Moving from biodiversity offsets to a target-based approach for ecological compensation

Simmonds, Jeremy S.; Sonter, Laura J. ; Watson, James E. M. ; Bennun, Leon; Costa, Hugo M.; Dutson, Guy; Edwards, Stephen ; Grantham, Hedley; Griffiths, Victoria F.; Jones, J.P.G.; Kiesecker, Joseph ; Possingham, Hugh P.; Puydarrieux, Philippe; Quétier, Fabien; Rainer, Helga ; Rainey, Hugo; Roe, Dilys ; Savy, Conrad E.; Souquet, Mathieu ; ten Kate, Kerry ; Victurine, Ray; von Hase, Amrei ; Maron, Martine

Conservation Letters

1   **Moving from biodiversity offsets to a target-based approach for ecological compensation**

2   Jeremy S. Simmonds[1,2], Laura J. Sonter[1,2], James E.M. Watson[1,2,3], Leon Bennun[4,5], Hugo M. Costa[3],

3   Guy Dutson[4], Stephen Edwards[6], Hedley Grantham[3], Victoria F. Griffiths[7], Julia P.G. Jones[8], Joseph

4   Kiesecker[9], Hugh P. Possingham[1, 10], Philippe Puydarrieux[6], Fabien Quétier[11], Helga Rainer[12], Hugo

5   Rainey[3], Dilys Roe[13], Conrad E. Savy[14], Mathieu Souquet[11], Kerry ten Kate[15], Ray Victurine[3], Amrei von

6   Hase[16], Martine Maron[1,2]

7   **Author affiliations:**

8   1.   Centre for Biodiversity and Conservation Science, The University of Queensland, St Lucia 4072,

9   Australia.

10   2.   School of Earth and Environmental Sciences, The University of Queensland, St Lucia 4072, Australia.

11   3.   Wildlife Conservation Society, Global Conservation Program, New York 10460, United States of

12   America.

13   4.   The Biodiversity Consultancy, Cambridge CB2 1SJ, United Kingdom.

14   5.   Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge CB2 3EJ,

15   United Kingdom.

16   6.   International Union for Conservation of Nature (IUCN), CH-1196 Gland, Switzerland.

17   7.   Department of Zoology, University of Oxford, Oxford OX1 3SZ, United Kingdom.

18   8.   College of Environmental Sciences and Engineering, Bangor University, Bangor LL57 2UW, United

19   Kingdom.

20   9.   The Nature Conservancy, Global Conservation Lands Program, Colorado 80524, United States of

21   America.

22   10.   The Nature Conservancy, Arlington, Virginia 22203, United States of America.

23   11.   Biotope, 34140 Mèze, France.

24   12.   Arcus Foundation, Cambridge CB1 2JD, United Kingdom.

25   13.   International Institute for Environment and Development (IIED), London WC1X 8NH, United Kingdom.

26   14.   International Finance Corporation, Nairobi, Kenya.

27   15. Forest Trends, Washington, DC 20036, United States of America and Hampshire GU515SS, United

28   Kingdom.

29   16. Forest Trends, Washington, DC 20036, United States of America and Cape Town 8001, South Africa.

30 **Author emails:**

31 Jeremy Simmonds (j.simmonds1@uq.edu.au); Laura J. Sonter (l.sonter@uq.edu.au); James E. M. Watson

32 (jwatson@wcs.org); Leon Bennun (leon.bennun@thebiodiversityconsultancy.com); Hugo M. Costa

33 (hcosta@wcs.org); Guy Dutson (guy.dutson@thebiodiversityconsultancy.com); Stephen Edwards

34 (steve.edwards@iucn.org); Hedley Grantham (hgrantham@wcs.org); Victoria F. Griffiths (vgriffiths@synergy-

35 global.net); Julia P. G. Jones (julia.jones@bangor.ac.uk); Joseph Kiesecker (jkiesecker@TNC.ORG); Hugh

36 Possingham (hugh.possingham@tnc.org); Philippe Puydarrieux (Philippe.PUYDARRIEUX@iucn.org); Fabien

37 Quétier (fquetier@biotope.fr); Helga Rainer (hrainer@arcusfoundation.org); Hugo Rainey (hrainey@wcs.org);

38 Dilys Roe (dilys.roe@iied.org); Conrad E. Savy (csavy@ifc.org); Mathieu Souquet (msouquet@biotope.fr); Kerry

39 ten Kate (KtenKate@forest-trends.org); Ray Victurine (rvicturine@wcs.org); Amrei von Hase

40 (avonhase@forest-trends.org); Martine Maron (m.maron@uq.edu.au)

41 **Short running title:** A novel alternative to biodiversity offsets

42 **Keywords:** averted loss; biodiversity loss; Convention on Biological Diversity; counterfactual;

43 environmental impact assessment; environmental policy; infrastructure development; mitigation

44 hierarchy; net gain; no net loss

45 **Type of article:** Review

46 **Number of words:** Abstract: 183; Whole manuscript (Abstract to Acknowledgements, inclusive):

47 4980

48 **Number of references:** 49

49 **Number of figures and tables:** Three figures; One table

50 **Corresponding author:**

51   Jeremy Simmonds

52   School of Earth and Environmental Sciences, The University of Queensland, St Lucia 4072, Australia.

53   Phone: +61 7 3365 6455; Email: j.simmonds1@uq.edu.au

54 **ABSTRACT**

55 Loss of habitats or ecosystems arising from development projects (e.g. infrastructure, resource

56 extraction, urban expansion) are frequently addressed through biodiversity offsetting. As currently

57 implemented, offsetting typically requires an outcome of 'no net loss' of biodiversity, but only

58 relative to a baseline trajectory of biodiversity decline. This type of 'relative' no net loss entrenches

59 ongoing biodiversity loss, and is misaligned with biodiversity targets that require 'absolute' no net

60 loss or 'net gain'. Here, we review the limitations of biodiversity offsetting, and in response, propose

61 a new framework for compensating for biodiversity losses from development in a way that is aligned

62 explicitly with jurisdictional biodiversity targets. In the framework, targets for particular biodiversity

63 features are achieved via one of three pathways: Net Gain, No Net Loss, or (rarely) Managed Net

64 Loss. We outline how to set the type ('Maintenance' or 'Improvement') and amount of ecological

65 compensation that is appropriate for proportionately contributing to the achievement of different

66 targets. This framework advances ecological compensation beyond a reactive, ad-hoc response, to

67 ensuring alignment between actions addressing residual biodiversity losses and achievement of

68 overarching targets for biodiversity conservation.

69 **INTRODUCTION**

70 The 196 Parties to the Convention on Biological Diversity (CBD) are currently setting ambitious post-

71 2020 biodiversity targets (Mace et al., 2018; Visconti et al., 2019). Yet, despite widespread

72 recognition of the need to slow and ultimately halt biodiversity loss, transformation of the natural

73 world for infrastructure, industry, commercial agriculture, urbanisation and resource extraction

74 (hereafter, 'development') continues to drive declines (IPBES, 2019). Ceasing all such transformation

75 is not feasible in the face of desirable development imperatives (Griggs et al., 2013; United Nations,

76 2018). Governments, developers and civil society therefore need tools for reconciling development

77 and conservation to reduce the rate of biodiversity loss.

78 The mitigation hierarchy is an approach for responding to biodiversity losses arising from

79 development. It has been embedded into numerous government, lender and corporate policies

80 (BBOP, 2012; Gardner et al., 2013; IFC, 2012; IUCN, 2018a; Rainey et al., 2014). Proponents of

81 development projects—where these are mandated by policy ('regulated sectors')—are required to

82 reduce adverse biodiversity outcomes through sequentially following four steps. Only after

83 completing avoidance, and then restoration/rehabilitation of disturbed areas onsite, should the

84 fourth step be taken – compensating for any residual losses through biodiversity offsetting. When

85 applied as the final step of the mitigation hierarchy, biodiversity offsets are typically intended to

86 achieve an outcome in which there is (at least) 'no net loss' of the impacted biodiversity due to a

87 particular project (BBOP, 2012; Bull, Gordon, Watson, & Maron, 2016; IUCN, 2016).

88 Biodiversity offsetting, however, is almost never designed to align with the achievement of national

89 or sub-national ('jurisdictional') biodiversity targets that aim to halt species and ecosystem decline,

90 or achieve biodiversity recovery. In large part, this is because no net loss of biodiversity at the level

91 of individual development projects can mean something quite different to no net loss at the

92 jurisdictional level (Maron, Brownlie, et al., 2018). When framed in relation to a jurisdictional

93 biodiversity target, no net loss implies that the amount of a particular biodiversity feature (e.g.

94   forest) should not fall below what we have now; in other words, it means no net loss relative to a

95   'fixed reference scenario' (Maron, Brownlie, et al., 2018). Under such a scenario, any lost forest (for

96   example) would need to be replaced to achieve absolute no net loss – that is, to maintain the

97   amount of forest at its current level (Figure 1).

98   This is rarely the intended meaning of no net loss in offset policies which guide compensation for

99   residual losses at the *development project level*, not the jurisdictional level. Project-level no net loss

100   is often framed relative to a counterfactual scenario of decline, in which biodiversity is expected to

101   be lost even without the development (and its offset) (Maron, Bull, Evans, & Gordon, 2015; IUCN,

102   2016). The rationale is that the protection provided by the offset action achieves a benefit by

103   averting a loss or decline that would otherwise have occurred. Such 'averted loss' offsetting (also

104   called avoided loss or protection offsetting) is one of the two main forms of biodiversity offsetting

105   (the other being restoration). It is referenced as a key approach to offsetting in policies and

106   standards espoused by financial institutions (IFC, 2012; World Bank Group, 2016), multistakeholder

107   platforms (BBOP, 2012; IUCN, 2016) and jurisdictions (Australia, Columbia and Chile (Maron,

108   Brownlie et al., 2018)). In a global review of over 12,000 individual offsets projects, Bull and Strange

109   (2018) found that approximately 66% used averted loss offsetting, either exclusively, or in

110   combination with other measures.

111   When framed this way, even best-practice offsets result in less biodiversity over time, as protection

112   of already-existing biodiversity, which is expected to decline in the future, can be exchanged for

113   biodiversity losses at the development site(s) (Bekessy et al., 2010; Buschke, Brownlie, & Manuel,

114   2017; Maron, Brownlie, et al., 2018; Moilanen & Laitila, 2016). Across multiple projects, offsetting

115   that achieves no net loss relative to a counterfactual scenario of biodiversity decline maintains the

116   declining trend, and corresponds with a net loss at the jurisdictional level (Figure 1) (Gibbons &

117   Lindenmayer, 2007; Quétier, van Teeffelen, Pilgrim, von Hase, & ten Kate, 2015).

118

119   <**Figure 1**>

120

121   Relative no net loss of biodiversity at the project level does not equate with the achievement of

122   absolute no net loss at the jurisdictional level. This mismatch causes conceptual confusion and

123   ambiguity about the meaning and intention of no net loss as a policy objective. It also makes it hard

124   to assess the contribution that project-level compensatory actions (e.g. biodiversity offsetting) are

125   making to broader conservation goals, such as the achievement of jurisdictional biodiversity targets

126   (Maron, Brownlie, et al., 2018). We are aware of only one national policy that links compensatory

127   actions to the achievement of a target (limiting ecosystem loss to pre-defined thresholds) – South

128   Africa's Draft National Biodiversity Offset Policy (Republic of South Africa, 2017). If offsetting

129   continues to occur in isolation from broader conservation imperatives, the risk is that at best,

130   offsetting will contribute minimally to conservation objectives, and at worst, will detract from

131   achieving such goals (e.g. where counterfactual-based approaches entrench ongoing declines

132   (Maron, Brownlie et al., 2018)). An overarching framework is therefore needed to align project-level

133   actions under the mitigation hierarchy, particularly of ecological compensation for residual losses,

134   with the biodiversity targets that a jurisdiction may strive to achieve.

135   Here, we propose such a framework, and review its suitability in applied conservation policy. We

136   refer throughout to 'ecological compensation' to distinguish our proposed approach as an

137   alternative to the narrower concept of biodiversity offsetting, which has strict rules about like-for-

138   like trades in biodiversity and aims to achieve at least no net loss relative to a counterfactual

139   scenario (BBOP, 2012; Bull et al., 2016; IUCN, 2016). We discuss the consequences of different

140   approaches to ecological compensation, and provide guidance on how, where and when the

141   framework we present could be operationalised. This framework entails several advantages over

142   current practice. First, it makes explicit the contribution of ecological compensation towards

143   meeting jurisdictional biodiversity targets. Second, it avoids the need for complex (and highly

144   uncertain) calculations of the counterfactual scenario. Third, it strengthens the focus on avoidance,

145   because it explicitly identifies instances where biodiversity losses require proportionate increases

146   through actions like restoration, which will not always be a feasible option. Fourth, it provides

147   conceptual clarity; the net outcome across impact and compensation sites for a particular project

148   would align with the desired net outcome at the jurisdictional level.

149   ***Jurisdictional-level biodiversity targets***

150   The framework we propose is general, and can apply to any biodiversity targets that describe a

151   desired state of biodiversity ('outcome-based targets') at any jurisdictional scale. Target-setting is

152   not a part of the framework, but the existence of quantifiable targets is a pre-requisite for its

153   implementation. Indeed, the targets that we refer to in this framework should be set independently

154   of, and have primacy over, policy relating to the mitigation hierarchy and compensation. This is to

155   prevent targets being designed to facilitate a particular policy approach.

156   Biodiversity targets are a familiar concept. Under the CBD Strategic Plan for Biodiversity 2010-2020

157   (UN CBD, 2010), more than 160 Parties to the CBD already have targets for biodiversity conservation

158   laid out in their National Biodiversity Strategy and Action Plans (a response to the 20 global Aichi

159   Targets agreed in 2010) (UNEP, 2019). However, these are often not outcomes-based targets (IUCN,

160   2018b) – a reflection of the fact that the Aichi Targets themselves are predominantly non-

161   quantifiable, and lack focus on desired outcomes (Barnes, Glew, Wyborn, & Craigie, 2018; Butchart,

162   Di Marco, & Watson, 2016).

163   As Parties to the CBD negotiate the post-2020 global biodiversity framework, there are increasing

164   calls for clear, quantifiable science-based targets for the retention and recovery of biodiversity and

165   nature (Dinerstein et al., 2019; Mace et al., 2018; Maron, Simmonds, & Watson, 2018; Visconti et al.,

166   2019; Watson & Venter, 2017). Such targets should be incorporated in national plans and actions,

167   and linked to the achievement of broader global goals (IUCN, 2018b; Mace et al., 2018). Plentiful

8

168   guidance on target-setting is available (Butchart et al., 2016; Carwardine, Klein, Wilson, Pressey, &

169   Possingham, 2009; Di Marco, Watson, Venter, & Possingham, 2016; Doherty et al., 2018; Maron,

170   Simmonds, et al., 2018; Maxwell et al., 2015; Watson & Venter, 2017). The framework we present

171   requires that targets are measurable, and explicitly reflect the desired state (outcome) of the

172   biodiversity feature (e.g. species population, ecosystem extent) on which the target focusses, rather

173   than a desired rate of change, or a mechanism for achieving the target. Examples of such targets

174   that already exist include the French Government's pledge to support and maintain a population of

175   500 wolves for the years 2018 to 2023 (Republique Francaise, 2018), and ecosystem-specific

176   retention thresholds that are incorporated into South Africa's Draft National Offset Policy (Brownlie

177   et al., 2017 (see Supporting Information 1)).

178   **RESULTS**

179   ***Aligning ecological compensation with biodiversity targets***

180   In this framework, targeted conservation outcomes such as desired species populations or minimum

181   ecosystem extents are set in absolute terms at the jurisdictional level. The required trajectory

182   needed to achieve a target for a particular species, assemblage or ecosystem (hereafter,

183   'biodiversity feature') depends on the level (e.g. number, amount, area) of the biodiversity feature

184   when the jurisdictional-level target for that biodiversity feature was set (Figure 2).

185

186   <**Figure 2**>

187

188   When a biodiversity feature is approximately at the target level ongoing 'No Net Loss' is required. All

189   losses of the biodiversity feature need to be balanced by proportionate gains in order to maintain

190   the biodiversity feature at the target level. It follows that when a biodiversity feature is below the

9

191   target level, 'Net Gain' is needed to achieve the target, whereby the biodiversity feature increases in

192   absolute terms to (at least) the point where the target is met. 'Managed Net Loss' may be

193   appropriate in exceptional circumstances when a biodiversity feature is above its target. Setting a

194   target below current levels might require that: (1) the particular biodiversity feature is very common

195   and widespread; (2) some losses at the jurisdictional level can occur without compromising the

196   ecological integrity and function of the feature (e.g. population viability, intactness); and (3)

197   continued, strictly managed drawdown to a pre-determined target level is socially acceptable.

198   Once a jurisdiction has established targets, and thus specified the required trajectory for its

199   biodiversity features, project-level actions under the mitigation hierarchy can be designed to

200   contribute to achieving these targets. The approach to compensating for residual losses at the

201   project level depends upon several factors. The *type* of compensatory action depends on whether

202   achievement of the jurisdictional biodiversity target requires Net Gain, No Net Loss, or occasionally

203   in specific situations allows for Managed Net Loss. The *amount* of compensation required for any

204   given project is guided by the amount of residual loss, how much of the affected biodiversity feature

205   remains relative to its particular target, and policy decisions regarding the share of responsibility

206   among sectors. Below, we set out each consideration.

207   ***Achieving jurisdictional outcomes – Improvement, Maintenance and Avoidance***

208   There are two broad types of ecological compensation in this framework: Maintenance and

209   Improvement. By 'Maintenance' we mean preventing a threat to ensure persistence of a biodiversity

210   feature at its *current* condition, extent or population (and conservation status), for example by

211   legally securing existing biodiversity at a compensation site. The aim of Maintenance is to prevent

212   existing biodiversity from being lost at a site in the future (i.e. avert future losses). The net result of

213   Maintenance interventions across a jurisdiction is a reduction in the biodiversity feature, because

214   the loss from development is compensated for by securing the persistence of the biodiversity

215   feature at another site(s), where it already exists.

216   This contrasts with 'Improvement', which involves producing a quantifiable *increase* in the

217   biodiversity feature. Improvement can take a range of forms, and result from a variety of

218   interventions such as habitat enhancement (e.g. improving condition of native vegetation) or

219   removal of pervasive pressures to allow populations to increase (e.g. invasive species control). In

220   reality, the interventions that achieve Maintenance and Improvement at a site can overlap—legally

221   securing a site and managing it at a moderate intensity might preserve that site's condition

222   (Maintenance), but if management intensity is increased it might achieve Improvement; similarly,

223   legal protection of a degraded site might over time allow its recovery (Improvement). Generally,

224   Improvement will require complementary Maintenance as a necessary prerequisite (e.g. securing a

225   site containing the focal biodiversity feature or its habitat, with a view to improving it).

226   Enhancing biodiversity, including via Improvement compensation actions, is ultimately essential for

227   achieving jurisdictional-level No Net Loss or Net Gain—only by increasing the extent and/or

228   condition or amount of a biodiversity feature can No Net Loss (or Net Gain) be achieved under this

229   framework (Figure 3a and 3b). When carefully linked to biodiversity targets, Maintenance can be

230   used to contribute to Managed Net Loss, until such time that the target is reached, after which

231   Improvement becomes an essential response to any permitted losses (Figure 3c). Further, while

232   Maintenance alone cannot achieve No Net Loss or Net Gain at the jurisdictional level, it may be a

233   necessary transitional intervention to ultimately achieving these outcomes in the common situation

234   where a biodiversity feature is (1) below its target; and (2) experiencing rapid and ongoing loss from

235   unregulated pressures, where the mitigation hierarchy is not fully applied. In these circumstances,

236   compensation through Maintenance may be appropriate for a transitional period alongside or in

237   advance of compensation through Improvement (Figure 3d). However, for such an approach to be a

238   step towards a No Net Loss or Net Gain, transition phases with strict limits must be set (see

239   Supporting Information 1).

240

241   <**Figure 3**>

242

243   Because this framework explicitly links ecological compensation requirements with jurisdictional-

244   level target outcomes, it strengthens the focus on rigorously applying the earlier steps of the

245   mitigation hierarchy. Jurisdictional No Net Loss or Net Gain cannot occur without losses being

246   compensated by Improvement actions such as restoration or increases in species' populations.

247   However, for some biodiversity features, achieving such gains through actions like restoration is

248   either hampered by great uncertainty, or is simply not possible (given, for example, substantial time

249   lags) (Curran, Hellweg, & Beck, 2014; Gibbons et al., 2016; Maron et al., 2012; Moilanen, van

250   Teeffelen, Ben-Haim, & Ferrier, 2009; Pilgrim et al., 2013). This reality limits considerably the types

251   of biodiversity features for which No Net Loss or Net Gain are feasible. Losses of irreplaceable

252   biodiversity features simply cannot be managed though a compensation approach, unless the

253   jurisdictional target involves Managed Net Loss. If an outcome of further (managed net) loss is

254   unacceptable, the only option is more rigorously to apply the earlier steps in the mitigation

255   hierarchy, and avoid losses entirely.

256   ***The amount of compensation required for a given loss***

257   This target-based framework no longer depends upon the complex and often counterintuitive

258   process of defining dynamic counterfactual scenarios to establish what type of action, and how

259   much, is required to compensate for a given loss (as offsetting does). This is because instead of a

260   dynamic counterfactual scenario, a reference point fixed at a particular level—the target—is used.

261   The *amount* of compensation required for any given project is determined by both how much

262   residual loss a particular biodiversity feature experiences as a result of a development project, and

263   the pathway (e.g. No Net Loss) required to achieve a target, along with several additional

264   considerations (outlined below) that are factored into the calculation of a compensation ratio. The

265   compensation ratios (sometimes called a 'multiplier') detailed here only need to be established

266   once—at the inception of a compensation scheme—and should be applied consistently to all

267   projects.

268   The compensation ratio sets the amount of Improvement or Maintenance required per unit of

269   residual loss to contribute to the achievement of a target, as depicted in Figure 3. The first step in

270   calculating the compensation ratio is to estimate how much of the affected biodiversity feature (x)

271   exists relative to its target (at time $t = 0$, when the target, B, was set). The current amount of x

272   comprises two parts: how much of what exists is already considered *effectively* protected from

273   adverse impacts (e.g., fully resourced protected areas) or planned to be so protected $(x_p(0))$; and

274   how much of what exists could still conceivably be lost (including because of development projects)

275   $(x_a(0))$. Places identified as being under effective protection (x_p) are not available to be used for

276   compensation.

277   Where No Net Loss or Net Gain is needed to achieve a target, the amount of compensation (gain via

278   Improvement) required for a given unit of loss to a particular biodiversity feature is:

279   [Equation 1]

280
$$\boldsymbol{Compensation\ ratio\ (Improvement)} = \frac{\left(\boldsymbol{B} - \boldsymbol{x_p(0)}\right)}{\boldsymbol{x_a(0)}}$$

281

282   Where Managed Net Loss is appropriate, the amount of compensation (securing existing biodiversity

283   via Maintenance) required for a given unit of loss to a particular biodiversity feature is:

284   [Equation 2]

285
$$\boldsymbol{Compensation\ ratio\ (Maintenance)} = \left(\frac{\boldsymbol{B} - \boldsymbol{x_p(0)}}{\boldsymbol{x(0)} - \boldsymbol{B}}\right)$$

286

287   For the transitional approach (Figure 3d), Equation 2 is used to set Maintenance requirements to

288   ensure that an interim target (threshold) of B_I is not breached, before switching to Improvement

289   using Equation 1 to achieve the desired target. More details on calculating the Improvement and

290   Maintenance compensation ratios (including for transitional approach) are provided in Supporting

291   Information 1 and Supporting Information 2.

292   To exemplify these ratios, compensation for a project-level loss of 100 ha of habitat, consistent with

293   Net Gain linked to a target of doubling the currently-available habitat for a species, requires an

294   Improvement ratio of 2:1. This is based on assumptions that none of the biodiversity feature is

295   currently protected, and all adverse impacts to this biodiversity feature are regulated (i.e. follow the

296   mitigation hierarchy). Here, a ratio 2:1 requires that 200 ha of 'new' equivalent habitat must be

297   successfully created (and maintained) to compensate for the loss. Similarly, Managed Net Loss in

298   which 90% of a remaining ecosystem is to be retained would require a Maintenance ratio of 9:1,

299   wherein nine times the area of residual loss is secured and retained into the future. Again, this

300   assumes no current protection of the ecosystem, and no unregulated losses. If, say, half the

301   remaining ecosystem was already effectively protected, the ratio would be 4:1.

302   These compensation ratios can vary with policy settings. For example, the ratios presented above

303   are based on a proportionate contribution towards the achievement of the target. In other words, a

304   unit of loss caused by a regulated sector requires the same amount of compensation as would a unit

305   of unregulated loss (the liability for which accrues, in effect, to the jurisdictional government) in

306   order to progress toward the target. However, in some instances a jurisdiction may require sectors

307   that are regulated to contribute disproportionately towards a target's achievement. For example,

308   the jurisdiction may require that some sectors make additional contributions towards a biodiversity

309   target, beyond just compensating for their own impacts. Alternatively, the government may

310   shoulder some of the responsibility for compensation to limit the requirements on certain sectors.

311   Government decisions about proportionate or disproportionate responsibility and policy scope

312   (which sectors or type of impact are regulated) can affect both compensation ratios for regulated

313   sectors *and* the amount of responsibility that falls on governments to address losses that are

314   contrary to the required trajectory needed to achieve target commitments. Therefore, they must be

315   made and factored in at the point of policy development when ratios are calculated (i.e. prior to the

316   policy's implementation) (Supporting Information 2). This allows for transparency and clarity about

317   which actor must do what action, how much of it, and why, to compensate for residual impacts in

318   line with meeting desired targets.

319   Time lags in and uncertainty about achievement of compensatory outcomes are also often dealt

320   with by adjusting ratios. These factors can be incorporated in this approach by increasing the ratios

321   as appropriate (Bull, Lloyd, & Strange, 2017; Laitila, Moilanen, & Pouzols, 2014; Moilanen & Kotiaho,

322   2018). This particularly applies to Improvement, where the unadjusted ratio assumes full and certain

323   compensation instantly. The compensation ratio for Improvement thus gives the *minimum*

324   compensation required for a particular unit of loss (to contribute to achievement of the target), and

325   would need to be increased accordingly to account for time lags and uncertainties (e.g. restoration

326   not being fully successful (Maron et al., 2012; Moilanen et al., 2009)).

Contrast with counterfactual-based offsetting

328   Both target-based ecological compensation, as described in this framework, and counterfactual-

329   based offsetting, require strict adherence to the mitigation hierarchy, quantification of residual

330   losses, and determination of compensatory requirements for these losses. The fundamental

331   difference lies in *how* the compensation required for a particular biodiversity feature is calculated—

332   now based on the overall jurisdictional biodiversity target and on policy choices for how to achieve

333   it, rather than a project-specific assessment underpinned by complex counterfactual scenarios. This,

334   and other differences, are summarised in Table 1. We note that some jurisdictions may lack the

335   enabling environment to (1) develop and implement compensatory policy; and (2) determine and

336   enact either targets for biodiversity conservation, or mechanisms for their achievement. In

15

337   circumstances such as these, counterfactual-based offsetting may be more appropriate, although

338   this should be considered a temporary solution given its inherent propensity for the uncapped

339   drawdown of biodiversity. As long as appropriate, scientifically-robust biodiversity targets can be set,

340   we propose that a move toward a target-based approach is desirable.

341

342   **<Table 1>**

343

344   **DISCUSSION**

345   While in its totality, target-based ecological compensation represents a novel alternative to the

346   prevailing biodiversity offsetting paradigm, its component parts are familiar, with most aspects of

347   existing standards remaining applicable (BBOP, 2012; Gardner et al., 2013; Gelcich, Vargas, Carreras,

348   Castilla, & Donlan, 2017; IUCN, 2016). A target-based system involves changes only to the final step

349   of the well-established mitigation hierarchy, primarily relating to the sizing of compensatory

350   requirements. The on-ground actions (improving or maintaining biodiversity in a particular place) are

351   no different to those in current offsetting practice, and are subject to the same challenges that

352   affect these, and indeed most, applied conservation activities. Biodiversity targets are already

353   central in international and jurisdictional policy. Target-based ecological compensation simply helps

354   to connect project-level responses to these broad biodiversity targets to achieve desirable outcomes

355   for stakeholders and biodiversity. It should be implemented synergistically with other conservation

356   and sustainable development considerations – trading up, landscape-level planning, and impacts to

357   people (see Supporting Information 3).

358   A shift to the approach we propose carries risks. First, changing existing regulations, which

359   (currently) promote averted loss offsetting, may result in sub-optimal biodiversity outcomes if the

360   biggest gains (in the short-term) can be made by protecting highly-threatened biodiversity from

16

361 unmanaged pressures. Our framework deals with this by incorporating a 'phased approach' (see

362 above; Supporting Information 1). Second, having outcomes-based targets places a level of

363 accountability on those who set the target, and those who are required to contribute to its

364 achievement. This may encourage the setting of 'easy' or unambitious targets, which may lead to

365 small compensatory requirements. This underscores the need for science-based targets that are

366 established independently of the design of the compensatory scheme. As long as such targets exist,

367 the simplicity of calculating compensatory requirements and the transparency of the contribution

368 this makes to a specific goal, lends itself to higher certainty for all stakeholders, and more

369 straightforward regulatory monitoring and compliance auditing.

370 Operationalising target-based ecological compensation can draw on lessons from other policy

371 frameworks. For example, REDD+ is a mechanism under the UNFCCC where local forest protection

372 contributes to achieving broader goals (carbon emissions targets). Challenges have been identified

373 regarding multi-level governance, relating to accounting (e.g. carbon crediting, incentives) and

374 implementation (e.g. decision-making) (Cortez et al., 2010; Ravikumar et al., 2015). This has

375 prompted the development of implementation frameworks (e.g. 'nested' approach proposed by

376 Cortez et al. 2010), from which a key lesson is that the achievement of national targets is reliant on

377 actors operating at multiple scales, thus necessitating protocols for their engagement, including in

378 decision-making and benefit sharing. In light of the REDD+ experience, coordination among actors,

379 and especially those undertaking projects 'on the ground', to contribute to the achievement of

380 jurisdictional biodiversity targets, will be crucial for successful implementation of target-based

381 ecological compensation.

382 In Brazil, requirements for the protection of a minimum proportion of native vegetation on private

383 properties (legal reserves under the 'Forest Code') aim to help achieve bioregional vegetation

384 retention targets. Brazil's overall approach has the benefit of transparency in desired outcomes, with

385 mechanisms designed explicitly to achieve it (Metzger et al., 2019). However, criticism of its

386 restrictiveness for business and landholders have led to relaxations of its requirements over time

387 (e.g. amnesty for illegal deforestation on small properties (Soares-Filho et al., 2014)), and even calls

388 for it to be extinguished (Metzger et al. 2019)). This underscores the risk of implementing any

389 environmental regulation that is reliant on contributions from industry and private individuals to

390 achieve a broader public-good goal (e.g. explicit environmental targets).

391 A target-based ecological compensation approach would be most effective when developed as a

392 coordinated jurisdictional policy, with both jurisdictional net outcomes set and

393 Improvement/Maintenance compensation ratios calculated at the outset. The main enabling

394 conditions (or conversely, barriers to implementation, where these conditions are lacking) for

395 embedding the approach at the jurisdictional level include basic information on the extent/amount

396 and condition of the biodiversity features that would be the focus of the policy, including how much

397 is considered to be already effectively protected, and regulatory control of at least some sectors that

398 cause biodiversity loss. Taken together, these would allow for the calculation of compensation ratios

399 and identification of valid locations for compensation. Once this (non-trivial) work is done, the

400 project-level process of identifying suitable ecological compensation would be greatly simplified.

401 In addition to government policy, most multilateral finance institutions reference 'no net loss' and

402 even 'net gain' requirements in relation to escalating biodiversity risks. For example, IFC

403 Performance Standard 6 requires no net loss where feasible in natural habitats, while net gain is

404 required for critical habitats (IFC, 2012). The simplified ratio-based protocol that is embedded in the

405 target-based approach could facilitate investment by these institutions, and, represents a desirable

406 objective for those multilateral finance institutions with mandates to engage the public sector on

407 policy reform to facilitate sustainable development.

408 Regardless of whether embedded in government policy or industry/corporate standards, this

409 framework does not imply that proponents of development projects are expected to bear the entire

410 burden of a jurisdiction achieving its particular biodiversity targets, nor that compensation alone be

411 used to achieve targets. Indeed, the share that falls on developers is a policy decision for

412 governments (See Results; Supporting Information 2). Fundamentally, it offers a systematic

413 approach to determining project-level compensation that is *consistent with the achievement* of

414 jurisdictional biodiversity targets. The more comprehensive the policy's scope—that is, the more

415 sectors that are regulated and required to compensate for losses to biodiversity arising from their

416 activities—the greater the contribution of proponents of development to meeting a jurisdiction's

417 biodiversity targets.

418 However, it will rarely, if ever, be the case that a compensatory policy is broad enough in scope to

419 capture all processes that result in the loss of biodiversity. This means that actors other than

420 proponents of development projects (e.g. governments) will need to address losses to biodiversity

421 that are beyond the scope of compensatory policy—the unregulated losses—in combination with a

422 wide suite of other complementary conservation actions that are implemented to contribute to

423 meeting targets. This ecological compensation framework involves setting out clearly the

424 expectation for both proponents of development and jurisdictional authorities as this relates to how

425 to address losses of biodiversity, whereby compensatory actions *alongside other conservation*

426 *investment* can contribute to achieving biodiversity targets.

427 Ecological compensation should always be an option of last resort. In instances where the

428 biodiversity features that are exposed to residual project losses are imperilled and irreplaceable—in

429 other words, they cannot be feasibly improved or recreated—ecological compensation is not

430 acceptable, and losses must be avoided altogether. Where residual losses *can* be reasonably

431 addressed through compensatory interventions, this target-based framework provides a pathway

432 towards more transparent and effective outcomes. It explicitly links compensatory actions to

433 broader biodiversity targets, and clarifies and simplifies the expectations on and requirements of

434 developers. In this regard, it represents a step towards the coordinated planning and integrated

435   actions that will be crucial to stem and reverse biodiversity losses in the face of ongoing

436   development pressures.

437   **ACKNOWLEDGEMENTS**

447   **REFERENCES**

448   Barnes, M. D., Glew, L., Wyborn, C., & Craigie, I. D. (2018). Prevent perverse outcomes from global

449   protected area policy. *Nature Ecology & Evolution, 2*(5), 759-762. doi:10.1038/s41559-018-

450   0501-y

451   Business and Biodiversity Offstes Progamme (BBOP). (2009). *Biodiversity Offset Design Handbook*.

452   (BBOP, Washington D.C.).

453   Business and Biodiversity Offstes Progamme (BBOP). (2012). *Standard on Biodiversity Offsets*. (BBOP,

454   Washington D.C.).

455   Bekessy, S. A., Wintle, B. A., Lindenmayer, D. B., Mccarthy, M. A., Colyvan, M., Burgman, M. A., &

456   Possingham, H. P. (2010). The biodiversity bank cannot be a lending bank. *Conservation

457   Letters, 3*(3), 151-158. doi:doi:10.1111/j.1755-263X.2010.00110.x

458 Brownlie, S., von Hase, A., Botha, M., Manuel, J., Balmforth, Z., & Jenner, N. (2017). Biodiversity

459   offsets in South Africa – challenges and potential solutions. *Impact Assessment and Project*

460   *Appraisal, 35*(3), 248-256. doi:10.1080/14615517.2017.1322810

461 Bull, J. W., Gordon, A., Watson, J. E. M., & Maron, M. (2016). Seeking convergence on the key

462   concepts in 'no net loss' policy. *Journal of Applied Ecology, 53*(6), 1686-1693.

463   doi:10.1111/1365-2664.12726

464 Bull, J. W., Lloyd, S. P., & Strange, N. (2017). Implementation gap between the theory and practice of

465   biodiversity offset multipliers. *Conservation Letters, 10*(6), 656-669. doi:10.1111/conl.12335

466 Bull J.W., & Strange, N. (2018). The global extent of biodiversity offset implementation under no net

467   loss policies. *Nature Sustainability, 1*, 790-798.

468 Buschke, F. T., Brownlie, S., & Manuel, J. (2017). The conservation costs and economic benefits of

469   using biodiversity offsets to meet international targets for protected area expansion. *Oryx*,

470   1-9. doi:10.1017/S0030605317001521

471 Butchart, S. H. M., Di Marco, M., & Watson, J. E. M. (2016). Formulating smart commitments on

472   biodiversity: lessons from the Aichi Targets. *Conservation Letters, 9*(6), 457-468.

473   doi:doi:10.1111/conl.12278

474 Carwardine, J., Klein, C. J., Wilson, K. A., Pressey, R. L., & Possingham, H. P. (2009). Hitting the target

475   and missing the point: target-based conservation planning in context. *Conservation Letters,*

476   *2*(1), 4-11. doi:doi:10.1111/j.1755-263X.2008.00042.x

477 Cortez, R., Saines, R., Griscom, B., Martin, M., De Deo, D., Fishbein, G., Kerkering, J., & Marsh, D.

478   (2010). *A Nested Approach tp REDD+*. (The Nature Conservancy. Arlington).

479 Curran, M., Hellweg, S., & Beck, J. (2014). Is there any empirical support for biodiversity offset

480   policy? *Ecological Applications, 24*(4), 617-632. doi:10.1890/13-0243.1

481 Di Marco, M., Watson, J. E. M., Venter, O., & Possingham, H. P. (2016). Global biodiversity targets

482   require both sufficiency and efficiency. *Conservation Letters, 9*(6), 395-397.

483   doi:doi:10.1111/conl.12299

484   Dinerstein, E., Vynne, C., Sala, E., Joshi, A. R., Fernando, S., Lovejoy, T. E., . . . Wikramanayake, E.

485   (2019). A Global Deal For Nature: guiding principles, milestones, and targets. *Science*

486   *Advances, 5*(4), eaaw2869. doi:10.1126/sciadv.aaw2869

487   Doherty, T. S., Bland, L. M., Bryan, B. A., Neale, T., Nicholson, E., Ritchie, E. G., & Driscoll, D. A.

488   (2018). Expanding the role of targets in conservation policy. *Trends in Ecology & Evolution,*

489   *33*(11), 809-812. doi:10.1016/j.tree.2018.08.014

490   Gardner, T. A., von Hase, A., Brownlie, S., Ekstrom, J. M. M., Pilgrim, J. D., Savy, C. E., . . . ten Kate, K.

491   (2013). Biodiversity offsets and the challenge of achieving no net loss. *Conservation Biology,*

492   *27*(6), 1254-1264. doi:10.1111/cobi.12118

493   Gelcich, S., Vargas, C., Carreras, M. J., Castilla, J. C., & Donlan, C. J. (2017). Achieving biodiversity

494   benefits with offsets: research gaps, challenges, and needs. *Ambio, 46*(2), 184-189.

495   doi:10.1007/s13280-016-0810-9

496   Gibbons, P., & Lindenmayer, D. B. (2007). Offsets for land clearing: no net loss or the tail wagging the

497   dog? *Ecological Management & Restoration, 8*(1), 26-31. doi:doi:10.1111/j.1442-

498   8903.2007.00328.x

499   Gibbons, P., Evans, M. C., Maron, M., Gordon, A., Le Roux, D., von Hase, A., . . . Possingham, H. P.

500   (2016). A loss-gain calculator for biodiversity offsets and the circumstances in which no net

501   loss is feasible. *Conservation Letters, 9*(4), 252-259. doi:10.1111/conl.12206

502   Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M. C., Shyamsundar, P., . . . Noble,

503   I. (2013). Sustainable development goals for people and planet. *Nature, 495*, 305.

504   doi:10.1038/495305a

505   Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019).

506   Summary for policymakers of the global assessment report on biodiversity and ecosystem

507   services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem

508   Services. Retrieved from:

509   https://www.ipbes.net/sites/default/files/downloads/spm_unedited_advance_for_posting_

510   htn.pdf.

511 International Finance Corporation (IFC). (2012). Performance Standards. Retrieved from:

512   https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/S

513   ustainability-At-IFC/Policies-Standards/Performance-Standards

514 International Union for Conservation of Nature (IUCN). (2016). IUCN Policy on Biodiversity Offsets.

515   Retrieved from: https://www.iucn.org/theme/business-and-biodiversity/our-work/business-

516   approaches-and-tools/biodiversity-offsets

517 International Union for Conservation of Nature (IUCN). (2018a). Global Inventory of Biodiversity

518   Offset Policies (GIBOP). Retrieved from: https://portals.iucn.org/offsetpolicy/

519 International Union for Conservation of Nature (IUCN). (2018b). Strengthening global biodiversity

520   governance post-2020: lessons from the climate regime? Retrieved from:

521   https://www.iucn.org/files/information-paper-global-biodiversity-governance-and-lessons-

522   climate-regime

523 Laitila, J., Moilanen, A., & Pouzols, F. M. (2014). A method for calculating minimum biodiversity

524   offset multipliers accounting for time discounting, additionality and permanence. *Methods*

525   *in Ecology and Evolution, 5*(11), 1247-1254. doi:10.1111/2041-210X.12287

526 Laurance, W. F. (2018). Conservation and the global infrastructure tsunami: disclose, debate, delay!

527   *Trends in Ecology & Evolution, 33*(8), 568-571.

528   doi:https://doi.org/10.1016/j.tree.2018.05.007

529 Mace, G. M., Barrett, M., Burgess, N. D., Cornell, S. E., Freeman, R., Grooten, M., & Purvis, A. (2018).

530   Aiming higher to bend the curve of biodiversity loss. *Nature Sustainability, 1*(9), 448-451.

531   doi:10.1038/s41893-018-0130-0

532 Maron, M., Hobbs, R. J., Moilanen, A., Matthews, J. W., Christie, K., Gardner, T. A., . . . McAlpine, C.

533   A. (2012). Faustian bargains? Restoration realities in the context of biodiversity offset

534   policies. *Biological Conservation, 155*, 141-148.

535   doi:https://doi.org/10.1016/j.biocon.2012.06.003

536 Maron, M., Simmonds, J. S., & Watson, J. E. M. (2018). Bold nature retention targets are essential for

537   the global environment agenda. *Nature Ecology & Evolution, 2*(8), 1194-1195.

538   doi:10.1038/s41559-018-0595-2

539 Maron, M., Brownlie, S., Bull, J. W., Evans, M. C., von Hase, A., Quétier, F., . . . Gordon, A. (2018). The

540   many meanings of no net loss in environmental policy. *Nature Sustainability, 1*(1), 19-27.

541   doi:10.1038/s41893-017-0007-7

542 Maxwell, S. L., Milner-Gulland, E. J., Jones, J. P. G., Knight, A. T., Bunnefeld, N., Nuno, A., . . . Rhodes,

543   J. R. (2015). Being smart about SMART environmental targets. *Science, 347*(6226), 1075-

544   1076. doi:10.1126/science.aaa1451

545 Metzger J.P., Bustamante M.M.C., Ferreira J., Fernandes, G.W., Libran-Embid, R., Pillar, V.D, …

546   Overbeck, G.E. (2019) Why Brazil needs its Legal Reserves. *Perspectives in Ecology and*

547   *Conservation*.

548 Moilanen, A., van Teeffelen, A. J. A., Ben-Haim, Y., & Ferrier, S. (2009). How much compensation is

549   enough? A framework for incorporating uncertainty and time discounting when calculating

550   offset ratios for impacted habitat. *Restoration Ecology, 17*(4), 470-478. doi:10.1111/j.1526-

551   100X.2008.00382.x

552 Moilanen, A., & Laitila, J. (2016). Indirect leakage leads to a failure of avoided loss biodiversity

553   offsetting. *Journal of Applied Ecology, 53*(1), 106-111. doi:10.1111/1365-2664.12565

554 Moilanen, A., & Kotiaho, J. S. (2018). Fifteen operationally important decisions in the planning of

555   biodiversity offsets. *Biological Conservation, 227*, 112-120.

556   doi:https://doi.org/10.1016/j.biocon.2018.09.002

557 Pilgrim, J. D., Brownlie, S., Ekstrom, J. M. M., Gardner, T. A., von Hase, A., Kate, K. T., . . . Ward, G.

558   (2013). A process for assessing the offsetability of biodiversity impacts. *Conservation Letters,*

559   *6*(5), 376-384. doi:10.1111/conl.12002

560   Quétier, F., van Teeffelen, A. J. A., Pilgrim, J. D., von Hase, A., & Kate, K. t. (2015). Biodiversity offsets

561   are one solution to widespread poorly compensated biodiversity loss: a response to Curran

562   et al. *Ecological Applications, 25*(6), 1739-1741. doi:10.1890/14-1217.1

563   Rainey, H. J., Pollard, E. H. B., Dutson, G., Ekstrom, J. M. M., Livingstone, S. R., Temple, H. J., &

564   Pilgrim, J. D. (2014). A review of corporate goals of No Net Loss and Net Positive Impact on

565   biodiversity. *Oryx, 49*(2), 232-238. doi:10.1017/S0030605313001476

566   Ravikumar, A., Larson, A.M., Duchelle, A.E., Myers, R. & Gonzales Tovar, J. (2015). Multilevel

567   governance challenges in transitioning towards a national approach for REDD+: evidence

568   from 23 subnational REDD+ initiatives. *International Journal of the Commons, 9*(2), 909-931.

569   DOI: http://doi.org/10.18352/ijc.593

570   Republic of South Africa. (2017). *National Environmental Management Act 1998 (ACT NO. 107 OF*

571   *1998): Draft National Biodiversity Offset Policy.*

572   Republique Francaise. (2018). *Plan national d'actions 2018-2023 sur le loup et les activités d'élevage*.

573   Soares-Filho B., Rajão R., Macedo M., Carneiro, A., Costa, W., Coe, M., … Alencar, A. (2014) Cracking

574   Brazil's Forest Code. *Science, 344*, 363-364.

575   United Nations Environment Programme (UNEP). (2019). National Biodiversity Strategies and Action

576   Plans (NBSAPs). Retrieved from: https://www.cbd.int/nbsap/

577   United Nations. (2018). *The Sustainable Development Goals Report 2018*. (New York, United States

578   of America).

579   Visconti, P., Butchart, S. H. M., Brooks, T. M., Langhammer, P. F., Marnewick, D., Vergara, S., . . .

580   Watson, J. E. M. (2019). Protected area targets post-2020. *Science, 364*(6437), 239-241.

581   doi:10.1126/science.aav6886

582   Watson, J. E. M., & Venter, O. (2017). A global plan for nature conservation. *Nature, 550*, 48.

583   doi:10.1038/nature24144

584   World Bank Group. (2016). *Biodiversity Offsets: A User Guide.* (World Bank Group, Washington D.C.).
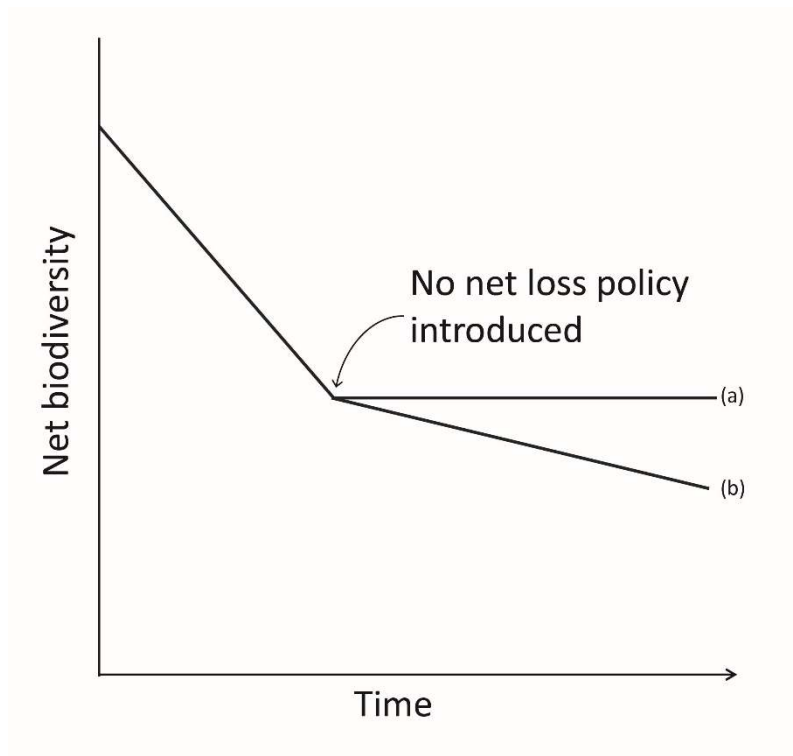
585

AUTHOR CONTRIBUTIONS

This framework was developed in a working group led by M.M. and J.E.M.W. All authors contributed

to the development of the framework. J.S.S. led the writing of the manuscript, and all authors

contributed to its preparation, and approved the final version for submission.

590   **Table 1.** Comparison between counterfactual-based offsetting and target-based ecological

591   compensation.

	Advantages	Risks and challenges
Counterfactual-based offsetting (aiming for no net loss relative to a counterfactual scenario)	• Can be implemented in the absence of any articulated conservation targets • Increases the attention on the difference made by a conservation intervention • Can be implemented for individual projects in poorly-regulated settings • Main concepts and approaches familiar to many practitioners / policy makers	• Outcomes are relative to a dynamic counterfactual trajectory that cannot be known in advance, only estimated • Biodiversity decline continues even though a project may achieve no net loss relative to a declining counterfactual • Constructing robust counterfactuals is conceptually complex and can be data-hungry • The type and amount of offset action required is highly sensitive to assumptions about the counterfactual trajectory • The end point of the biodiversity trajectory is implicit or unknown • Relatively easy to manipulate the counterfactual and thus undermine the net outcome
Target-based ecological compensation (aiming for net jurisdictional outcomes aligned with	• Aligns outcomes of actions regulated by compensatory policy with overarching conservation objectives	• Requires articulation of conservation targets, potentially creating incentive to 'set bar low' to facilitate 'business as usual' compensatory policy (not advocated by this framework)

| specific biodiversity targets) | • Outcomes are explicit and relative to a fixed, known point in time
 • 'No Net Loss', 'Net Gain' and 'Managed Net Loss' have intuitive meanings
 • Standardises calculation of the type and amount of compensation required
 • Complex, dynamic counterfactual scenarios are not required | • Requires estimate of the difference between the target state and current state of impacted biodiversity features
 • When targets are at odds with actions occurring or planned outside the scope of the compensatory policy, target-based actions can be suboptimal
 • Target-based ecological compensation is a relatively new concept (although similar approaches exist in some jurisdictions) and will take adjustment |

592

593

Figure 1. 'No net loss' relating to different reference scenarios. No net loss at the jurisdictional level

implies that loss is stopped in absolute terms compared to a fixed reference scenario – i.e. that all

biodiversity losses are addressed by gains of the same size, thus maintaining biodiversity at the same

level compared to before the loss occurred (a). However, in reality, no net loss commitments

frequently only require that individual projects achieve no net loss relative to a declining

counterfactual, by protecting biodiversity that might otherwise be lost in the future due to

unregulated impacts ('averted loss') (b). Such project-level no net loss results in ongoing loss of

biodiversity at the jurisdictional level, albeit at a slower rate (figure adapted from Maron, Brownlie,
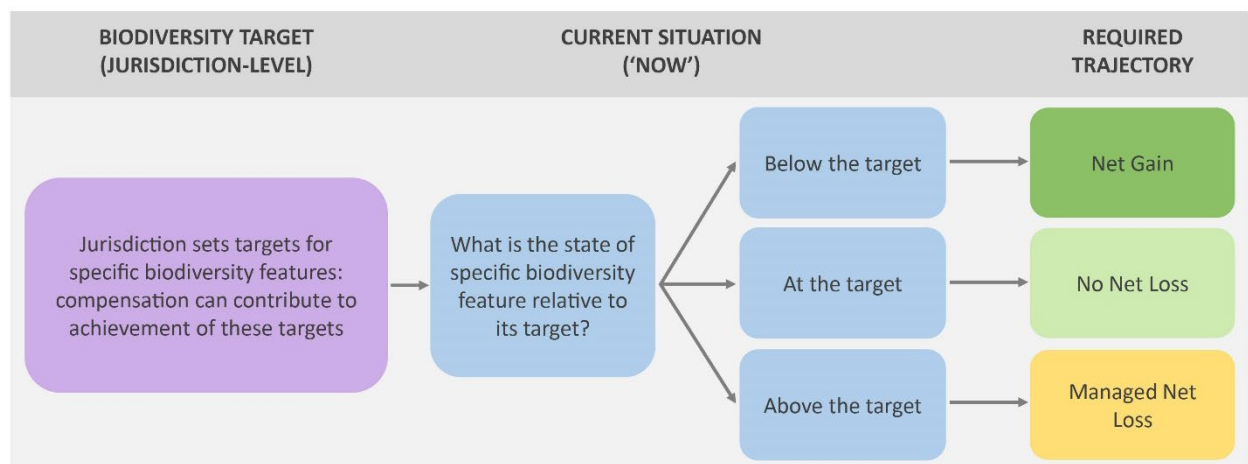
et al. (2018)).

BIODIVERSITY TARGET (JURISDICTION-LEVEL)	CURRENT SITUATION ('NOW')	REQUIRED TRAJECTORY

Jurisdiction sets targets for specific biodiversity features: compensation can contribute to achievement of these targets → What is the state of specific biodiversity feature relative to its target?

- Below the target → Net Gain
- At the target → No Net Loss
- Above the target → Managed Net Loss

603

Figure 2. Aligning ecological compensation with jurisdictional biodiversity targets starts with

establishing the trajectory required to achieve net target outcomes. The required trajectory depends

on whether a biodiversity feature is below, at, or above its jurisdictional biodiversity target at the
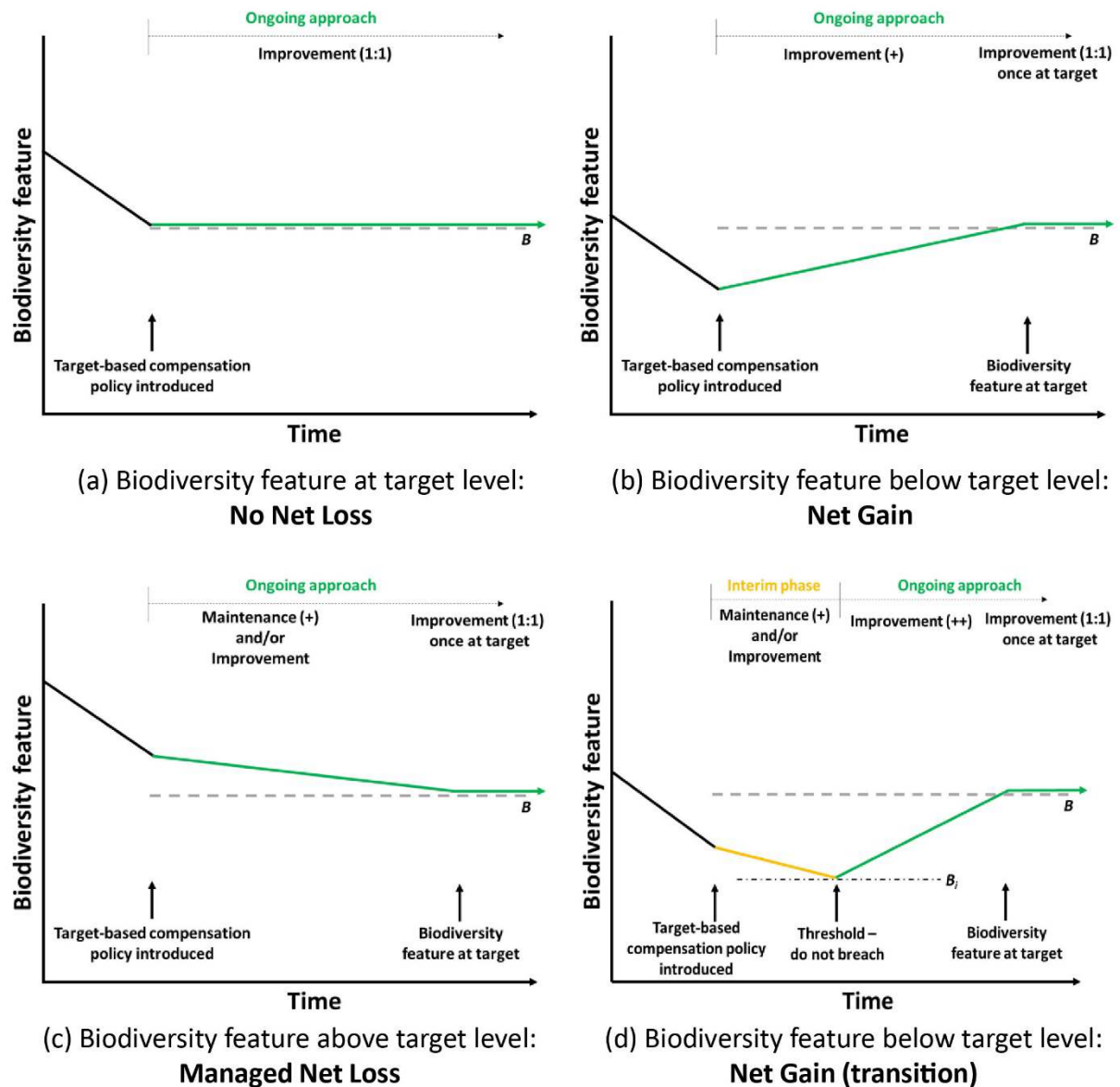
time the target is set ('now').

Figure 3. Illustration of the target-based ecological compensation approach for contributing to the achievement of a) No Net Loss; b) Net Gain; c) Managed Net Loss; and d) Net Gain using a transitional approach in which Maintenance actions can be undertaken for a period of time to help stem unregulated losses, before Improvement actions become the default requirement. The dashed line on each plot represents the target level (B) for the biodiversity feature. The indicative amount of Improvement and/or Maintenance (denoted by '+') depends on the difference between the level of the biodiversity feature and the target (and in the case of the transitional approach (d)), the threshold (B_i) below which the biodiversity feature cannot decline) (see Supporting Information 1).

617   Importantly, compensation for residual losses from development is one of a suite of complementary

618   measures to achieve the desired trajectory and ultimately achieve a target. At such time that the

619   target is met, maintaining the biodiversity feature at this level requires losses to be compensated for

620   by Improvement at a ratio of 1:1 (or targets could be revised towards ambitious new objectives).

Moving from biodiversity offsets to a target-based approach for ecological compensation

Simmonds et al.

Supporting Information 1

Calculating the compensation ratios in target-based ecological compensation

The calculation of an ecological compensation requirement typically factors in a ratio (also called a 'multiplier'). The ratio is a number, usually greater than 1, which tells you how much of a biodiversity feature needs to be replaced/secured per unit of the feature lost. These ratios, in the past, have taken into account issues such as time discounting (biodiversity features produced in the future do not fully compensate for biodiversity features produced now), uncertainty, and risk of failure (Bull, Lloyd, & Strange, 2017; Laitila, Moilanen, & Pouzols, 2014; Moilanen, van Teeffelen, Ben-Haim, & Ferrier, 2009).

Here, we present ratios that accommodate the need to meet target values for various biodiversity features in the landscape – for example, a target for the number of breeding individuals of a species might be a minimum of 10000, a target for the area of suitable habitat for a species might be 5000 home ranges or more, a target for the area of a vegetation community in a region might be at least half of its original extent in good condition, which translates to a minimum area and condition score.

The formulae below assume no time lags (e.g. in the case of Improvement, new features are created instantly). Issues such as time lags will modify the ratios in ways already described (Bull et al., 2017; Laitila et al., 2014; Moilanen & Kotiaho, 2018).

Let $x(t)$ be the state of the biodiversity feature at time t where 0 <= $x(t)$ <= 1 for all t. This is made up of two parts, the part that is permanently and effectively protected $x_p(t)$, which are places that are not available for any compensatory related change, and $x_a(t)$ which is the part that could be destroyed or used for compensation at the end of the mitigation hierarchy. Hence the amount of the biodiversity feature is the sum of the protected and available parts: $x_p(t)$ + $x_a(t)$ = $x(t)$ at all times. Further:

Let B be the target state of the biodiversity feature and we assume this is time independent (constant).

The ratios we present below assume that (1) all sectors that cause loss of biodiversity will provide compensation; and (2) that each sector's compensation will be a proportionate contribution to the achievement of the target (i.e. everyone compensates equally for the losses they cause). However, in some instances, not all causes of biodiversity loss will fall within the scope of policy that regulates implementation of the mitigation hierarchy. That is, the loss of biodiversity will be a function of regulated and unregulated losses. At the inception of a target-based ecological compensation policy, a government may choose to adjust compensation requirements (with implications for the calculation of compensation ratios) on sectors regulated by the mitigation hierarchy, in one of several ways:

- Compensation from regulated development is disproportionately low. The government would need to address shortfalls arising from disproportionately low compensation.

- Compensation from regulated development is disproportionately high. A disproportionately large share of achieving the target is placed on regulated sectors.

- The achievement of the target is solely the responsibility of regulated sectors, by way of the compensation they provide for the losses they cause.

Where there are unregulated losses that are going uncompensated, the requirement to address these in a way that is consistent with achieving targets accrues to other actors (e.g. the government).

We provide examples of how these policy choices affect compensation ratios, and what this means for the responsibility that falls on both regulated sectors *and* governments, in an editable spreadsheet in Supplementary Information 2.

Case 1: No Net Loss; the biodiversity feature is at the target ($x(0) = B$)

If there is no unregulated loss of the biodiversity feature, the compensation ratio (Improvement) is 1. This also applies to all cases once targets are met.

If there is unregulated loss of the biodiversity feature, then either:

- the compensation ratio (Improvement) is 1 and the liability accrues to the authority (e.g. government) to create the biodiversity feature to compensate for unregulated loss; or

- the compensation ratio is adjusted (increased) to enhance the share of the responsibility for achieving the target that falls on regulated sectors.

Case 2: Net Gain; the biodiversity feature is below the target ($x(0) < B$)

The compensation ratio (Improvement) needs to be set so that, once (hypothetically) all of the (available for development) biodiversity feature at $t = 0$ ($x_a(0)$) has been lost, we have met the target. Hence the ratio is $(B - x_p(0))/(x(0) - x_p(0)) = (B - x_p(0))/x_a(0)$, which is the inverse of the fraction of the available biodiversity feature that remains relative to the target. In the special case that none of target is effectively protected $x_p(0) = 0$ then this is $B/x_a(0)$.

For example if the target is $B = 1000$, the effectively protected amount is $x_p(0) = 200$, and the current total biodiversity feature state is $x(0) = 600$ (so the available amount of the biodiversity feature is $x_a(0) = 400$) then the compensation ratio (Improvement) is 2 assuming no unregulated losses.

The compensation ratio (Improvement) can be summarised as follows:

$$Compensation\ ratio\ (Improvement) = \left(\frac{B - x_P(0)}{x_a(0)}\right)$$

Case 3: Managed Net Loss; the biodiversity feature is above the target ($x(0) > B$)

If there is no unregulated loss of the biodiversity feature and $x_p(0) > B$, no compensation is necessary because we already have met our target in fully protected areas.

If $x_p(0) < B$, then the compensation ratio (Maintenance) is:

$$Compensation\ ratio\ (Maintenance) = \left(\frac{B - x_p(0)}{x(0) - B}\right)$$

For example if the target is $B = 1000$, the effectively protected amount is $x_p(0) = 200$, and the current total amount of the biodiversity feature is $x(0)$ = 1400, then the compensation ratio (Maintenance) is 2.

If the current state of the biodiversity feature (at $t = 0$) is only marginally above the target (B), then the compensation ratio (Maintenance) will be very large, and may be unfeasibly high to practically implement. For example, should $x(0) = 10000$, and $B = 9900$ (implying a drawdown of 1% of the biodiversity feature to its target), the compensation ratio (Maintenance) will be 99:1 (assuming no unregulated losses, and no current protection). In such circumstances, a mixture of compensation provided using Maintenance only (as described above), and a separate calculation of compensation where Improvement is used according to a different (Managed Net Loss-specific Improvement) ratio calculation of $\left(B - x_p(0)\right)/x(0)$, may be an option – and if effective Improvement is unfeasible for that biodiversity feature, then avoidance is the only way in which the target can be met.

Provided below is an example of a Managed Net Loss protocol - South Africa's Draft National Biodiversity Offset Policy and provincial guidelines.

Box 1. Example of Managed Net Loss: South Africa Draft National Biodiversity Offset Policy and provincial guidelines

This policy is designed to contribute to achieving specific biodiversity targets for terrestrial ecosystems (Brownlie et al., 2017; Buschke et al., 2017). The minimum extent of each ecosystem that must be retained intact (relative to its original or historical extent) has been determined based on a scientific process (Desmet & Cowling, 2004). These ecosystem extent thresholds – in effect, targets – guide compensation requirements. The amount of compensation for residual losses from development depends on how much of the impacted ecosystem remains, relative to its historical extent and target, and how much of it is formally protected.

Where an ecosystem is below its retention threshold or target, development may not occur, other than under exceptional circumstances. For above-target ecosystems, compensation is done by protecting another place where the impacted ecosystem occurs using a Maintenance ratio scaled based on the difference between the current and desired minimum extent of the ecosystem and how much of it is protected. The net outcome in absolute terms is a Managed Net Loss – because the protected biodiversity existed at the time of the loss from the development. This target-based system carefully manages losses to avoid ecosystem extent falling below scientifically-robust thresholds. This policy avoids the 'no net loss' wording – because it is not designed to achieve no net loss.

Case 4: No Net Loss or Net Gain (transition)

A potential limitation of target-based ecological compensation is that desired No Net Loss or Net Gain outcomes (e.g. Figure 3a and Figure 3b in main review article) may not be immediately feasible in a situation of steep, continued, unaddressed and unregulated biodiversity loss. Indeed, a focus solely on Improvement actions like restoration before large-scale biodiversity loss has ceased could even be counterproductive. In such cases, a phased transition designed to ultimately achieve No Net Loss or Net Gain outcomes, that is embedded in the principles of this target-based framework, may be the most appropriate approach (Figure 3d in main review article).

The phased transition would temporarily accept a strictly controlled interim phase in which Maintenance (plus some Improvement, where feasible) interventions first aim to slow the decline of the biodiversity feature that is the focus of the compensation by securing sites where it currently exists (i.e. resembling a Managed Net Loss). Maintenance ratios in this phase would be designed not to achieve the ultimate desired target for that biodiversity feature, but to avoid breaching a pre-defined threshold limit to loss (Figure 3d in main review article). The threshold would need to be set such that enough of the focal biodiversity (extent of ecosystem; population of species) remained to allow for recovery to be feasible. Well before the threshold is reached, the approach transitions to require an Improvement ratio such that the desired No Net Loss or Net Gain outcome can be approached over time as the trajectory of the focal biodiversity feature reverses. As for all jurisdictional No Net Loss and Net Gain outcomes, this is possible only for biodiversity features that can be 'improved', such as through restoration or interventions that drive population increase. Further, the lower the initial threshold, the larger the subsequent Improvement ratio must be to achieve the target.

The phased transition to target-based compensation carries risks, but where a jurisdiction aims to, and can feasibly (in time) achieve a No Net Loss or Net Gain outcome for a particular biodiversity feature, and that same feature is in steep and ongoing decline, the short-term alternatives are few. They include: (1) immediate prevention of all actions causing biodiversity decline; (2) acceptance of less-ambitious biodiversity targets that allow for further drawdown of biodiversity, with compensatory policy designed to achieve an outcome of Managed Net Loss (i.e. capping ongoing losses at a pre-defined level); (3) use of counterfactual-based offsetting alongside unmanaged ongoing net losses; or (4) no compensation for losses at all – in other words unmanaged loss without limit – which poses serious risks for nature and people.

Calculating compensation requirements where the ultimate outcome of No Net Loss or Net Gain is achieved using a transitional approach involves a combination of Cases 2 and 3, as described above. Compensation using Maintenance (Case 3) is used first, to secure existing elements of the biodiversity feature, in the face of ongoing and severe threats. The approach switches to compensation through Improvement (Case 2), *well before* the biodiversity feature reaches a pre-determined threshold below which it is not permitted to decline. Thus, there is the intermediate threshold below which the biodiversity feature cannot decline (B_I) and the ultimate (No Net Loss or Net Gain) target (B).

Critically, determining the intermediate threshold (B_I) should be based primarily on ecological considerations: the threshold would need to be set such that enough of the focal biodiversity (e.g. extent of ecosystem; population of species) remained to allow for recovery to be feasible. However, establishing a compensation ratio (Maintenance) that can be practically implemented is another consideration here.

The following equation allows for comparison of values for the intermediate threshold (B_I), given input of different compensation ratios (Maintenance) (M_m):

$$B_I = (x_p(0) + x(0)M_m)/(1 + M_m)$$

For example, where $x_p(0) = 200$ and $x(0) = 1080$, compensation ratios (Maintenance) (M_m) of 10, 5 and 1 would mean intermediate threshold values (B_I) of 1000, 933 and 640, respectively.

This calculation provides a means by which to select the intermediate threshold (B_I) value that accounts for what can be practically implemented regarding maximum compensation ratios (Maintenance). Importantly, the lower the compensation ratio (and thus, intermediate threshold (B_I) value), the greater amount of compensation (and thus the higher the compensation ratio) will be when the approach switches to Improvement. Again, the primary consideration must always be the ecological attributes of the specific biodiversity feature, and the landscape context in which that feature occurs. In other words, the intermediate threshold (B_I), and the compensation ratio M_m must never be so low as to render recovery of the biodiversity feature, and enhancement through Improvement to achieve the ultimate No Net Loss or Net Gain target (B), unfeasible.

References

Brownlie, S., von Hase, A., Botha, M., Manuel, J., Balmforth, Z., & Jenner, N. (2017). Biodiversity offsets in South Africa – challenges and potential solutions. *Impact Assessment and Project Appraisal*, 35(3), 248-256. doi:10.1080/14615517.2017.1322810

Bull, J. W., Lloyd, S. P., & Strange, N. (2017). Implementation gap between the theory and practice of biodiversity offset multipliers. *Conservation Letters, 10*(6), 656-669. doi:10.1111/conl.12335

Buschke, F. T., Brownlie, S., & Manuel, J. (2017). The conservation costs and economic benefits of using biodiversity offsets to meet international targets for protected area expansion. *Oryx*, 1-9. doi:10.1017/S0030605317001521

Desmet P., & Cowling R. (2004). Using the species-area relationship to set baseline targets for conservation. *Ecology and Society*, 9, 11.

Laitila, J., Moilanen, A., & Pouzols, F. M. (2014). A method for calculating minimum biodiversity offset multipliers accounting for time discounting, additionality and permanence. *Methods in Ecology and Evolution, 5*(11), 1247-1254. doi:10.1111/2041-210X.12287

Moilanen, A., & Kotiaho, J. S. (2018). Fifteen operationally important decisions in the planning of biodiversity offsets. *Biological Conservation, 227*, 112-120. doi:https://doi.org/10.1016/j.biocon.2018.09.002

Moilanen, A., Van Teeffelen, A. J. A., Ben-Haim, Y., & Ferrier, S. (2009). How much compensation is enough? A framework for incorporating uncertainty and time discounting when calculating offset ratios for impacted habitat. *Restoration Ecology, 17*(4), 470-478. doi:10.1111/j.1526-100X.2008.00382.x

Moving from biodiversity offsets to a target-based approach for ecological compensation

Simmonds et al.

Supporting Information 3

Conservation planning and sustainable development considerations in target-based ecological compensation

Trading up to higher conservation imperatives

Target-based ecological compensation is well-aligned with other key conservation imperatives and broader sustainable development considerations. For example, in this target-based framework, 'trading up' may be an option in certain circumstances. Trading up, or 'out-of-kind' trading refers to the practice of compensating for the loss of one particular biodiversity feature (at the development site) by benefiting another type of (generally greater conservation value) biodiversity feature elsewhere (Bull, Milner-Gulland, Suttle, & Singh, 2014; Moilanen & Kotiaho, 2018; Quétier & Lavorel, 2011). Compensation for residual losses affecting biodiversity features that are above their target might be directed to other biodiversity features that are below their target. For example, Improvement actions to increase the amount and/or quality of the focal (below-target) biodiversity feature might be preferred over Maintenance actions focussed on the above-target feature. However, this would mean that the development-related losses of the impacted (above-target) biodiversity feature are not compensated, and so this type of 'trading up' would only be appropriate where these losses are carefully managed and strictly limited (e.g. by other regulatory instruments) to ensure that the 'above target' biodiversity feature does not decline below its target.

Landscape level planning

There is a need to move beyond what can be achieved by site-level planning for individual projects to consider development scenarios at a larger scale and assess the integrated opportunities for achieving better economic, social, and environmental outcomes (Kiesecker & Naugle, 2017). Landscape conservation plans designed to guide application of the mitigation hierarchy (Fitzsimons, Heiner, McKenney, Sochi, & Kiesecker, 2014; Kiesecker, Copeland, Pocewicz, & McKenney, 2010) and optimal habitat protection and restoration strategies (Possingham, Bode, & Klein, 2015) are needed to maintain critical levels of habitat amount and configurations and ensure viable conservation outcomes. The establishment of outcome-based biodiversity targets, and linking ecological compensation to the achievement of these targets, lends itself well to supporting broader, strategic development planning of this nature. Further, embedding mitigation decisions into strategic plans that also consider a range of future development scenarios (Evans & Kiesecker, 2014), can benefit governments, businesses and communities by supporting more informed development decisions. Planning at this larger scale also informs strategies for long-term landscape resilience, such as ensuring functional watersheds for clean drinking water (Evans & Kiesecker, 2014) and connected habitat for species (Monteith, Hayes, Kauffman, Copeland, & Sawyer, 2018) – strategic use of target-based ecological compensation, with its explicit and transparent approach to determining compensatory requirements, has the potential to make important contributions to such endeavours.

Impacts on people

It is also crucial to recognise that biodiversity has social value, and so losses and gains in biodiversity resulting from development (and associated efforts to address biodiversity losses through the mitigation hierarchy), will affect people too—both positively and negatively (Bull, Baker, Griffiths, Jones, & Milner-Gulland, 2018; Griffiths, Bull, Baker, & Milner-Gulland, 2019; Sonter et al., 2018). People's use and non-use values associated with biodiversity therefore need to be considered when (1) setting biodiversity conservation targets; and (2) designing and implementing ecological compensation to ensure they are equitable, socially acceptable and sustainable. Because the rationale behind the type and amount of ecological compensation required using the target-based approach can be readily explained and placed in the context of broader objectives (e.g. biodiversity conservation, ecosystem service provision), stakeholder understanding and engagement with the process may be improved by this framework. Considering people in the design of ecological compensation measures is necessary for moral reasons (e.g. human rights and ethical reasons), practical reasons (e.g. gaining a social licence to operate, or because of the need to ensure involvement of local people to enable compensatory actions to be delivered), and policy or regulatory requirements (BBOP, 2009; Bidaud et al., 2018; Bull et al., 2018; IFC, 2012).

References

Business and Biodiversity Offstes Progamme (BBOP). (2009). *Biodiversity Offset Design Handbook*. (BBOP, Washington D.C.).

Bidaud, C., Schreckenberg, K., & Jones, J. (2018). The local costs of biodiversity offsets: comparing standards, policy and practice. *Land Use Policy, 77*, 43-50. https://doi.org/10.1016/j.landusepol.2018.05.003

Bull, J. W., Milner-Gulland, E. J., Suttle, K. B., & Singh, N. J. (2014). Comparing biodiversity offset calculation methods with a case study in Uzbekistan. Biological Conservation, 178, 2-10. doi:https://doi.org/10.1016/j.biocon.2014.07.006

Bull, J. W., Baker, J., Griffiths, V. F., Jones, J. P. G., & Milner-Gulland, E. J. (2018). *Ensuring No Net Loss for people and biodiversity: good practice principles*. (Oxford, UK).

Evans, J. S., & Kiesecker, J. M. (2014). Shale gas, wind and water: assessing the potential cumulative impacts of energy development on ecosystem services within the Marcellus Play. *PLoS one, 9*(2), e89210. doi:10.1371/journal.pone.0089210

Fitzsimons, J., Heiner, M., McKenney, B., Sochi, K., & Kiesecker, J. (2014). Development by Design in Western Australia: overcoming offset obstacles. *Land, 3*, 167-187.

Griffiths, V. F., Bull, J. W., Baker, J., & Milner-Gulland, E. J. (2019). No net loss for people and biodiversity. *Conservation Biology, 33*(1), 76-87. doi:doi:10.1111/cobi.13184

International Finance Corporation (IFC). (2012). Performance Standards. Retrieved from: https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Policies-Standards/Performance-Standards

Kiesecker, J. M., Copeland, H., Pocewicz, A., & McKenney, B. (2010). Development by design: blending landscape-level planning with the mitigation hierarchy. *Frontiers in Ecology and the Environment, 8*(5), 261-266. doi:doi:10.1890/090005

Kiesecker, J., & Naugle, D. (2017). *Energy Sprawl Solutions: Balancing Global Development and Conservation* (Island Press).

Moilanen, A., & Kotiaho, J. S. (2018). Fifteen operationally important decisions in the planning of biodiversity offsets. Biological Conservation, 227, 112-120. doi:https://doi.org/10.1016/j.biocon.2018.09.002

Monteith, K. L., Hayes, M. M., Kauffman, M. J., Copeland, H. E., & Sawyer, H. (2018). Functional attributes of ungulate migration: landscape features facilitate movement and access to forage. *Ecological Applications, 28*(8), 2153-2164. doi:doi:10.1002/eap.1803

Possingham, H. P., Bode, M., & Klein, C. J. (2015). Optimal conservation outcomes require both restoration and protection. *PLoS Biology, 13*(1), e1002052. doi:10.1371/journal.pbio.1002052

Quétier, F., & Lavorel, S. (2011). Assessing ecological equivalence in biodiversity offset schemes: key issues and solutions. Biological Conservation, 144(12), 2991-2999. doi:10.1016/j.biocon.2011.09.002

Sonter, L. J., Gourevitch, J., Koh, I., Nicholson, C. C., Richardson, L. L., Schwartz, A. J., . . . Ricketts, T. H. (2018). Biodiversity offsets may miss opportunities to mitigate impacts on ecosystem services. *Frontiers in Ecology and the Environment, 16*(3), 143-148. doi:doi:10.1002/fee.1781