Extended Abstract

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Paper/Poster Title	Ecological and Economic Implications of Alternative Metrics in Biodiversity Offset Markets

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Abstract	***200 words max***
Consideration of the incentives facing both landowners as potential biodiversity offset providers, and developers as potential buyers of credits, is critical when considering the real-world policy implications of choosing a specific offset metric and the resultant impacts on biodiversity. The expectation is that the least profitable land parcels are the ones most likely to be conserved, which determines the spatial location of biodiversity offset credits. We developed an ecological-economic model to compare the ecological and economic outcomes of offsetting for a habitat-based metric and a species-based metric. We were interested in whether these metrics would adequately capture the indirect benefits of offsetting on species not defined under the no net loss policy. We simulated a biodiversity offset market for a case study landscape, linking species distribution modelling and an economic model of landowner choice based on economic returns of the alternative land management options (restore, develop, or maintain existing land use). The biodiversity offset markets for the habitat and species metrics achieved no net loss of the intended metric. However, the underlying species distributions, layered with the agricultural and development rental values of parcels, resulted in very different landscape outcomes depending on. Neither metric adequately captured the indirect benefits of offsetting on related habitats or species. Where policymakers are aiming for the metric to act as an indicator to mitigate impacts on a range of closely related habitats and species, then a simple no net loss target is not adequate. Furthermore, if we wish to secure the most ecologically beneficial design of offsets policy, we need to understand the economic decision-making processes of the landowners.	

Keywords	Biodiversity metrics. No net loss. Biodiversity loss. Simulation model. Ecological-economic modelling
JEL Code	Q240, Q280, Q570, Q580 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***
Biodiversity offsets provide ‘measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts’ (BBOP 2009). Offsetting is considered the final step in the mitigation hierarchy once all other steps (avoid, minimize, restore) have been undertaken (Alridge et al 2019). One of the most contentious issues in the design of offsetting schemes is the choice of the offset metric: how gains and losses in biodiversity are assessed and compared. This metric forms the trading unit within an offset market. Across the disciplines of economics and ecology, the choice of metric is seen as critical in	

determining the success of offsetting as a policy instrument (Heal 2005; Bull et al 2013). Recent literature has begun to assess alternative offset metrics that include more detailed species data and compare their performance with habitat-based metrics (Maseyk et al 2016; McVittie and Faccioli 2020; Marshall et al 2020b). However, there has been little quantitative work examining the economic aspects of alternative offset metrics, and none within the context of a market. Consideration of the incentives facing both landowners as potential offset providers, and developers as potential buyers of credits, is critical when considering the real-world policy implications of choosing a specific offset metric.

Methodology	***100 – 250 words***

Using an ecological-economic modelling framework we simulated a biodiversity offset market that secured no net loss of three alternative metrics: no net loss of low-intensity grassland (habitat-based), no net loss lapwing (species based) and no net loss of curlew (species based) for a case study region. We compared these two metrics in the specific context of an offset market where farmers supply credits to housebuilders who are required by law to acquire sufficient credits to offset the predicted impacts of land-use change.

An agent-based model was developed in Stata MP (Version 16) to model landowners' choices based on the relative economic returns of the alternative land management options for each parcel. The model calculated the profitability of each land parcel for housing development, offset provision and current land use. The model also identified the number of offset credits a parcel could supply if restored to low-intensity grassland, and the number of offset credits required if the parcel were developed for new housing. By integrating the profitability of the parcel with the potential offset demand and supply, we were able to construct spatially explicit supply and demand curves for offset credits. This allowed us to calculate the market-clearing (equilibrium) price for one offset credit. Using this equilibrium price, we could then determine whether a land parcel remains under current land use, supplied offsets or was developed for housing. Three landscape configurations were generated using the three, alternative metrics. Using ArcGIS, we compared where development would take place under each metric, how the distribution of low-intensity grassland would shift and the changes in the abundance of lapwing and curlew. Based on this we examined whether no net loss of low-intensity grassland could benefit the lapwing and curlew, or whether a more targeted species metric was needed to secure the conservation of these species.

Results	***100 – 250 words***

The landscape-scale outcomes were substantially different depending on the choice of either a habitat or species-based metric. The distribution of curlew and lapwing abundance was non-uniform across grassland parcels throughout the landscape and as a result, there was divergence in grassland parcels that are traded under the habitat and species metrics. To confirm this result, we compared the equivalent costs of grassland credits under a uniform distribution of species across grassland parcels (with a focus on no net loss of grassland). Under the grassland metric, a grassland offset cost £499 per ha. The equivalent cost for this grassland offset using a uniform lapwing distribution was £13,588 per bird, compared to £14,127 per lapwing using the non-uniform distribution. For curlew, the equivalent cost for this grassland under the uniform curlew model was £19,683 per bird, compared to £22,005 per curlew under the non-uniformly distributed curlew model. Consequently, significantly more low intensity grassland parcels were developed for housing under the lapwing species metric (M = 1.96, SD = 9.12) compared to the grassland metric (M =0.54, SD = 3.55) ($t(16696) = 13.27$, $p =<0.001$)). Despite higher levels of development under the lapwing species metric, there were fewer grassland offsets created. The increases in grassland under the habitat metric (M = 0.54, SD = 5.8) were significantly greater than gains in grassland under the lapwing metric (M = 0.29, SD = 3.16) ($t(16696) = 3.48$, $p <0.001$). Consequently, there is a substantial loss of grassland under the lapwing species metric (16,267 ha).

Discussion and Conclusion	***100 – 250 words***

From a policy perspective, each of the metrics considered here achieves their intended policy targets: no net loss of grassland, no net loss of curlew, or no net loss of lapwing. However, we have shown that the underlying species distributions, layered with the agricultural and development rental values of parcels, result in very different landscape outcomes depending on the metric chosen. What these results show is that if the policymaker is aiming for the metric to act as an indicator to mitigate impacts on a range of closely related habitats and species, then a simple no net loss target is not adequate. In conclusion, our modelling shows that there are significant economic and ecological implications following the choice of metric for a biodiversity offset trading scheme. Since these differences in outcomes relate to predictable spatial relationships in observable variables (agricultural profits and development rents), the results have broad implications for biodiversity offset schemes globally. It is clear that, if we wish to secure the most ecologically beneficial design of offsets policy, whether that is based on habitats, species or some other metric, we need to understand the economic decision-making processes of the landowners. We also need to design incentive-based policies that offer the highest incentives for conserving and enhancing the most ecologically beneficial sites in a landscape.