

Biodiversity offsets, their effectiveness, and their role in a Nature-Positive future

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Abstract

Biodiversity offsetting is a mechanism for addressing impacts of development projects on biodiversity, but the practice remains controversial and its effectiveness generally poor. In the context of the Global Biodiversity Framework and the emergence of new approaches for mitigating damage, an increasing need exists to learn from the lessons of the past. In this Review, we explore biodiversity offsetting, its effectiveness, and its future prospects, including in relation to calls for ‘nature positive’. Offsets often fall short of their stated goal: to achieve at least ‘no net loss’ of affected biodiversity. However, such failure is uniquely prominent as offsets have more explicit quantitative objectives than most other conservation approaches, the effectiveness of which is also variable. These clear objectives provide the potential for transparency lacking from alternative approaches to addressing negative human impacts on biodiversity. As promising alternatives are scarce, offsetting and offset-like mechanisms remain a necessary component of strategies to halt and reverse nature loss. However, improving their performance is essential. No quick and easy solution exists; instead, upholding best practice principles and rigorous implementation— including in the face of challenges from opposing narratives and interest groups — remains key.

39 [H1] Introduction

40

41 Biodiversity offsets[G] are used as a strategic tool to mitigate impacts on biodiversity in the
42 context of the mitigation hierarchy[G]¹ — a framework that determines the sequence of
43 approaches to be taken when mitigating environmental impacts. Under the mitigation
44 hierarchy, efforts should first be made to avoid impacts on biodiversity. If avoidance is not
45 possible, impacts should be minimised; next, any temporary impacts must be repaired and
46 the affected biodiversity restored on-site. Finally, if any impacts remain, offsets are used to
47 at least fully counterbalance them through equivalent gains elsewhere. As such, the full
48 application of the mitigation hierarchy should achieve at least ‘no net loss’ of biodiversity,
49 and preferably a net gain, for a given project. Offsets have become an appealing solution to
50 ‘unavoidable’ impacts on biodiversity, and have increasingly been embedded in impact
51 mitigation policy over the past two decades² (Box 1). However, despite increasing integration
52 into policy frameworks, the design and execution of offset policy — and offsets themselves
53 — often fall short of recommended good practice^{3,4}.

54

55 Offsets are no panacea. Biodiversity decline is driven by myriad factors over which humans
56 have varying degrees of leverage. However, at least for impacts directly and immediately
57 caused by project development — such as the removal of a forest for an industrial
58 development, or the dredging of sea floor for a shipping lane — biodiversity offsets promise
59 to at least counterbalance the damage done. By this standard, offsets often fail^{5,6}. Some of
60 these failures are because of limited policy scope: by design or otherwise, most impacts
61 proceed without any requirement for associated offsets (or impact assessment), even in
62 jurisdictions where offset policies exist. Second, where offsets are required, failures result
63 from policies specifying offset requirements that, even if implemented as intended, could not
64 be expected to counterbalance the losses. Finally, failures of implementation are
65 commonplace, involving promised offsets not proceeding or not achieving the outcomes
66 intended⁴. Collectively, these shortcomings contribute to the perspective that offsets are a
67 ‘license to trash’ and enable greenwashing, providing cover for damaging projects that might
68 otherwise be subject to greater scrutiny or even not proceed⁷. On the other hand, evidence
69 exists that the prospect of offsets sometimes leads to avoidance of impacts, and early stage
70 project cancellation⁸, and individual offsets have achieved important biodiversity
71 outcomes^{9,10}.

72

73 Beyond the controversy over offsets and their effectiveness, the context in which offsets
74 exist is evolving rapidly. First, over the past 10 years, the requirement for no net loss as the
75 outcome from offsetting has started to be superseded by ‘net gain’¹¹ and ‘net positive’¹².
76 Second, although typically applied to individual project-level impacts, the need to extend the
77 logic to addressing all impacts associated with economic activity, including throughout value
78 chains[G], is increasingly recognized^{13,14}. Now, a novel concept — ‘nature positive[G]’¹⁵⁻¹⁹ —
79 looks set to reshape how sectors that traditionally employed biodiversity offsetting and the
80 mitigation hierarchy engage with their impacts on nature^{14,20,21}. The role of offsets in this
81 context is uncertain and contested, and this juncture provides an opportunity to take stock of
82 the role and potential of offsets as a tool for better biodiversity outcomes, to identify barriers
83 to their effectiveness, and to identify how they must evolve if they are to be a useful part of
84 the transition ahead.

85

86 In this Review, we trace the evolution of biodiversity offsetting from its inception to present-
87 day practices, including the recent enthusiasm for net gain approaches in offsetting, broader
88 calls for nature positive, and the emergence of biodiversity credit[G] markets^{22,23}. We
89 summarise the reasons behind the widespread underperformance of offsets in achieving
90 their intended conservation goal of at least ‘no net loss’ of biodiversity^{6,24-26}, and explore
91 whether and why offsetting is peculiarly prone to failure relative to other conservation
92 approaches, such as protected area establishment and payments for ecosystems services²⁷⁻
93 ³⁰. Given the complex socio-political environment in which any conservation interventions

94 must operate³¹, we outline approaches that could help safeguard offset schemes against
95 failure^{28,32,33}. Looking ahead, we explore how biodiversity offsets interact with, and can
96 contribute to, a nature-positive future^{34,35}.

97

98 **[H1] Biodiversity offset policies and approaches**

99

100 The textbook case for biodiversity offsetting starts from acceptance that at least some
101 project development involving negative biodiversity impacts is necessary and desirable for
102 improving people's wellbeing. This approach recognises that, despite best efforts to avoid
103 and minimise impacts and restore affected biodiversity, some residual impacts might remain
104 (Figure 1). The only way for these residual impacts to proceed without further eroding
105 biodiversity is to ensure that they are at least fully counterbalanced with equivalent
106 biodiversity gains elsewhere — that is, achieve at least 'no net loss' of affected biodiversity.
107 Achieving these gains could be done by, for example, restoring a degraded site or protecting
108 a site from threats. Equivalence requires not only that the benefits from these actions accrue
109 to the same species, ecosystems, or other biodiversity components negatively impacted by
110 the proposed development, but that the benefits are at least as large as these impacts and
111 persist for the same duration (often, in perpetuity). This section outlines how biodiversity
112 gains are delivered on-the-ground through various mechanisms, and how the definition of
113 success varies depending on important differences between relative net outcome [G] and
114 absolute net outcome [G] goals of offsetting. Finally, it outlines the range of approaches to
115 governance and implementation of offsets.

116

117 *[H2] Biodiversity offsetting practices*

118 In practice, offsets rely on implementing conservation or restoration interventions, in targeted
119 locations, to generate the measurable gains they aim to deliver for biodiversity. The types of
120 interventions broadly aim either to prevent declines of biodiversity that would otherwise have
121 occurred — 'averted loss' or 'avoided loss' offsets — or to improve species populations or
122 other components of biodiversity over time — 'improvement offsets' or 'restoration offsets'³⁶.
123 Some offsets combine interventions that aim to achieve both avoided loss and improvement
124 gains.

125

126 Averted loss offsets involve mechanisms to decrease ongoing pressures or threats to
127 biodiversity, through legal protection (for example, establishing a protected area) or working
128 with local people, governments and businesses to stop or change harmful land-use or
129 natural resource extraction practices (for example, reducing deforestation, hunting pressure,
130 or harvesting of wild plants). These mechanisms often require alternative livelihood schemes
131 or compensation payments, alongside conservation agreements or public-private-community
132 partnerships³⁷. Effective enforcement of such agreements or partnerships is necessary for
133 success. The role of government in such arrangements is highly variable, depending on local
134 land tenure regimes (for example, whether a developer can buy and privately own land for its
135 offset needs) and governance of natural resource use (for example hunting or fishing rights).
136 Because offsetting requires changes in human behaviours, social and economic impacts for
137 affected peoples need to be carefully considered and addressed³⁸.

138

139 Restoration interventions are those which are focussed on proactive repair and improvement
140 of degraded ecosystems by removing barriers to natural processes (for example, by
141 removing dams, dykes or drains to restore rivers or former wetlands) and enabling native
142 vegetation to re-establish itself (through top-soil stabilisation, afforestation and planting, or
143 assisted natural regeneration), or even recreating whole habitats (such as breeding ponds
144 for amphibians). Restoration offsets can often require invasive species to be actively
145 removed or managed.

146

147 Importantly, effective offsets address the appropriate processes or limiting factors that
148 enable the targeted biodiversity to respond. Offset interventions must therefore be designed
149 and implemented according to the species, habitat and/or ecological processes they target,
150 and the baseline conditions at the offset site. As such, considerable information is often
151 required to design an appropriate offset and, in many cases, that information is not
152 available³⁹. Such knowledge gaps concerning effective conservation or restoration
153 approaches — especially when working with already rare and highly threatened species or
154 habitats — are a strong indication that offsets are not an appropriate response to potential
155 impacts on those biodiversity features, and that avoidance is necessary. Offsets are simply
156 not always feasible.

157
158 The fundamental requirement of an offset is that it generates a measurable benefit, or gain,
159 for the affected biodiversity on-the-ground. As such, although actions such as research or
160 monitoring might be necessary to enable or evaluate the performance of an offset, these
161 actions alone do not constitute an offset according to best practice⁴⁰. Further, the
162 reintroduction of locally extinct species and the restocking or genetic rescue of severely
163 depleted populations may be appropriate as an offset, but captive breeding alone would not
164 qualify.

165
166 Finally, for losses and gains to be equivalent, the gains must endure for at least as long as
167 the loss. As most losses are permanent, offset sites tend to require some form of in-
168 perpetuity protection (and often, ongoing funding) if they are genuinely to achieve at least no
169 net loss^{41,42}. Although various mechanisms for achieving these outcomes exist (such as
170 protected area designations, easements, on-title conservation agreements and trust funds),
171 these are not always put in place. In principle, however, securing offset sites in the long-term
172 can mean they are suitable as Other Effective Area-Based Conservation Measures
173 (OECMs) and, therefore, could contribute towards achieving international targets for
174 protected and conserved area coverage^{43,44}, although using offsets to achieve such targets
175 can introduce perversities^{44,45}.

176

177 *[H2] Relative versus absolute net outcomes*

178 Although the goal of at least no net loss appears straightforward, in practice its meaning can
179 vary substantially depending upon the frame of reference^{46,47} (Figure 2). Offsets have
180 typically required no net loss, or net gain, to be achieved relative to the outcome if neither
181 the impact nor the offset had occurred. Owing to widespread, ongoing biodiversity loss, this
182 'counterfactual scenario' is generally presumed to be one of biodiversity decline (Figure 2a).
183 This assumed decline enables 'averted loss' benefits to be generated through the prevention
184 of damage to biodiversity that already exists⁴⁸. As such, a successful offset exchange that
185 achieves 'no net loss' across impact and offset sites can result in less biodiversity after the
186 impact than before — if the loss in biodiversity is equal to or less than the decline that would
187 have occurred regardless⁴⁷.

188

189 The use of counterfactual scenarios poses many challenges to the practice of offsetting^{25,49}.
190 For example, the benefit at an offset site (which must be sufficient to at least counterbalance
191 the loss at an impact site) is calculated as the difference in biodiversity outcomes between
192 two scenarios: the scenario in which the offset action occurs, and the counterfactual
193 scenario in which the offset action does not occur⁵⁰. Estimating this benefit therefore involves
194 an assumption about a non-observable, hypothetical trajectory of biodiversity⁵¹. Ideally, this
195 assumption ought to be drawn from the recent trajectory of biodiversity at comparable sites,
196 adjusted for any site-specific constraints⁵²; however, counterfactual scenarios are often not
197 established appropriately⁵³. To further complicate matters, estimating a counterfactual
198 scenario requires consideration of effects beyond the offset site itself. For example, if the
199 habitat at a potential offset site had a 50% chance of being destroyed if not protected as an

200 offset, then the additional benefit of protection might be 50% of the value of the site.
201 However, if the hypothetical destruction of that site would itself have been required to be
202 offset, the net benefit would be zero^{47,52}. Clearly, an incentive exists to overstate both the
203 counterfactual decline at a potential offset site and the risk to the site, as doing so would
204 increase the estimated benefit from that offset and thereby reduce the size of an offset
205 obligation⁵⁴.

206
207 Offset approaches that aim for relative no net loss or relative net gain can be valid, although
208 challenging to design and manage. These approaches aim only to neutralise the impact
209 attributable to the project, without regard to any wider goals or targets for biodiversity
210 conservation. Net outcomes from such offsets, across impact and offset sites, can therefore
211 be misaligned with broader policy goals such as 'nature positive' approaches, in which
212 biodiversity must be improved in absolute terms over time⁵⁵. To address this misalignment,
213 alternative approaches to counterfactual-based offsetting exist. For example, offsets can
214 require 'absolute' net outcomes relative to fixed baselines (Figure 2b) rather than dynamic
215 counterfactual scenarios. Target-based ecological compensation is an approach that aligns
216 offset outcomes with the absolute outcomes desired for the wider landscape⁵⁵. This
217 approach is less commonly-used, although offset policies in South Africa, England and
218 Australia's Northern Territory, for example, require absolute outcomes across impact and
219 offset sites^{23,56}, with the latter two requiring absolute net gain. The key difference between
220 relative and absolute net gain policies is that the latter cannot generate gains from averting
221 losses, only from re-creating biodiversity or improving its condition at the offset sites.

222
223

224 *[H2] Biodiversity offset governance and implementation*

225 Offsets require that the costs of compensation fall upon those responsible for the damage,
226 consistent with the 'polluter pays' principle^{57,58}. Offsets also incentivise the avoidance and
227 minimisation of impacts on biodiversity by internalising the cost of the compensation⁸ and, in
228 theory, setting limits on impacts based on what is considered 'offsettable'^{55,59}. The concept of
229 offsetting is well-established in the context of pollutants (such as greenhouse gas emissions)
230 and has been extended to include no net harm to people affected by the development and
231 accompanying offset^{37,38,60,61}.

232
233 Biodiversity offset systems have a variety of forms⁶². Some jurisdictions have no
234 government-mandated offset requirements, but offsetting might still occur voluntarily or
235 under requirements set by financiers of developments^{28,62,63}. However, at least 37 countries
236 have laws that require or enable offsets for some types of biodiversity impacts, and over 100
237 have provisions of some form for offsetting².

238
239 Offsets are generally delivered through three broad pathways (Figure 3): developer-led, in
240 which the developer directly provides an offset through activities on its own land or through
241 individually negotiated contractual arrangements with a third party; market-based, in which
242 (ideally) pre-certified units of biodiversity gain are able to be purchased by a developer
243 (sometimes multiple credits from single sites) to acquit their offset obligation; and through in-
244 lieu fees, in which developers pay a required amount into a trust fund, to which the obligation
245 to procure the required biodiversity gains is transferred. Many systems involve a mix of these
246 approaches or hybrids among them, and the involvement from private sector brokers and
247 states as a buyer or seller varies (Figure 3)⁶². In the case of government-mandated offsets,
248 the general role of the state is to mandate that certain biodiversity impacts must be
249 compensated, enabling willing land managers to sell biodiversity gains to buyers who cause
250 (or have assumed responsibility for) residual biodiversity loss. The state also sets relevant
251 exchange rules by which trades must abide (such as equivalence requirements)⁶⁴ and
252 regulates the trades, often through a statutory body such as a government department.

253 Ideally, the state also ensures adequate monitoring and compliance, and transparent
254 reporting on net outcomes for biodiversity.

255

256 **[H1] Effectiveness of biodiversity offsetting**

257

258 Over the past two decades, biodiversity offsets have become a contentious part of
259 conservation policy. Offsets can be contested on a range of grounds: those subject to offset
260 requirements might see obligations as too onerous or inefficient; others see offsets as
261 ethically dubious, reducing nature to a commodity to be traded⁶⁵. These perspectives each
262 require a focussed discussion, which is outside the scope of this Review. Rather, this section
263 considers a third major category of critique: the extent to which offsets are effective in
264 achieving their stated goal of (at least) no net loss of biodiversity. Myriad factors can limit
265 offset effectiveness³ (Table S1, Supplementary Information), although changes and
266 safeguards to address these limitations are possible.

267

268 The consistent underperformance of biodiversity offsets against their stated objectives can
269 be due to poor policy design (that is, even when implemented perfectly in line with policy the
270 offsets would not achieve required net outcomes for biodiversity⁴⁷), and compliance or
271 implementation failures. Often, both shortcomings are present, and most associated issues
272 (Table 1) can emerge at either design or implementation stage.

273

274 This section considers the effectiveness of biodiversity offsetting in terms of a) the extent to
275 which offsets generate gains at the site level; b) the extent to which offset trades achieve
276 their stated goal of at least 'no net loss' across the impact and offset sites (the exchange
277 level); and c) the potential broader net effect on biodiversity of the inclusion of offsets in the
278 policy mix (the system level).

279

280 *[H2] Site-level outcomes*

281 Most assessments of ecological outcomes of biodiversity offsets at the site level have
282 concluded that the evidence available to evaluate offset performance is very limited^{5,6,28,66-71}.
283 As a result, offset outcomes have rarely been evaluated relative to a robust counterfactual
284 scenario to explore whether the biodiversity gains delivered by the offset would not have
285 been delivered in the absence of the offset. Centralized offset registers or databases are
286 crucial to enable effective tracking, management, and transparency of offsetting activities,
287 ensuring accountability and facilitating informed decision-making by regulators,
288 stakeholders, and the public⁷². For example, RIBITS (Regulatory In-Lieu Fee and Bank
289 Information Tracking System) has a pivotal role in monitoring and managing mitigation
290 banking activities across the United States, providing valuable centralized data for regulatory
291 compliance. However, RIBITS' effectiveness is hindered by issues such as inconsistent data
292 quality, complex and differing regulatory requirements, and missing files or reports, which
293 collectively contribute to a reduction in transparency and accessibility of this otherwise
294 instrumental system^{70,73}.

295

296 Where robust evaluations of offset performance have been conducted, 'avoided loss' offsets
297 (the majority of the offset system) have been found to deliver no or little additional
298 biodiversity gain in New South Wales²⁵ and Victoria²⁶ (Australia), respectively, although
299 offsets targeting increases in vegetation cover starting with low baselines did deliver
300 additional increases. Additionally, the majority of wetland area gains in the US wetland
301 mitigation banking system were found to have been unlikely to occur in the absence of
302 offsetting⁶⁸, but the ecological quality of those compensatory wetlands could not be
303 assessed. In some cases, offsets may even be harmful; some species conservation banks
304 (used for compensation of impacts on threatened species) in California were concluded to
305 potentially have prevented improvements that would likely have occurred in their absence⁷⁴.

306

307 *[H2] Exchange-level net outcomes*

308 Even when outcomes at an offset site can be evaluated, assessing the net outcomes
309 associated with the offset exchange might not be possible. This discrepancy can occur
310 because, even if outcomes at offset sites are discoverable, the impacts being offset are not
311 known or linked to the offset site, or differing methodologies or metrics are used for
312 assessing impacts and offsets²⁶. Such traceability challenges mean that few examples exist
313 of comprehensive evaluations of net outcomes. One of the most comprehensive recent
314 evaluations showed that a large mine in Madagascar was on track to deliver no net loss of
315 forest through its offsets⁹. This was achieved through 'averted loss' offsets and was only
316 possible because the background rates of deforestation in the region were very high, so the
317 net loss of forest over time was similar to what was expected in the absence of the mine's
318 activities. Net outcomes for the numerous and often endemic species of animals and plants
319 that were targeted by the mine's biodiversity action plan could not be evaluated. Similarly,
320 the ecological equivalence of wetland losses and gains in the US could not be assessed, but
321 the area of wetlands established fell short of those lost by on average 1600 acres per year⁶⁸.

322

323

324 *[H2] System-level outcomes*

325 Beyond the direct effects of offsets, it has been suggested that their presence in the policy
326 mix can undermine impact avoidance. Broadly, two strands of empirical evidence support
327 this 'licence to trash' argument. The first suggests that offsetting has quickly become the
328 norm over impact avoidance in several systems where it has been applied (for example,
329 Australia and North America^{24,75}). The second has demonstrated that introducing the option
330 of offsetting into the impact mitigation process increases the scope for negotiation between
331 project proponents and planners⁷⁶, suggesting that some projects which would previously
332 have been rejected outright might instead be considered favourably in the planning system.
333 On the other hand, the prospect of offsets likely incentivises early impact avoidance that
334 might never be detected or attributed, as it occurs prior to a formal project proposal or
335 through informal discussions during the environmental impact assessment (EIA) process⁷⁶.
336 Allowing project proponents to try a variety of project plans in a software that allowed them
337 to calculate their offsetting liability associated with different spatial configurations of
338 development was shown to result in final submitted plans associated with substantially lower
339 biodiversity impacts than their initial spatial configuration⁸. Additionally, two studies which
340 tested for changes in deforestation rates or development approvals coinciding with the
341 introduction of offset policies (in New South Wales, and Florida) found no association
342 between the introduction of offsetting policies and rates of ecological harm^{25,77}

343

344

345 **[H1] The relative performance of offsets in the policy mix**

346

347 Given the widely recognised challenges to offset success (Table 1) and frequently reported
348 failures to achieve their objective, it is tempting to conclude that perhaps offsets are not
349 worth persisting with. However, before reaching such a conclusion, it is worth exploring if
350 offsets are any more peculiarly prone to failure than other types of conservation mechanisms
351 — and if so, the potential reasons for this discrepancy.

352

353 *[H2] Relative susceptibility of offsets to failure*

354 Offsets often fail to achieve their goal of at least fully counterbalancing damaging impacts on
355 components of biodiversity. However, the (appropriately) strict definition of success for

356 offsetting is unusually clear and measurable — the requirement is to achieve ‘at least no net
357 loss’, and any outcome that falls short of is, by definition, inadequate⁷⁸. Other categories of
358 conservation mechanism, such as protected area establishment or payment for ecosystem
359 services (PES) schemes, often have less explicit or more complex criteria for ‘success’⁷⁸,
360 and rarely state a fixed quantitative requirement for additional biodiversity gain. It could
361 therefore be that offsets are similar to other interventions in terms of their typical
362 impact/effect, but that their clear success/failure criterion means they are more easily
363 judged^{70,73}.

364
365 The lack of quantification of additional benefit from conservation interventions other than
366 offsets is starting to be addressed. Overall, robust counterfactual-based evaluation reveals
367 that most conservation interventions of many types have modest and context-specific
368 impacts⁷⁹⁻⁸², and all fail at least some of the time. In a recent meta-analysis, conservation
369 actions were found to improve biodiversity outcomes relative to a counterfactual scenario in
370 about two-thirds of cases⁸¹; however, no evidence of effectiveness was found for one-third of
371 interventions and effect size for the remainder varied depending on factors such as the
372 degree of targeting for each action⁸¹. For example, although overall positive effects on forest
373 cover and deforestation reduction have been observed for PES schemes⁸³, the effects were
374 heterogeneous, some robust evaluations found no effect on forest cover⁸⁴, and selection
375 bias frustrated the quality of evidence. Overall evidence for the effectiveness and cost-
376 effectiveness of PES in achieving environmental gains remains poor⁸³⁻⁸⁶.

377
378 Most robust evaluations of the effectiveness of protected areas have focussed on the extent
379 to which deforestation is reduced by protected area establishment. In general, protected
380 areas are found to reduce deforestation by a modest amount; for example, protected areas
381 were estimated to have prevented deforestation across 10% of their extent over 37 years in
382 Costa Rica⁸⁷, and 10.5% of their extent in Queensland over 30 years⁸⁸. Effective
383 management of wildlife populations is another key objective of protected area establishment.
384 Globally, protected areas have been found to result in improvements in about one-quarter of
385 waterbird populations⁸⁹, but declines occurred in a similar fraction of populations. Effective
386 stakeholder engagement has been identified as the most important factor associated with
387 successful outcomes from protected areas⁹⁰.

388
389 Carbon offset credits through forest protection (REDD+) are one of the few intervention
390 types that have a similar quantitative success criterion to biodiversity offsets: these
391 interventions must avoid an amount of deforestation and forest degradation which, if it
392 occurred, would result in at least the amount of emissions that any credits sold claim to
393 represent. However, independent evaluations suggest that shortfalls of 75% or more are
394 common^{91,92}. Comparisons of the conservation effectiveness of carbon offsets with that of
395 publicly-funded conservation⁹³, as well as other comparisons between conservation on
396 private versus publicly-managed land⁹⁴, have shown a high degree of context specificity. In
397 general, forest protection for carbon offsets achieves similar ecological outcomes to
398 protected areas⁹³, but other land management such as indigenous stewardship might
399 outperform either public or private ownership^{94,95}.

400
401 Even though offsets (both carbon and biodiversity) might not be unusual in having limited
402 effectiveness, certain features do set them apart from other common conservation
403 approaches. One important distinction is that offsets are intended to deliver a specified
404 amount of benefit that is used to compensate for that same amount of damage⁷⁸. Any
405 shortfall therefore represents not just an opportunity cost, as is the case for a PES scheme
406 or a new protected area that did not achieve the hoped-for biodiversity benefit, but a
407 realised, on-the-ground loss of biodiversity that might not have been permitted to occur had
408 the inadequacy of the offset been known. In combination with the bias towards conservation
409 typically occurring in locations where additionality is low⁹⁶, this potential for negative net
410 outcomes increases the prominence of any shortfall in performance.

411

412 *[H2] Slow progress in offset policy and practice*

413 Perhaps a greater concern than the poor performance of offsets to date might be the lack of
414 evidence of their continuous improvement over time. Although a range of concerns afflict
415 offset policy and practice (Table 1), the solutions to these often appear straightforward, and
416 many can be addressed through policy reform. In general, however, relatively little
417 improvement over time has been observed (Table1).

418

419 Some evidence exists that offsetting systems have learnt from decades of policy trial and
420 error. For example, the 2008 compensatory mitigation rule in US wetland mitigation systems
421 marked an important change from previous approaches, as it made all types of offset
422 providers subject to the same standards and created a level playing field between mitigation
423 types (previously, mitigating banking had been subject to higher standards than developer-
424 led mitigation)⁹⁷⁻¹⁰⁰. In France, international experiences were instrumental in improving
425 decades-old legislation by introducing a no-net-loss requirement, rules for equivalence, a
426 public register of offsets, and the option to use government-certified 'offset banks'¹⁰¹. In
427 England's new biodiversity offsetting system, policymakers learned from established failings
428 of Australian 'avoided loss'-based offsetting systems to create a system based on a static
429 baseline (Figure 1b)²³.

430

431 However, this progress has not been universal. Many cases of backsliding exist, such as the
432 downgrading of Victoria's (Australia) aim of biodiversity net gain to no net loss, and
433 consistent governance failures or under-resourcing of offset systems around the world
434 leading to systemic compliance failure remain^{4,102,103}. If the only constraint on success of
435 biodiversity offsetting policies was insufficient knowledge manifesting in poor policy design,
436 the performance of offsetting systems would be expected to increase over time to a greater
437 extent than observed. A proposed explanation¹⁰⁴ for this lack of improvement is that, when
438 an effective offsetting policy in which the true biodiversity costs of development are fully
439 internalised is proposed, potentially impacted sectors organise politically to counter such
440 change. These potential conflicts between conservation and other interests influence the
441 design and implementation of offset systems.

442

443 Developers are often heavily involved in offset policy design as one of the key interest
444 groups engaged in consultation¹⁰³, and are therefore able to influence the direction of policy
445 and its implementation. Important motivations for developers include reducing resistance to
446 new development and simplifying the planning system¹⁰², which are often at odds with the
447 needs of a robust offset system. Offset procurers also have a vested interest in offsets not
448 being costly; however, monitoring and enforcement costs comprise a substantial proportion
449 of the overall costs of offsetting, and are necessary to ensure the promised environmental
450 outcomes are truly being delivered.

451

452 Ultimately, the combination of these political economy issues with the evidence of low
453 effectiveness of biodiversity offsetting policies means that offsetting cannot be relied upon as
454 the sole, or even the main, solution for navigating trade-offs between economic expansion
455 and the conservation or recovery of biodiversity. Even were the challenges outlined in Table
456 1 to be addressed, in many jurisdictions, there would simply be insufficient land to fully offset
457 future infrastructure development plans¹⁰⁵. Avoidance of biodiversity impacts therefore
458 remains the most critical component of the solution^{49,106}, and whether offsetting policies
459 incentivise or hinder this (by legitimising development) in the long-term remains unclear.

460

461 **[H1] Offsets in the context of nature positive**

462

463 After decades of increase in the prevalence of biodiversity offsets, their future now appears
464 to be at a crossroads. An increasingly negative view of offsets is starting to lead to rejection
465 of their validity, but also to increasing focus on related but distinct emerging concepts,
466 terminologies, and frameworks. Notable among such concepts is nature positive — an
467 outcome-based societal goal to “halt and reverse nature loss by 2030 on a 2020 baseline,
468 and achieve full recovery by 2050”¹⁰⁷. The vision of nature positive, consistent with that of
469 the Kunming-Montreal Global Biodiversity Framework (GBF) adopted in 2022, is that decline
470 of nature will be not just slowed but reversed, so that more nature will exist in the future than
471 today. The concept has been embraced not only by civil society organisations, but also by
472 government and business, and pledges to contribute to nature positive are mounting^{35,108}.

473
474 Offsets in some form appear to have an essential role in a nature positive future, as a need
475 remains to address legitimate residual biodiversity losses after rigorous application of the
476 mitigation hierarchy (Fig. 1). Indeed, offsets could also have a proportionally larger role if
477 used to expand the scope of losses being mitigated (for example, along corporate value
478 chains¹⁴) and/or if they make meaningful contributions to biodiversity outcomes beyond no
479 net loss¹⁰⁹. Target 19 of the GBF¹¹⁰ and other reports cite offsets as a source of funding to
480 support biodiversity recovery and a potential substantial contributor towards the current
481 biodiversity funding gap¹¹¹. However, the extent to which offsets will actually contribute to
482 halting and reversing global biodiversity loss is unclear. A new wave of guidance,
483 terminology and actors could instead result in the replacement of offsets by alternative
484 actions that appear similar to offsets, but in reality enable an exemption from the strict
485 outcome requirements and well-established standards expected of (if not achieved by)
486 offsets³⁵ (Table 1).

487
488 A spectrum of guidance on the role and use of biodiversity offsets is emerging to support
489 private sector alignment with nature positive, in the form of biodiversity-related performance
490 standards and risk disclosure frameworks. This guidance ranges from a complete exclusion
491 of offsets from acceptable ‘nature positive-aligned’ actions¹¹², to agnosticism about whether
492 and when offsets are acceptable¹¹³, to clear guidance on how to successfully implement
493 offsets¹¹⁴. A particular area of interest is the expansion of compensation beyond direct, site-
494 level footprints to the biodiversity impacts of a business’s value chain. However, a major
495 challenge is that current life-cycle assessment methods used to determine business value
496 chain impacts tend to produce aspatial outputs or outputs with very coarse spatial resolution,
497 in biodiversity units that cannot currently be practically translated into the project-scale
498 biodiversity gain measures required for site-scale offset¹¹⁵. Ongoing research is exploring
499 how to establish equivalence for diffuse value chain offsets¹¹⁶.

500
501 Perhaps the area of greatest ambiguity relates to the rapidly growing interest in the potential
502 for biodiversity credits (or “certificates”)¹¹⁷ to finance conservation and the improvement of
503 biodiversity¹¹⁸. The hope is that industry commitments to nature positive will drive the
504 emergence of voluntary markets in biodiversity, in which business will seek to purchase
505 biodiversity credits to demonstrate improvements in environmental performance, particularly
506 if they must also disclose environmental damage. However, despite obvious parallels, some
507 proponents of biodiversity credits have sought to distance them from offsets¹¹⁹⁻¹²¹. Some
508 guidance explicitly states that use of biodiversity credits does not constitute offsetting¹²²,
509 although some still use the language of ‘net’ outcomes (implying a balancing of losses and
510 gains)¹²³. Others state that purchased credits should not replace compliance-based offsets,
511 but that credits could potentially be used for compliance offsetting depending on local
512 jurisdictional requirements^{124,125}.

513
514 Suggestions have been made that the lowest-risk use of credits is to mitigate biodiversity
515 losses along value chains when the type and amount of losses are unknown or
516 unknowable^{35,126}. Such a use could not strictly be considered offsetting, as the net outcome
517 could never be known. Regardless, most demand for biodiversity credits will likely be driven

518 by some form of counterbalancing of negative environmental impacts, whether or not this
519 counterbalancing is referred to as offsetting. However, this conceptual ambiguity carries the
520 risk that true offsets (that deliver biodiversity gains equivalent in type, amount, and duration
521 to impacts) will be quickly replaced by other conservation actions that might deliver some
522 gains but are unlikely to deliver the correct amount or kind, and without the traceability
523 essential to support biodiversity outcome claims, such as no net loss, net gain and Nature
524 Positive outcomes³⁵.

525
526 Contrasting trends are visible: on the one hand, increasing discomfort around offsets and
527 their negative associations; and on the other, increasing interest in offset-like actions and
528 terminology proposed as a solution to nature decline. In part, this disconnect might be
529 consistent with the increasingly diverse backgrounds of those involved in bridging the worlds
530 of biodiversity and business, many of whom have backgrounds not in ecology and
531 conservation science, but rather in business administration, economics or political science²⁶.
532 Others bring experience from the carbon markets, which face many of the same challenges
533 as biodiversity markets, although biodiversity markets pose substantial new complexities.
534 This growing diversity of actors engaging with the challenge of nature recovery is positive,
535 but also carries risks. Loss and dilution of institutional memory can lead to over-simplification
536 of the complexities and wickedness of 'nature positive' goals, and institutional amnesia¹²⁷.
537 Learning from the lessons of the past is crucial.

538

539 *[H2] The future of offsets*

540 The future of offsets in the context of nature positive and other shifts is uncertain. Alternative
541 futures for offsets and biodiversity exist (Box 2), and decisions by business, governments,
542 and civil society will help determine which future emerges.

543

544 In a positive scenario, the persistent problems with offsets (Table 1, Table S1) are
545 addressed, and newly emerging risks associated with dilution of offsets by cynical
546 interpretation of nature positive goals and biodiversity credits are forestalled through strong
547 integrity requirements and guardrails^{35,128}. The increased engagement of a wide range of
548 sectors in the nature conservation discourse, coupled with genuine attempts to learn from
549 the mistakes of the past, could prove a welcome first step towards reforming the role of
550 offsets in achieving the genuine transformative change called for under the GBF. At worst,
551 the pursuit of nature positive could become a flash in the pan, undermined by greenwashing,
552 and could set back progress and decades of lessons learned on high-integrity
553 implementation of the mitigation hierarchy and offsets.

554

555 **[H1] Summary and future directions**

556

557 Biodiversity offsets in practice suffer from many of the same flaws and challenges as other
558 conservation interventions. Most of these flaws can, in theory, be largely addressed.
559 However, some intrinsic factors make improving offset practice particularly difficult. A
560 fundamental tension exists between instituting necessary controls on integrity and respecting
561 limits to the use of offsetting as a response to environment–development conflict, and the
562 reality of the political influence of those with an interest in facilitating development projects
563 with minimal impediments⁴¹. In this context, the recent raft of frameworks seeking to
564 mainstream consideration of nature conservation through mechanisms such as biodiversity
565 credits should be viewed with caution as well as optimism.

566

567 Research can support refinements to current practice in several ways. Understanding the
568 limits to what can be offset is increasingly important – certain species, ecosystems and
569 places are fundamentally irreplaceable and shouldn't be impacted. The need for further
570 development of methods to evaluate and attribute impacts on biodiversity through entire

571 value chains is increasingly recognised¹²⁹. Similarly, better understanding is required of
572 which products, activities, and value chains can be substituted to enable avoidance of
573 biodiversity loss, particularly where such losses cannot be addressed through offsets.
574 However in most cases, most of the solutions to the challenge of poor offset performance
575 are well known, and the required actions have been identified for more than a decade (Table
576 S1). The fundamental problems that prevent continuing improvement in biodiversity
577 offsetting are generally not those that technically focussed research can address. Instead,
578 the problems stem from resistance to genuine reform owing to conflicting motivations and
579 values, and associated power dynamics^{104,130}.

580
581 In light of these fundamental and continuing challenges to improved outcomes from offsets,
582 the most basic and necessary change requires widespread improvements in environmental
583 regulation — simply preventing further conversion of natural systems, especially those of
584 high environmental value^{21,131,132}. However, any such changes face fierce — and usually
585 effective — resistance from the same actors that frustrate improvements in offset policy.
586 Furthermore, legitimate and desirable human development needs, and even associated
587 environmental goals (such as the shift to renewable energy), will be almost impossible to
588 meet without causing at least some damage to biodiversity. Eliminating offsets as a
589 response to these residual impacts risks shifting the responsibility for addressing this
590 damage away from the proponents to broader society, violating the polluter-pays principle.
591 Simple taxes on environmental damage might enable more 'efficient' investment in
592 environmental benefits than insisting on like-for-like replacement of losses, as well as
593 disincentive impacts. However, if set high enough to disincentivise damage, these taxes
594 would likely also be strongly opposed¹³³. A risk also exists that such approaches would
595 become an avenue for the loss of ecologically irreplaceable ecosystems and habitat in
596 exchange for those that are easily-replaceable³⁵ — or worse, simply replace existing
597 environmental expenditures⁵⁴. In short, none of these alternatives is a promising
598 replacement for biodiversity offsetting.

599
600 Despite inherent flaws, the mitigation hierarchy, with offsetting fixed firmly in its appropriate
601 place, remains key to navigating the complex landscape of environmental challenges. The
602 transparent, quantitative outcome requirements and well-established guidelines set the
603 mitigation hierarchy and biodiversity offsetting apart from other conservation approaches. No
604 obvious alternative can replace offsets without introducing uncertainty about outcomes and
605 accountability that enables greenwashing. However, acknowledging the continued role of
606 offsetting does not imply passive acceptance of the serious flaws in how offsets are currently
607 employed; instead, it underscores the need for continued efforts to improve offset policy and
608 practice²¹. Our focus should shift toward strategies that reduce reliance on offsets, and that
609 use properly designed and fully costed offsets as the disincentive they ought to be.

610
611 Despite the mounting evidence of poor performance of offsets and the systemic pressures
612 and interests that impede their improvement over time, plausible and appealing alternatives
613 are few. Furthermore, despite several emerging frameworks for mainstreaming nature that
614 explicitly or implicitly reject offsets, most of these frameworks nevertheless rely on offsets to
615 succeed. Therefore, the unceasing task of improving rigor and integrity in offset policies and
616 markets remains critical to achieving anything close to a nature positive future.

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620

621 **Reference list**

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Acknowledgements

1000 We thank Malcolm Starkey from The Biodiversity Consultancy for feedback on sections of
1001 this manuscript. S.O.S.E.z.E. is funded by Horizon 2020 project SUPERB (Systemic
1002 solutions for upscaling of urgent ecosystem restoration for forest-related biodiversity and
1003 ecosystem services; Ref.: GA-101036849)

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Author contributions

1006 All authors researched data for the article, made a substantial contribution to discussion of
1007 content, wrote the article and reviewed and/or edited the manuscript before submission.

1008

Competing interests

1009 M.M., F.Q., S.O.S.E.z.E., L.J.S. and A.v.H. have advised government, nongovernment
1010 organizations and industry bodies on nature positive and the mitigation hierarchy, and are
1011

1012 members of the IUCN's Impact Mitigation and Ecological Compensation Thematic Group,
 1013 under the Commission on Ecosystem Management. Rewilding Europe (F.Q.) has a
 1014 commercial arm that invests in ecosystem restoration projects in Europe.

1015

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1017 **Peer review information**

1018 Nature Reviews Biodiversity thanks XXX for their contribution to the peer review of this work.

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1021 **Display items:**

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1023 *Tables*

1024

1025 **Table 1.** Common criticisms and challenges to biodiversity offsetting, categorised based on
 1026 Maron, et al. ³, and suggested responses that could help address each criticism. For more
 1027 detail on each of these points, with supporting citations, see Table S1, Supplementary
 1028 Information.

1029

Category	Key issues	Recommendations
Philosophical/ ethical: appropriate consideration of the intrinsic value and fungibility of nature	Offsetting is criticized for failing to respect nature's intrinsic values. Offsets may make harming nature more acceptable by reframing it as fungible.	Acknowledge the ethical concerns, improve public engagement, and limit offsets to a last resort Advocate for avoidance of harm and set strict rules for limits to impacts and transparency
Social: ensuring offsets adequately address impacts on what people value	The frame of reference for 'no net loss' is often unclear (Fig. 2). Narrow focus on specific species or ecosystems can neglect other important biodiversity components. Contributions of nature to people are often overlooked. Offsets can negatively affect local communities and indigenous peoples.	Establish explicit frame of reference that aligns with jurisdictional biodiversity goals Include broad biodiversity components and stakeholder input on which biodiversity components to target Ensure offsets are located and targeted to benefit affected communities Implement robust stakeholder engagement and ensure fair distribution of costs and benefits
Technical: ensuring offsets are designed appropriately to achieve their stated outcome goals, with minimal perverse outcomes	Offsets can become a default over avoidance, which is not always recorded. Offsets for some impacts not ecologically justifiable. Metrics might not fully capture biodiversity changes. Counterfactual scenarios can exaggerate outcomes; offsets might simply displace damage elsewhere. Current multipliers might be too small to account for	Require detailed alternative analyses and transparent justification for using offsets. Define clear limits to what can be offset and ensure accountability for violations. Use a range of metrics linked to global biodiversity goals and multiple components of biodiversity. Justify counterfactual scenarios and limit averted loss offsets. Integrate leakage considerations into policies and size offsets accordingly.

	<p>uncertainties and time lags. Arbitrary discounting and accounting methods misrepresent biodiversity gains. Limited provision exists for enduring maintenance of gains.</p>	<p>Increase multipliers and use verified gains to manage uncertainty. Ensure transparency and appropriate accounting methods. Ensure arrangements for enduring/in perpetuity protection and, where required, funding.</p>
<p>Governance: strong controls around implementation and transparency and the maintenance of integrity (good governance provides safeguards against most other issues)</p>	<p>Insufficient skills and resources are available for effective policy implementation. Conflicts of interest and limited power within agencies can corrupt offset processes. In lieu fees might replace central biodiversity funding. Inadequate monitoring and evaluation undermine offset success.</p>	<p>Invest in capacity building and performance incentives for government staff. Enable independent audits and increase capacity for monitoring. Track funds specifically for offset outcomes and ensure public oversight. Implement robust monitoring systems with public scrutiny and sufficient resources.</p>

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1036 *Figure legends*

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Figure 1. Biodiversity offsets in the context of the mitigation hierarchy. The mitigation hierarchy is a longstanding framework for mitigating impacts on biodiversity through a sequential series of steps. Potential impacts from a development project must first be evaluated, and any negative impacts first avoided and then minimised as far as possible. If some impact on biodiversity is expected to remain after these preventative steps, the two remedial steps must be used; first, repairing or restoring damage on-site and only then, as a last resort, seeking to offset any residual impacts through actions that benefit the same biodiversity at and off-site offset area. The net outcome is required to be at least no net loss, or, increasingly, net gain.

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Figure 2. Contrasting trajectories for biodiversity emerging from different frames of reference for no net loss and net gain: a) no net loss and net gain relative to a counterfactual scenario, and b) no net loss and net gain as absolute outcomes over time, relative to a fixed baseline.

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Figure 3. Actors and organisations involved in delivering biodiversity offsets through different delivery pathways. Legislative frameworks and/or policies set the requirements for offset provision and, sometimes, the way in which they are delivered. Many delivery pathways are possible, and vary among jurisdictions. A project developer with impacts incurs the obligation to provide an offset, and while they may deliver this directly on land they control, more commonly it is delivered by a third party. Connecting the developer to this offset provider might involve several types of intermediaries, who provide services ranging from information about potential offset providers through to a platform through which the developer can purchase existing offset 'credits' already generated by a provider to acquit their offset obligation. In some cases, the developer can pay into a trust to which the

1062 obligation to deliver the required offset is then transferred. Regardless of the delivery
1063 mechanism, the regulator or agency responsible for the overarching offset regulation or
1064 policy ideally monitors and enforces compliance with the policy, although the extent to which
1065 this occurs in reality is often limited.

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1070 *Boxes*

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1073 **Box 1. A brief history of biodiversity offsetting**

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1075 The development of offset policy and practice is most often traced back to the US in the
1076 1970s; however, key concepts underpinning offsets are much older (see figure). A 2021
1077 review⁴¹ analysed the emergence and spread of biodiversity offsetting discourses through
1078 contemporary history, starting with rising environmental concerns in the 1960s (“Silent
1079 Spring”) and the adoption of the US National Environmental Protection Act in 1969. These
1080 developments paved the way for the mainstreaming of environmental impact assessment
1081 (EIA) and various sectoral policies requiring the mitigation and compensation of
1082 environmental impacts, including the US Clean Water Act of 1972, the US Endangered
1083 Species Act of 1973, and the French Nature Protection Law of 1976, which was the first in
1084 Europe, prior to the adoption of the European Union’s EIA Directive in 1985 and the
1085 ‘Habitats’ Directive in 1992¹³⁴. Sectoral policies also contributed to the development of
1086 offsetting; for example, India’s Forest Conservation Act of 1980 included a requirement for
1087 compensatory afforestation¹³⁵. Such legislation provided the context in which requirements
1088 for offsets and the achievement of ‘no net loss’ or ‘net gain’ were later introduced.

1089

1090 Policy momentum built over the following decades, and biodiversity compensation principles
1091 were included in the Convention for Biological Diversity (CBD) in 1992. In 2006, the CBD
1092 called for guidance on offsets (Decision VIII/17). Bilateral and multilateral financial
1093 institutions also began to impose ‘no net loss’ and ‘net gain’ requirements — and specified
1094 the use of offsets in achieving these aims — on developers seeking project finance (for
1095 example, the International Finance Corporation in 2012 and the World Bank in 2016¹³⁶).
1096 As of 2019, biodiversity offsetting (mandatory or voluntary) was part of public policy in more
1097 than 100 countries^{2,137}. Reference to ‘no net loss’ is increasingly replaced with language such
1098 as ‘net gain’ and ‘net positive’, and calls are increasingly being made to apply the mitigation
1099 hierarchy, including offsetting, to impacts incurred throughout value chains, beyond direct
1100 and indirect project footprints^{13,14}. The need to better align outcomes from offsets with
1101 jurisdictional targets for biodiversity is increasingly recognised, such as in the context of
1102 spatial planning or strategic environmental assessment (SEA)¹⁰⁹.

1103

1104 At the same time, unfavourable perceptions of biodiversity offsets, heightened by criticisms
1105 of carbon offsets, have accumulated, in some cases resulting in emerging conservation
1106 discourses, such as nature positive and biodiversity credits, moving away from the traditional
1107 language of offsetting.

1108

1109 **Box 2. Alternative futures for biodiversity offsets**

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1111 These scenarios represent a collective range of possibilities, and the future will likely lie
1112 somewhere within this spectrum. Although all three futures assume that the need to care for
1113 nature continues to be recognised and accepted, even this is not assured — worse
1114 outcomes are possible¹³⁸.

- 1115
- 1116 *[bH1] Scenario 1. “Strengthened offsets and improved biodiversity outcomes”*
- 1117 Biodiversity outcomes
- 1118 • Slowing of declines and partial reversals of biodiversity decline
- 1119
- 1120 System processes
- 1121 • Mandatory offset systems delivering absolute net gains.
- 1122 • Offsets set limits to what can be impacted, and internalise full cost.
- 1123 • Avoidance is incentivised as a result.
- 1124 • Compliance is supported by extensive investment (by government and private sector)
- 1125 in environmental recovery.
- 1126
- 1127 Necessary conditions
- 1128 • Lessons learnt on offset effectiveness are used to improve policies (and pressures
- 1129 against improvements are resisted).
- 1130 • Institutional knowledge is valued and retained.
- 1131 • Emerging industry that supplies and provides assurance over biodiversity outcomes.
- 1132
- 1133 *[bH1] Scenario 2. Business as usual*
- 1134 Biodiversity outcomes
- 1135 • Continued decline maintaining the current trajectory of biodiversity loss.
- 1136
- 1137 System processes
- 1138 • Policy pays lip service to nature’s needs, but is systematically poorly administered.
- 1139 • Responsible agencies are understaffed, underresourced, and not sufficiently
- 1140 empowered.
- 1141
- 1142 Necessary conditions
- 1143 • Policy effectiveness and quality reliant on effective and empowered individuals to go
- 1144 beyond what the system requires of them.
- 1145 • Continued industry backlash against strong regulation and rigorous mitigation
- 1146 requirements.
- 1147 • Attention to impacts beyond direct footprint is limited.
- 1148
- 1149 *[bH1] Scenario 3. [Weakened offsets, greenwashing, and further biodiversity decline”*
- 1150 Biodiversity outcomes
- 1151 • Decline steepens owing to increased impacts enabled under the guise of nature-
- 1152 positive greenwashing and poor-quality ‘offsets’.
- 1153
- 1154 System processes
- 1155 • Reduction in scope of what requires offsets, and/or abandonment of equivalence
- 1156 requirements.
- 1157 • Offsets present in name only, replaced by approaches that do not require rigorous
- 1158 loss-gain accounting.
- 1159 • Biodiversity markets achieve little but provide greenwashing and enrich wealthy
- 1160 landowners, who are in turn incentivised to perpetuate the system.
- 1161 • Offset and credit trading systems become bloated and increase transaction costs,
- 1162 reducing cost-effectiveness of investment in nature.
- 1163 • Greenwashing either remains effective, or is called out leading to ‘greenhushing’, in
- 1164 which claims about environmental outcomes are avoided altogether.
- 1165
- 1166 Necessary conditions
- 1167 • Lack of scrutiny of emerging practices and their outcomes.
- 1168 • Intensified industry lobbying and capture of regulatory agencies by industry interests
- 1169 • Geopolitical events lead to a deprioritisation of nature conservation.

- 1170 • Weakened or captured civil society organisations.

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1172

1173 Glossary

1174

1175 **Biodiversity offset:** An action beneficial to biodiversity that is used to compensate for an
1176 ecologically equivalent negative impact on biodiversity in another location so that at least ‘no
1177 net loss’ of biodiversity occurs.

1178

1179 **Mitigation hierarchy:** The hierarchical sequence of actions applied to mitigate negative
1180 environmental impacts, and usually rendered as: avoid, minimise, restore, offset.

1181

1182 **Biodiversity credit:** A measurable unit of biodiversity gain, sometimes distinguished
1183 explicitly from units of gain used as offsets, that can be exchanged between a seller and a
1184 buyer (including both public and private actors) in a biodiversity market.

1185

1186 **Nature positive:** According to the Nature Positive Initiative, nature positive refers to “A
1187 global societal goal defined as ‘*Halt and Reverse Nature Loss by 2030 on a 2020 baseline,*
1188 *and achieve full recovery by 2050... involving measurable net-positive biodiversity outcomes*
1189 *through the improvement in the abundance, diversity, integrity and resilience of species,*
1190 *ecosystems and natural processes*”

1191

1192 **Absolute net outcome:** As applied to biodiversity, an overall outcome in which the state of
1193 the targeted biodiversity is measured relative to a fixed point in the past, or a fixed former
1194 state.

1195

1196 **Relative net outcome:** As applied to biodiversity, an overall outcome in which the state of
1197 the targeted biodiversity is measured relative to a counterfactual scenario — usually one in
1198 which neither the impact nor the offset occurred.

1199

1200 **Value chain:** The full range of activities conducted by a business in supplying and
1201 supporting a product or service from procuring raw materials to waste management.

1202

1203

1204 ToC blurb

1205 Biodiversity offsets, applied as part of the mitigation hierarchy, aim to ensure that ‘no net
1206 loss’ of biodiversity occurs as a result of human development projects and activities. This
1207 Review explores offsetting approaches, their effectiveness in comparison with other
1208 conservation mechanisms, and the future of offsetting in the context of ‘nature positive’
1209 goals.