressed knowledge gaps specifically identified in the Carnaby's Cockatoo Recovery Plan (DPaW 2013). Since completion, the information from both research offsets has been shared and utilised, even in government planning processes. For example, use of the same satellite tracking techniques pioneered by one research student has confirmed the relationship between night roosts and usable adjacent foraging habitat (Groom *et al.* 2014, 2017; Groom 2015). Calculations of energy yield from key Swan Coastal Plain food resources (Johnston 2013; Johnston *et al.* 2016, 2020) have been incorporated into foundational calculations within population viability analysis (Williams *et al.* 2017). Without the application of these research findings, only 'best estimates' of the value of the vegetation at risk from future development could have been achieved and there would be less certainty about what would be required to ensure the survival of Carnaby's cockatoo in light of the proposed level of clearing.

Research may not be applicable for every offset. In the case of Carnaby's cockatoo, research offsets were a suitable choice because addressing knowledge gaps has been beneficial for informed planning and conservation management. The Western Australian Environmental Protection Authority (EPA 2019) has recently identified a list of priority research gaps for Carnaby's cockatoos, some of which are being addressed by current research efforts; others are yet to receive attention. However, at some time in the future, researching Carnaby's cockatoo may not provide such benefits. Over time, a suitable offset for a species may change, which confirms the need for flexibility in the offset process in order to optimise outcomes for the impacted biodiversity values.

Transparency

Both the Western Australian and federal offset policies feature the term 'transparent', indicating that the offset process must be as clear and unambiguous as possible. Western Australian and federal authorities regulating the offset process and informed by their respective policies achieve transparency in different ways. The Western Australian government is responsible for the Western Australian Offsets Register where past, current and future development projects and their associated offsets are listed and offset details broadly given. The register is online and easily accessible to the public (Government of WA 2016). A search feature allows specific projects and offsets to be found. The register increases transparency of the offset process by clearly providing offset information. However, many offset records referred to secondary documentation (e.g. an offset proposal, a revegetation management plan or rehabilitation plan) that mostly could not be found online at the time approval was granted or shortly after. A check of the online register in 2020 indicated that more records had subsequently been added, but this was not the case for all approvals. Adding these documents to the Western Australian Offsets Register would deliver greater clarity and more detail on applied offsets. Additionally, primary project approval documentation via clearing permits listing offset approval conditions was not available from a single online repository and was seldom available at the time of the development. Consequently, it is unknown if there were approval conditions requiring compliance reporting. No compliance reporting for Western Australian–approved projects was found online, suggesting that compliance reporting was not a focus of the Western Australian offset process. Compliance reports are important for transparency as they remove any question about offset conditions not being fulfilled. Even without an approval condition to do so, companies with an environmental impact may wish to publish these reports to demonstrate their social licence to operate, allowing developers who can demonstrate respected company values to gain support from the public.

The federal regulating authority also has transparent aspects to the development and offset approval process, as well as the offset implementation process. The referrals list website documents stages of the development project approval (Department of the Environment and Energy 2016). It provides documentation regarding project referrals and evidence of invitations for public comment on referrals. Project approval documents (primary and/or secondary) are the most important documents made available, something that was mostly not available for Western Australian–approved projects at the time of this study (2016). These documents list the conditions under which clearing is approved and include offset conditions. Often specified within federal project approvals is a condition to make offset plans and compliance reports publicly available through the proponent's website. Offset conditions often stipulated that compliance reports be published yearly and kept on the proponent's website for at least a year, if not in perpetuity. The federal regulating authorities could benefit from a system similar to the Western Australian Environmental Offsets Register, where all information regarding offsets is located in a single location, including compliance reports that were often difficult to locate on proponents' websites.

Reporting

No final reports were found or mentioned in any offset documents analysed. There may have been reports generated but they were not made publicly visible. Within all three offset policies there are no specific reporting directions regarding who reports are provided to, or how often they are to be submitted. May *et al.*

(2017) demonstrated that poor reporting (15% compliance for past offsets) is commonplace in Western Australia. The potential absence of reporting is problematic, as what does not work effectively when implementing offsets is not being formally recognised in the form of a report, and therefore is unlikely to be acted upon or improved upon in future offsets.

Reporting of revegetation outcomes for Carnaby's cockatoo offsets could be particularly useful as most habitat to be revegetated on the Swan Coastal Plain would be *Banksia* woodland, a main foraging resource for the birds (Johnston *et al.* 2016, 2020). Recently federally listed as a threatened ecological community, *Banksia* woodland is notoriously difficult to restore. Reporting could be a very useful tool to inform methodology and the costs associated with successful *Banksia* woodland restoration. As ecological restoration is a recent discipline, scientific discussion has developed and recognises that restoration is often far from successful (Benigno 2012; Ritchie 2014). A commonly applied *Banksia* woodland restoration technique is to collect the topsoil seedbank of an area to be cleared and spread it onto an area to be restored; however, establishment success with this technique is often low (Benigno 2012). Benigno (2012) found that the level of soil compaction at a restoration site, as well as drought stressors, had effects on the ability of two common overstorey *Banksia* species to establish. Establishment success does not necessarily indicate restoration success. Ecological functionality is a better indication of restoration success (Ritchie 2014). Reporting a scientifically informed trial-and-error process of *Banksia* woodland restoration would provide valuable data for isolating effective techniques and would avoid the unnecessary repetition of ineffective ones.

Timeliness

Time lag has been well established as a challenge for offsets (Maron *et al.* 2012, 2016; Gardner *et al.* 2013). To prevent a time lag, a logical solution is to complete offsets before development occurs. For on-ground offsets, the forward planning required and delay to development while waiting for an offset to be completed suggests that this would be unlikely to happen. For Carnaby's cockatoo, it was found that a time lag is evident as most timeframes specified for Western Australian–approved offset actions are set for a point in time after clearing occurs. Time lag is particularly an issue for on-ground management offsets including revegetation, rehabilitation and restoration offsets (EPA 2019). As the time lag increases, so too does the risk of an offset failing to achieve no net loss. A computer modelling study focussing on a south-eastern red-tailed black cockatoo (*Calyptorhynchus banksia graptogyne*) and their main food source found that offsets were unable to accomplish no net loss due to time lags in resource maturity (Maron *et al.* 2010). This is particularly an issue for Carnaby's cockatoo where extended time lags result in an effective net loss of habitat, which risks a resource bottleneck (Maron *et al.* 2012; Curran *et al.* 2014).

Limitations

This study has been limited in scope by the availability of some documentation online. Offset reports, offset proposals and plans constitute a few document types that were unable to be accessed. However, not being accessible does not necessarily imply that they do not exist. Additionally, it was found that a search of the Western Australian Environmental Offsets Register did not capture a complete list of development projects despite use of several search terms. Some developments impacting Carnaby's cockatoo with offsets were missed and not captured in the Western Australian offset sample size. Finally, Western Australian offset data, and results produced therein, are based on the assumption that all data on the Environmental Offsets Register is complete and up to date.

Conclusion

Environmental offsets may be the key to a sustainable relationship between development and the persistence of biodiversity, where the negative impact to the target biodiversity is compensated for by positive impact actions. Using Carnaby's cockatoo as a case study of how offsets have been applied, it was found that good outcomes were produced but there are key areas for improvement for the benefit of both Carnaby's cockatoo and the offset process.

Offsets established as part of the approval process for development of key habitat for Carnaby's cockatoo have predominantly been of a form that has resulted in a change in ownership of freehold land with the intention that the tenure be converted to conservation estate at some point in the future. Very few offsets have resulted in the establishment of new habitat.

Lands purchased appear to have been strategically located either adjacent to existing conservation estate, or within an unfolding corridor of habitat suitable for Carnaby's cockatoos, and to the north of Perth. There is uncertainty regarding the capacity of government departments to cover the cost of managing purchased offset land now and in perpetuity. To date, funds have been provided to purchase offset land but not for ongoing management. An opportunity exists to consider management funding as an additional form of offset, to help ensure that lands purchased as part of offsets can be maintained or improved into the future. However, the selection of offset areas has sought to target large areas in very good condition because these are more likely to persist in the longer term and have relatively low need for active management. Some longer-term decline is still possible, but the intent has been to minimise this.

Offsets for Carnaby's cockatoo have yielded important research results. The two research projects funded by Carnaby's cockatoo offsets have already had a significant impact for the scientific community and future of planning for Perth. This choice of offset appears to be a successful and suitable one while gaps in the knowledge of Carnaby's cockatoo ecology remain.

All offset policies investigated clearly stated that the offset process is to be transparent. When investigating transparency of Carnaby's cockatoo offsets, it was found that there was a lack of secondary documentation, compliance reporting and general reporting to be found freely accessible online. Without these documents being available, it was largely unknown if there was an offset reporting requirement. Reporting should be a major component of the offset process. Reporting back to offset regulators would allow the offset process to improve and prevent continued application of ineffective offsets. A reporting procedure may already be in place that is not visible to the public. It may be in the interest of developers or regulators to

release these documents online for demonstration of their social licence to operate and advocate to the community a reputable offset process overall.

A stewardship program may be an alternative option for consideration. The program would be targeted at private landowners in the wheatbelt region where remnant bushland is unlikely to be cleared due to environmental approval barriers. A stewardship program would deliver an allowance to the landowner with conditions for conservation management and upkeep of bushland on their property. Management actions may include installation of fences and artificial nest hollows, feral species control, weed control, and other measures such as fire break maintenance. Stewardship programs already exist in Australia, and overseas. For example, the Trust for Nature, Victoria, has a stewardship program that complements a covenant program. When a covenant is established, the landowner is automatically entered into the stewardship program. Staff and landowners work together and create a specific management plan for the covenanted area, ensuring its good health into the future (Trust for Nature 2016). This could effectively increase the quality of Carnaby's cockatoo habitat, encouraging population growth as well as ecosystem health.

A similar program could be applied in Western Australia. If a similar amount of funding dispensed for Carnaby's cockatoo land purchase to date (over AU$5 000 000) was placed into a high-interest-earning bank account, the interest generated could be utilised for stewardship payments to the landowners. An area-specific management plan would be produced with a stewardship program, allowing specific management practices to be applied to the offset area. This program would require regulation. A monitoring, reporting and compliance system would need to be in place that would allow two-way communication between the landowner and a regulating department (such as DBCA). If the stewardship program were to be applied in conjunction with existing conservation covenant programs in Western Australia, monitoring, reporting and compliance systems in place could be applied to the stewardship program as well.

Some aspects of Carnaby's cockatoo offset use in Western Australian were unable to be analysed. Rehabilitation and other on-ground management offsets were not documented in enough detail with data publicly available online to be able to examine important characteristics such as timeframe, measurement techniques or other offset qualities. The study by Thorn *et al.* (2018) demonstrates the importance of measuring offset quality before accepting proposed land purchases as valid offsets. Other documents that could have provided these data were mostly unavailable online, reducing transparency and accountability of the offset process. If documentation and transparency improve this may open an avenue for future investigation into on-ground management activity. As on-ground management such as rehabilitation and restoration are the only type of offset that actually replace the biodiversity value impacted, it is important to review how these offsets are being applied in Western Australia.

While offsets were the focus of this study, it is fitting to discuss the importance of the mitigation hierarchy. The steps in this hierarchy (avoidance, mitigation and rehabilitation on-site) are the key to ensuring as small a development impact as is possible. Offsets must always be the last resort. While a neutral or positive relationship between biodiversity and development is the proposed outcome of offsets, it is important to remember that loss of an area-specific ecosystem remains, and offsetting will not produce or protect an exact replica of habitat originally impacted. Avoidance and mitigation action should have the highest priority when planning a development.

Overall, this case study demonstrates the strengths of the existing offset process and identifies opportunities for improvements. Existing offset policy is better than having no policy, where previously development would not have been subject to assessment or required to replace lost biodiversity (Fallding 2014). Policy makers and developers working within the offset system should focus on the issues of net loss of habitat and transparent reporting.

Conflict of interest

We declare no conflict of interest in relation to this research.

Acknowledgements

We thank Alex Errington, Manda Page, Lei Zhang and Geoff Barrett from the Department of Biodiversity, Conservation and Conservation for access to data on the value and location of land purchased as part of offset approvals, and for access to data on location of conservation covenants conserving Carnaby's cockatoo habitat. Thanks also to the Western Australian Department of Primary Industries and Regional Development, in particular Andrew Watson, his colleagues and the GIS team for providing covenant location data for inclusion into the analysis. Adam Peck from BirdLife Australia kindly provided access to the 2016 geocoded data for the Great Cocky Count roost locations. The Federal Department of Environment and Energy kindly provided access to data on Carnaby's cockatoo offset conditions approved under federal legislation. We thank David Mitchell for his comments on an earlier draft of this paper and Hugh Finn for his valuable input. This research did not receive any specific funding.

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