Public preferences for the design of biodiversity offset policies in Australia

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Abstract

Understanding the social acceptability of biodiversity offsets is important in order to properly design offset policy. This study used a discrete choice experiment to quantify preferences of the Australian community for a migratory shorebird offset, in the context of an oil and gas development. The attributes in the choice experiment were comprised of several offset policy characteristics, with a view to informing future policy design of the social dimensions related to offset acceptability. We found that the practice of offsetting was accepted by the community as a means to allow economic development. The ability to exchange protection of a species impacted by the development for a more endangered species was a desirable policy characteristic, as was having the offset implemented by a third party or the government, as compared with the company responsible for the development. Direct offset activities were preferred over indirect, and there was a strong aversion to locating the offset at a site other than where the impact occurred. While some policy characteristics were less desirable from a social perspective, it was possible to compensate for these by increasing the amount of biodiversity protected by the offset.

Keywords: choice experiment; nonmarket valuation; shorebird offset; environmental offset.

JEL classifications: Q510, Q570, Q580

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1 Introduction

Biodiversity offsets are used to compensate for unavoidable environmental impacts resulting from development. The potential for offsets to allow economic development to proceed while accounting for environmental damage has drawn international interest from government and non-government agencies, and the development companies themselves. Offset policies are being implemented by governments worldwide to formalize the appropriate design of biodiversity offsets. While the objectives of these policies are often similar for different governments and regions, typically centred on the concept of 'no net loss' (Bull & Brownlie 2015), there is variability in the specific policy characteristics to achieve this (Mckenney & Kiesecker 2010).

Being a fledgling area of policy, ecological constraints should necessarily be considered in offset policy design: the scientific evidence cautions that offsets must be designed carefully, or they can fall short of delivering the environmental objectives they promise (Dickie et al. 2013; Temple et al. 2012; ICMM IUCN, 2012; Quétier et al. 2014; Treweek et al. 2009). However, a better understanding of community acceptance and the tradeoffs people are willing to make could help to set the social boundaries within which offset policies could operate, subject to ecological and economic feasibility (Burton et al. under review; Richert et al. 2015). This could increase flexibility from an ecological perspective, for example, to allow protection of a more critical habitat than the one impacted.

Research on offsets to date has primarily focussed on physical design aspects (e.g. Dickie et al. 2013; Department of Environment and Conservation NSW 2011; Quétier & Lavorel 2011; Madsen et al. 2010; Middle & Middle 2010; Hayes & Morrison-Sanders 2007). There is some work on social acceptability: Bougherara et al. (2013) study community acceptance of firms making versus buying offsets for milk production attributes in France. Burton et al. (under review) make the first known attempt to quantify preferences of the West Australian community for biodiversity offsets, in the context of an Australian oil and gas development impacting on the habitat of a species of a nationally protected migratory shorebird. Paredes (2015) conducted a similar study with Australia's Queensland community.

In Australia, offsets are governed by both State and Commonwealth policies. Offsets are a requirement when a proposed development cannot avoid or mitigate all environmental impacts. The offset policies are aimed at equivalence: a proponent must demonstrate that the offset will achieve 'no net loss' of the impacted environmental matter, typically by protecting or improving equivalent environmental matter elsewhere. State offset policies apply to any residual environmental damage likely to occur as a result of development within the relevant region (e.g. Government of Western Australia 2011); the Commonwealth's Environmental Protection and Biodiversity Conservation (EPBC) Act Offset Policy applies in addition when a protected 'matter of national environmental significance' is affected by the proposed development (Australian Government 2012). The Australian policies, particularly the latter, are very prescriptive in terms of permissible offset design: there is a strong emphasis on direct (like-for-like) offset activity and limited scope to substitute protection for other species, habitats or locations.

As a precursor to this study, the pilot study by Burton et al. (under review) relaxed the existing policy setting to investigate the social acceptability of a limited set of changes in the design of a biodiversity offset for shorebirds using a discrete choice experiment (Hensher et al. 2005; Louviere et al. 2000). Specifically, that study investigated three aspects of an offset design.

First, it compared preferences for direct versus indirect offsets. In a direct offset, as the name implies, the relationship between the activity and the ecological outcome is more direct, and could be perceived as more reliable. Current policy suggests that the use of indirect offsets be minimised if possible.

Second, the study considered offset location. Although there may be arguments that support introducing the offset close to where the impact occurs, in some cases, ecologically, it could be an advantage to locate an offset elsewhere. For example, for species found in multiple regions, targeting conservation efforts at critical habitat bottlenecks could be beneficial. However, issues of governance and a desire for local solutions to local problems may lead respondents to reject offsets away from the impact site.

Third, the study investigated the species protected by the offset. A strict definition of no net loss would require that the offset action be directed at protecting the species impacted by development, but it is possible to make a case that greater benefits might be achieved by protecting a more endangered species within the offset. Investigating this aspect offers an initial response to the question posited by Bull and Brownlie (2015, p.5) as to "the extent to which loss of biodiversity is accepted in exchange for conservation of biodiversity of a higher priority".

In summary, the pilot found: a preference for a combination of direct and indirect offsets; a preference for siting the offset within Western Australia where the hypothetical impact occurred, and not elsewhere in Australia or internationally; and, a diversity of preferences within the sample for which species was protected.

A limitation of the pilot was its relatively small sample size (n=204), and the restriction of the respondent sample to Western Australia. Thus, in coming to the conclusion that there was a preference to keep the offset in Western Australia, it was not possible to differentiate an ecological imperative (keeping the offset near the impact) and a geo-social one (keeping the offset in the same state as the respondent). In expanding the study to a national representative sample we overcame this limitation, and provide a more appropriate frame for preferences, given the ecological issue is one of national significance. We also took the opportunity to expand the number of attributes being considered in the current study.

An important inclusion in this study was an attribute varying the number of individuals of the species protected by the offset, so that potentially more birds would be protected as compared to those being impacted by development. Understanding these preferences enabled us to determine the tradeoffs people were prepared to accept between the different policy attributes; that is, whether an undesirable policy characteristic would be accepted if a multiplier was applied to the protected matter.

In addition, we explored the acceptability of different parties implementing the offset. It was anticipated that respondents might have more confidence in one implementer over another. For example, individuals might be averse to the developer implementing the offset (Bull & Brownlie 2015), relative to an independent party.

Finally, economic and environmental tradeoffs were examined in terms of the general acceptability of offsetting. The economic benefits were captured by altering the number of jobs the development would create, where it was hypothesised that more jobs would lead to greater acceptance of the offset.

2 Methods

Discrete choice experiments were used to measure the community's preferences for biodiversity offsets. Choice experiments have been widely applied in the environmental non-market valuation literature to quantitatively measure the tradeoffs that people are willing to make between different environmental attributes (Adamowicz 2004). A survey is used to present a sequence of hypothetical questions (choice scenarios) to respondents, each of which contains a set of possible policy options (alternatives), which include statements of the outcomes of those policies. The outcomes are described in terms of the policy's features or characteristics (attributes). The set of attributes are the same for each alternative in the choice scenario, but they can take on different levels or amounts, varying the outcome of each alternative. Respondents are asked to select their most preferred policy package out of the set of alternatives given. An 'opt-out' alternative is commonly included in the choice scenario so that a respondent is not forced to choose a policy alternative they do not prefer.

In this choice experiment, the hypothetical policy context was an oil and gas development in the vicinity of a beach on the Kimberley coast in Australia's north-west. Respondents were advised that some environmental impacts from the development could be avoided or mitigated, but there would be residual impacts on the use of the beach as a feeding ground by 1000 Ruddy Turnstones, a species of shorebird. These birds are protected under Australia's EPBC Act as a migratory species, and would thus require an offset to compensate for the impact if the development were to go ahead (Australian Government 2012).

The choice scenarios were constructed using attributes that varied the way in which an offset could be implemented. It is important to note that respondents were informed that each offset package would achieve the outcome of no net loss from an ecological perspective, to remove any uncertainty around the probable success of each option presented. The attributes included the proportion of direct offsets, location of the offset, who would implement the offset, what species and how many individuals would be protected by the offset, and the size of the development (Table 1). An 'opt-out of development' option was also specified. This would avoid the possibility of respondents being forced to make choices between offset packages when they fundamentally would prefer to see the development as a whole not proceed at all.

Table 1. The offset policy attributes included in the choice experiment, with level specifications and variable names.

Attribute	Level	Variable name	(and coding)
Proportion of direct offset activity	50%,60%,70%,80%, 90%,100%	*Percent*	(continuous)
Location of offset	Western Australia	*Loc_WA*	(base level)
	Northern Territory	*Loc_NT*	(= 1 if present, 0 otherwise)
	New Zealand	*Loc_NZ*	(= 1 if present, 0 otherwise)
	China	*Loc_China*	(= 1 if present, 0 otherwise)
Offset implementer	Government	*Imp_Gov*	(base level)
	Developer	*Imp_Dev*	(= 1 if present, 0 otherwise)
	Third Party	*Imp_3rd*	(= 1 if present, 0 otherwise)
Species protected by offset	Eastern Curlew	*EC*	(base level)
	Ruddy Turnstone	*RT*	(= 1 if present, 0 otherwise)
Number of birds protected	500*, 1000, 1500, 2000	*Birds*	(continuous)

* The level of 500 was only included if the species was the more endangered, but non-impacted, Eastern Curlew as the stated impact of the development is 1000 birds, and hence this has to be achieved for the Ruddy Turnstone.

In Australia, most offset policies prescribe that the majority of an offset should be direct; that is, an on-ground intervention aimed at improving the environment of the impacted species. However, the potential to use other compensatory measures, or 'indirect offsets', also exists, particularly where it can be demonstrated they will provide greater environmental benefit than a direct offset (Australian Government 2012; Government of Western Australia 2011). We varied the proportion of direct (50-100%) and indirect (0-50%) offset used in the offset package, defining an indirect offset as research that would ultimately improve existing on-ground management of the birds.

For a migratory shorebird species, it is possible to intervene at various points in its flyway to improve its welfare (Bamford et al. 2008). In an offset context, an intervention located away from the development site might not affect the welfare of the specific individuals impacted by the development, but it could ensure no net loss to the species overall. Personal discussions with ecologists familiar with this matter have suggested that the greatest opportunity for conservation gains for migratory birds in the East-Asian-Australasian flyway lie outside of Australia, even if the development impact occurs within Australia. Accordingly, shorebird offsets in regions other than Australia might be cheaper and more effective if targeting critical habitat bottlenecks. An attribute capturing the different regions the shorebirds travel through was included, with categorical levels of Western Australia, Northern Territory, New Zealand and China.

While the financial obligation and overall responsibility for an offset's success lies with the developer, they do not necessarily have to implement the offset themselves. We included an attribute to reflect this, where the implementer could be the developer, the Government's environment department for the region in which the offset occurs, or a third party company with a proven track record in offsets.

Offsets are typically aimed at protecting the species impacted by a development; in this case, the Ruddy Turnstone. However, we envisaged the community may be accepting of an offset targeting a more endangered species than the one impacted; the Eastern Curlew.

The species protected by the offset was also a feature of the Burton et al. (under review) study, with the results indicating heterogeneous community preferences. To clarify preferences for each species, we extended the investigation to include an attribute that varied the number of individual birds that would be protected by the offset. The previous study set the number of birds at 1000; here, we allowed the Ruddy Turnstone to range from 1000 to 2000 individuals protected, and the Eastern Curlew from 500 to 2000. The difference in the minimums reflected that at least 1000 Turnstones had to be protected as that was the number impacted by development, while a smaller number of curlews might be acceptable given their more endangered status.

Finally, there was a split design, with two different survey versions: in one the development was described as leading to 500 new jobs, in the other 1000 new jobs for the community. This inclusion was intended to remind respondents that while there was an environmental impact, there were also benefits to the local economy. It was thought that this difference in economic size of the development would not change the preferences for the attributes of the offset, but may influence selection of the opt-out alternative.

The two survey versions otherwise consisted of identical information. First, respondents were introduced to the concept of biodiversity offsets and asked about their existing knowledge of them. Next, they were presented with the hypothetical development and attribute descriptions, and then the choice experiment. The choice scenarios were designed with three policy alternatives and an opt-out alternative. Ngene (Rose et al. 2012) was used to generate an s-efficient design using the parameters estimated from the Burton et al. (under review) study as priors (see Rose & Scarpa 2008 for an overview of efficient designs), resulting in 24 choice scenarios blocked into four groups of six. Each respondent received one block of six questions.

Debriefing questions followed the choice experiment, asking respondents about the certainty of their answers and whether they found the choice scenarios or information provided confusing. A section asking respondents about their attitudes towards the oil and gas industry was included, which had a set of 15 questions aimed at measuring respondents' social license to operate for the industry (see Supporting Information). Finally, socio-demographic information was collected.

It is worth noting that there was no personal cost included in the design of this choice experiment. Conventionally there is some cost included, so that 'partworths' (or monetary values for changes in attributes) can be calculated. However, in the current context, asking for a personal expenditure to achieve an offset that is a legal requirement (and the financial responsibility of the developer) was deemed inappropriate, and may well have lead to protest behaviour. The main interest of this study is in the tradeoffs across attributes, rather than placing a dollar value on offset outcomes *per se*.

The survey was administered online by a market research company. A nationally representative sample (stratified by age, gender and location) of 1371 respondents completed the survey during October and November 2014.

Data were analysed using Intercooled Stata/IC 13.1 (Statacorp 2013) to estimate a mixed multinomial logit model (see Supporting Information for a description of random utility theory and the multinomial logit model, and Train 2009). Heterogeneity in the sample was accounted for by modelling the alternative specific constant (ASC) as a normally distributed random parameter, with estimates for the mean and standard deviation of the distribution. Also, individual specific covariates were interacted with the ASC, to shift the mean of the distribution, or with attribute variables. The ASC captures the utility associated with a labelled alternative, in this case the opt-out. Note that alternative modelling approaches that capture additional heterogeneity exist, including mixed logit models with all parameters treated as random (Train 2009). Several alternative models were estimated with this data, and while they did better explain the distribution of preferences across individuals in the sample, the results for an average individual were similar and did not alter the policy conclusions which are the focus of this paper. Thus, reporting the simpler econometric model was preferred.

3 Results

The first step was to analyse the social license to operate questions. A social license to operate is an implicit contract between an industry or company and its stakeholders, where the risk of socio-political challenges to the industry's operations is reduced if it behaves in a manner befitting its stakeholders' values (Prno & Slocombe 2012). The greater the social license to operate, the lower the risk. Following the approach of Richert et al. (2015), two measures of the social license to operate for Australia's oil and gas industry were derived from the 15 questions (see Supporting Information): a measure of 'economic legitimacy' (*SLO_Econ*), which is attained when respondents believe the industry will provide economic benefits; and, a measure of 'social legitimacy' (*SLO_Soc*), which is reached when respondents believe the industry will improve community wellbeing and will act in consideration of community interests. The Supporting Information provides further detail on how these measures were derived, and the relationship between them. In the current context, it was anticipated that a stronger social license (i.e. higher scores for economic or social legitimacy) would lead to increased acceptance of offsets, and of the developer implementing them.

Table 2 reports the choice model results. Of note is the fact that the number of jobs involved in the development did not influence choices: it was initially introduced as an interaction with the opt-out ASC, to allow for the possibility that the probability of rejecting the development entirely may be influenced by its economic impact, but this was not significant and was dropped from the model.

These results show that respondents preferred higher levels of direct offset relative to indirect (*Percent*), and that they had a preference for more birds being protected by the offset (*Birds*). The effect of changing bird species is reflected in two coefficients: the impact of changing species on the marginal value of additional birds protected (*RTxBirds*), and a species specific dummy (*RT*). The former is negative, suggesting that the marginal effect of an additional Ruddy Turnstone being protected is less than that of an Eastern Curlew, but the species specific dummy is positive, suggesting that there is an initial preference for RT over EC. The results suggest that, at the original level of 1000 birds affected, respondents were (statistically) indifferent between the two species, but as numbers increased, the marginal value gained from additional Ruddy Turnstones was less than that for Eastern Curlews, implying they valued the more endangered species more.

Table 2. Mixed logit regression estimates for the choice model.

Variable	Coefficient	(Std Error)	
Percent	0.004	(0.001)	***
RT	0.282	(0.105)	***
Birds	8.7E-4	(3.8E-5)	***
RTxBirds	-3.3E-4	(6.9E-5)	***
Loc_NT	-0.190	(0.037)	***
WAxLoc_NT	-0.492	(0.126)	***
Loc_NZ	-0.435	(0.054)	***
WAxLoc_NZ	-0.624	(0.184)	***
Loc_China	-1.128	(0.056)	***
WAxLoc_China	-0.846	(0.185)	***
Imp_Dev	-0.189	(0.032)	***
SLO_Econ x Imp_Dev	-0.054	(0.036)	
SLO_Soc x Imp_Dev	0.211	(0.035)	***
Imp_3rd	0.101	(0.030)	***
SLO_Econ x ASC	-1.089	(0.168)	***
SLO_Soc x ASC	-0.929	(0.159)	***
ASC	-2.825	(0.239)	***
Std Dev. ASC	*3.774*	*(0.202)*	***

Notes: *** denotes significance at the 99% level of confidence.
Log likelihood = -9198.1811; number of choice occasions = 8226; number of individuals = 1371.
Interaction variable definitions:
SLO_Econ: social license to operate economic legitimacy variable, normalised so mean=0, std dev.=1
SLO_Soc: social license to operate social legitimacy variable, normalised so mean=0, std dev.=1
WA: dummy variable =1 if respondent lives in Western Australia

The preference ranking of offset location was Western Australia (where the impact occurred), Northern Territory (*Loc_NT*), New Zealand (*Loc_NZ*) and then China (*Loc_China*). We investigated whether there was an 'own state' preference by interacting the location with a dummy variable indicating whether the respondent was a West Australian resident (*WA*). These residents gained greater disutility from shifting the offset out of the impact State compared to residents of other states. Unfortunately the sample of Northern Territory respondents was not large enough (reflecting the small population size of the region) to estimate a model that would identify if Territory residents had greater preferences to bring the offset *to* the Northern Territory.

The developer was less preferred as the implementer of the offset (*Imp_Dev*), and a third party more preferred (*Imp_3rd*), relative to the government. The developer was interacted with the social license to operate variables based on the expectation that as the social license increases, the developer would be a more acceptable implementer. This was the case for the social legitimacy variable (*SLO_Soc x Imp_Dev*), where the coefficient was positive and significant, but not for economic legitimacy (*SLO_Econ x Imp_Dev*).

Given the normalization of the social license variables (with zero mean and a standard deviation of one), respondents who had a social legitimacy score one standard deviation from the mean would have an implied marginal utility for the developer being the implementer of +0.02 (-0.189+0.211). This means that this group of the sample were essentially indifferent between the government and the developer implementing the offset. Conversely, those who held a lower social legitimacy score would be even more averse to an offset implemented by the developer. The implication is that a relatively small proportion of the sample preferred the developer over the government as the implementer (those at the upper end of the distribution of the social legitimacy score).

The coefficient on the ASC can be interpreted as the utility associated with the opt-out, but it only has meaning relative to the utilities associated with the offsets, and its sign and significance can alter as one changes coding of other attributes. As such, although the ASC is negative, it is not a good indication of the general acceptance of offsets, as compared with opting out of development. A better measure is the frequency of choice occasions that the opt-out was selected: in this case, only 13% of the time. The large estimate of the standard deviation of the ASC relative to the mean implies there was considerable heterogeneity in the sample in its attitude towards the opt-out.

However, one can identify the absolute impact of variables on the ASC. The social license variables influenced the estimate of the mean of the opt-out ASC. Individuals who held higher social license scores (*SLO_Econ x ASC, SLO_Soc x ASC*) tended to hold a lower utility for the opt-out; or conversely, those who held a low social license to operate for the oil and gas industry tended to select the opt-out option more often.

Although there is no cost attribute in the model one can still estimate tradeoffs across attributes through marginal rates of substitution. These are calculated by dividing the marginal utility of an attribute parameter by that of the numeraire, which can be any continuous attribute: in this case, the number of Ruddy Turnstones that arise from the offset. It is important to be careful on the interpretation of these values as the numeraire used (bird numbers) has a positive effect on utility (unlike a personal cost attribute, which would reduce utility as the cost increases). The interpretation of the resulting marginal rates of substitution is the change in the number of Ruddy Turnstones protected that is required to exactly compensate for a change in another attribute. A negative number indicates a change in the attribute that respondents value (i.e. bird numbers can be reduced), while a positive number implies that the attribute change reduces utility, and more birds are needed to compensate for it.

Table 3 reports the marginal rates of substitution for the attributes. It is important to note that these are the additional Ruddy Turnstones that must be protected by the offset. If the Eastern Curlew were to be used as the numeraire the numbers would be 61% of those in Table 3, due to the higher marginal value placed on the species.

Table 3. Marginal rates of substitution, using the number of Ruddy Turnstones as the numeraire.

Variable	Coefficient	95% CI	
percent	-8	-12	-5
Loc_NT	353	206	500
WA x Loc_NT	1266	752	1780
Loc_NZ	807	55	1060
WA x Loc_NZ	1966	1198	2733
Loc_China	2092	163	2521
WA x Loc_China	3663	2678	4646
Imp_Dev	351	204	499
SLO_Econ x Imp_Dev	100	-33	233
SLO_Soc x Imp_Dev	-392	-547	-237
Imp_3rd	-188	-301	-75

Notes: For the location variables, these represent the marginal rates of substitution for respondents who live in WA, and those not in WA.
For the social license to operate interactions, these represent the change in marginal rates of substitution as the SLO changes by one, equivalent to one standard deviation.

For offset location, if the default is 1000 Ruddy Turnstones in an offset in Western Australia, an additional 353 birds would have to be included to compensate for moving the offset to the Northern Territory, 807 for New Zealand, and 2092 to compensate the movement to China (i.e. the offset in China would require a total of 3092 birds to be seen as equivalent to the 1000 birds in Western Australia). For a resident in Western Australia, these values were much higher: to shift the offset to China an additional 3663 birds must be included in the offset.

In terms of direct versus indirect offsets, eight fewer birds would be required for every additional percentage point of direct offset. That is, an increase from 90% to 95% would require 40 fewer birds; a decrease from 90% to 85% direct would require 40 additional birds to be considered acceptable.

Table 3 also shows that a change in implementer from government to the developer would require an additional 351 birds in the offset for a respondent with mean social license to operate scores. Individuals with a social legitimacy score that is one standard deviation above the mean would prefer the developer to undertake the offset, and in fact would be content with a slightly smaller number of birds protected (351-392=-41). Although reported, note that the effect that economic legitimacy has on the developer is not significantly different from zero. Acceptance of the use of a third party implementer would be feasible with a lower number of birds protected, relative to government implementation.

Discussion

With biodiversity offsets being increasingly used worldwide to compensate for unavoidable environmental damages resulting from development, it is important for governments to set appropriate policies for offset implementation. Getting the science right is obviously critical in meeting the objective of 'no net loss'; however, there might be different methods by which that could be achieved, or flexibility in how an offset can be designed within the ecological limits. Given that, it is also important to ensure that offset policies reflect what is acceptable by community standards. This study explored the community's acceptance of a number of potential policy characteristics, in the context of Australian biodiversity offsets for migratory shorebirds impacted by an oil and gas development. Being a new area of study, it is important to note that the extrapolation of these results to other biodiversity contexts or to international policy settings must be viewed with caution.

There seemed to be a widespread acceptance of the use of offsets in this context, with respondents rarely opting out of development. We had anticipated that a larger development, in terms of number of jobs created (and corresponding economic benefit to the community), would influence the willingness to allow the project to proceed. This was not a significant factor, implying that, at least for the number of jobs under consideration, the scale of the development was not influencing attitudes towards environmental management. However, the acceptance of offsets as a result of development suggests respondents did recognise the economic and environmental tradeoffs implicit in the choice scenario, which shows support for policy to continue the practice of considering offsets where environmental damages cannot be avoided or mitigated.

The social license to operate that individuals held for the oil and gas industry did influence the general acceptance of offsetting: intuitively, those who granted a lower social license to operate were more averse to the development proceeding, relative to those granting a higher social license for the industry. From a developer's perspective, this would suggest that maintaining a positive relationship with the local community will be important for gaining approval to embark on projects requiring offsets (Richert et al. 2015).

There was a preference for more shorebirds to be protected by the offset, and, once the number of birds exceeded the number impacted (1000 birds), the marginal value for each additional bird was greater for the more endangered Eastern Curlew relative to the impacted Ruddy Turnstone. This suggests that the 'trading-up' of species was accepted by the community. Currently in Australia, the Commonwealth legislation does not allow this substitution (Australian Government 2012); however, some State policies suggest it could be possible if the ecological benefit would exceed that of an offset for the impacted species (Government of Western Australia 2011). In the event that the science recommends an offset should substitute the focus to a more critically endangered species (or habitat), it could be worthwhile having flexibility in offset policies to allow this.

There was a preference for direct (like-for-like) offsets versus indirect offsets (or other compensatory measures). This finding supports the current Australian position for the majority of an offset to be undertaken in direct form (Australian Government 2012). However, indirect offsets became more acceptable upon changing other parameters: specifically, increasing the number of shorebirds protected by the offset beyond the number impacted (an additional eight Ruddy

Turnstones for every percentage point) was an acceptable tradeoff for increasing the proportion of indirect offset activity. This finding highlights that, where direct offsets may not be practicable, indirect offsets can be considered (assuming they are ecologically plausible), but there should be some multiplier to protect more of the impacted matter (i.e. over and above any multiplier required to improve confidence levels in biodiversity outcomes, see Bull & Brownlie 2015).

Similar to the findings of Burton et al. (under review), respondents preferred the offset to be located close to the site of impact (Western Australia). Utility diminished as the offset moved offshore, with China the least preferred location. This effect was present for the entire sample, irrespective of which state they lived in, although this reaction was emphasised if the respondent was a West Australian resident. Thus, this study has confirmed that although there is some aspect of 'local offsets for local people', the broader community sees a value in having the offset close to the point of impact. However, as was the case for indirect offsets, it was possible to compensate for the disutility of moving the offset away from the impact site by increasing the number of birds protected. A substantial increase in the number of birds was required, especially as the offset was located further away (thousands of birds). From a community perspective, therefore, offsets are unlikely to be acceptable if they are too distant from the impact site. This is an interesting divergence from an ecological perspective: in the case of migratory shorebirds, anecdotally, the ability to offset internationally at sites with habitat bottlenecks would be desirable. Policy design will need to be mindful of these potentially conflicting views.

As anticipated, respondents were more accepting of an offset if it was implemented by the government (i.e. the relevant environmental department for the region), relative to the developer themselves. A third party with a proven track record in offsetting was the most preferred implementer. Individuals who held a high social license to operate, granting the oil and gas industry with social legitimacy, would accept the developer as an implementer. This was a very small proportion of individuals, as social legitimacy is difficult for the industry to achieve (Richert et al. 2015). While economic legitimacy is more readily granted to the oil and gas industry, it did not improve the acceptability of the developer as an implementer. This implies that, even when a developer has a generally positive relationship with the local community (i.e. being granted with economic legitimacy), the large majority would still prefer that an offset policy denotes implementation via the transferring of funds from the developer to the government or a third party. Currently, Australian policies are not prescriptive as to who should implement an offset, and could benefit from considering this result.

In conclusion, the choice experiment has shown a general acceptance of biodiversity offsets by the Australian community in the context of an oil and gas development. It also provides support for increasing the flexibility in some offset policy characteristics. In particular, the trading up of species was considered acceptable. Other policy characteristics would be accepted provided that appropriate compensation was offered by protecting more biodiversity. This was relevant for increasing the proportion of indirect offset activity and moving the offset to a location away from the impact site. Acceptability of offsetting improved if the responsibility of implementation was shifted away from the development company and to a third party.

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Supporting information

S1: Measuring Social License to Operate

In measuring the Social License to Operate (SLO) we follow the implementation reported in Richert et al. (2015), which itself was based on the work of Boutilier and Thomson (2011). A set of 15 questions, modified from those used by Boutilier and Thomson (2011) to make them relevant for our context, were presented to respondents. These were hypothesized to be linked to three underlying levels of SLO. It is Boutilier and Thomson's contention that SLO is earned progressively, from Economic legitimacy to Interactional trust to Institutionalised trust, and the questions are designed to identify the level of SLO on these three criteria.

Richert et al. (2015), using a smaller Western Australia sample, found that only two levels were identified in their data, which they term "Economic legitimacy" and "Social legitimacy" (the latter consisting of the two higher levels of Boutilier and Thomson's hierarchy). Economic legitimacy was measured by the first four questions in Table S1 below, while social legitimacy was determined by scores to the remaining 11 questions.

For our data we applied a factor analysis to the responses to the 15 questions, and identified two factors with Eigenvalues exceeding one (values of 8.55 and 1.18: the next highest value was 0.23). Inspection of the scoring coefficients indicated that the two factors were again associated with a grouping of the first four questions and the second block of 11 questions. Correlation between a simple average of the answers in the two groups and the predicted factors was 0.97 and 0.94. This confirms the earlier finding of Richert et al. (2015) that at this level of abstraction (dealing with an industry as a whole, rather a specific company as in Boutilier and Thomson's work), two measures of SLO can be identified.

An important prediction from Boutilier and Thomson (2011) is that the level of SLO awarded by individuals will follow their hierarchy. In our context this means it is unlikely to see individuals awarding a higher score for social legitimacy compared to that awarded for economic legitimacy. Figure S1 is a scatter graph of the two scores (with a small amount of jitter applied, to separate individuals with identical scores). This gives a strong indication that the prediction is true: only 5% of respondents give a higher average score for social legitimacy than for economic legitimacy, although, as is clear from the figure, the full range of values is given for both across the sample.

In the statistical analysis of the choice model we use the scores generated by averaging the answers to the blocks of questions, normalised so that they have a mean of zero and standard deviation of one (i.e. defining the variables *SLO_Econ, SLO_Soc*). Using the scores generated by the factor analysis generates trivially different results, with no consequences for the conclusions of the paper.

Table S1. Questions used to determine the degree of social license to operate.

	Please state whether you agree/disagree with the following statements: *(5pt Likert scale, 1= strongly disagree, 5= strongly agree)*
1	"Australia can economically benefit from the oil and gas sector"
2	"Australia needs to have the cooperation of the oil and gas sector to achieve the Country's most important goals"
3	"The presence of the oil and gas sector in Australia is a benefit to the Australian population"
4	"In the long-term, the oil and gas sector makes a contribution to the well-being of Australia"
5	"The oil and gas sector does what it says it will do in the media"
6	"I am very satisfied by the oil and gas sector in Australia"
7	"The oil and gas sector listens to the Australian population's concerns"
8	"The oil and gas sector in Australia treats everyone fairly"
9	"The oil and gas sector respects Australia's way of doing things"
10	"The Australian population and the oil and gas sector have a similar vision for the future of Australia"
11	"The oil and gas sector gives more support to those it negatively affects"
12	"The oil and gas sector shares decision-making with the Australian government"
13	"The oil and gas sector takes into account the interests of the Australian population"
14	"The oil and gas sector is concerned about the welfare of the Australian population"
15	"The oil and gas sector openly shares information that is relevant to the Australian population"

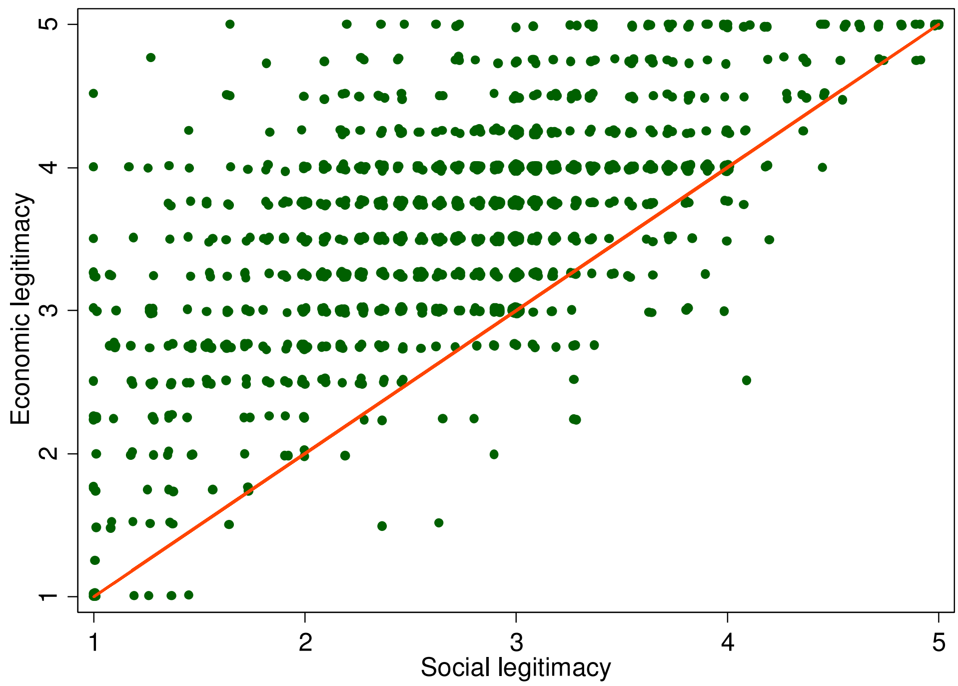

Figure S1. Scatter plot of individual scores for Economic and Social legitimacy. Average of the relevant scores (n=1371).

S2: Estimation of discrete choice models.

The core concept underpinning the estimation of discrete choice models is that of a utility function, which links an individual's subjective judgement of welfare gained from an outcome to a number of observable characteristics of that outcome, usually through a linear additive function:

$$U_{ij} = \beta X_j + \varepsilon_{ij} \qquad \text{(Equation S1)}$$

That is, the utility obtained by individual *i* from outcome *j* is determined by a linear function of a vector of attributes *X*, weighted by parameters *β*, and an unobservable 'random' element ε. This random utility specification accounts for the possibility that not all aspects that determine choice have been quantified by the researcher. If an individual is faced with *J* alternatives, and an assumption that the random element follows a Type I Extreme value distribution, then the probability that they select option *n* is given by:

$$P(Y = n) = \frac{\exp(\bar{\beta} X_n)}{\sum_j \exp(\bar{\beta} X_j)} \qquad \text{(Equation S2)}$$

Where $\bar{\beta}$ are normalised parameters, to account for the influence of the error variance.

Equation S2 is the standard conditional logit formulation, and information on which options are chosen, and the attributes associated with all options, allows one to identify the normalised parameters, which represent the marginal utilities associated with the attributes, and hence a measure of the sign and intensity of preference for those attributes.

The standard model assumes that preferences are homogeneous within the sample. Heterogeneity can be accommodated by allowing the estimated parameters to vary across individuals. A common form of this model is the random parameter (or mixed logit) model, where β in equation S1 is replaced by $f(\beta \mid \theta)$, that is, parameters are distributed according to some function, and the θ are parameters that describe that function. A common assumption is that the random parameters follow a normal distribution, and the θ's to be estimated are the means and variance/covariance matrix that describe their distribution. It is assumed that an individual has the same random parameters governing all choices. More detail on both the conditional and mixed logit models is given in Train (2009).