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Perspective

# Fifteen operationally important decisions in the planning of biodiversity offsets

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ABSTRACT

Many development projects, whether they are about construction of factories, mines, roads, railways, new suburbs, shopping malls, or even individual houses, have negative environmental consequences. Biodiversity offsetting is about compensating that damage, typically via habitat restoration, land management, or by establishment of new protected areas. Offsets are the fourth step of the so-called mitigation hierarchy, in which ecological damage is first avoided, minimized second, and third restored locally. Whatever residual damage remains is then offset. Offsetting has been increasingly adopted all around the world, but simultaneously serious concerns are expressed about the validity of the approach. Failure of offsetting can follow from either inappropriate definition of the size and kind of offset, or, from failure in implementation. Here we address planning of offsets, and identify fundamental operational design decisions that define the intended outcome of an offsetting project, and organize these decisions around objectives, offset actions, and the three fundamental ecological axes of ecological reality: space, time and biodiversity. We also describe how the offset ratio of a project (size of offset areas compared to impact area) can be constructed based on several partial multipliers that arise from factors such as degree of compensation required relative to no net loss, partial and delayed nature of restoration or avoided loss gains, time discounting, additionality, leakage, uncertainty, and factors associated with biodiversity measurement and offset implementation. Several of these factors are partially subjective and thus negotiable. The overall purpose of this effort is to allow systematic, well informed and transparent discussion about these critical decisions in any offset project.

## 1. Introduction

Ecological damage caused by infrastructure projects or other activity can be sometimes compensated by restoring habitats, by establishing new protected areas, or by other methods of conservation management. This process is called biodiversity offsetting (ecological compensation) (e.g., ten Kate et al., 2004; McKenney and Kiesecker, 2010; BBOP, 2012; IUCN, 2016), or offsetting in short. Offsets are the fourth step of the so-called mitigation hierarchy (ten Kate et al., 2004; IUCN, 2016), in which negative ecological impacts are (i) avoided altogether, (ii) minimized by appropriate project design, (iii) reduced by habitat restoration in the impact area, and only then (iv) compensated by offsetting. Conceptually, offsets resemble the "polluter pays" principle.

To set the stage, we recap major terminology of offsets. In-kind means that biodiversity losses are compensated with gains for exactly the same biodiversity (species, habitats, biotopes etc.). In out-of-kind (flexible) offsets gains can be accepted for biodiversity features different from those suffering damage (Bull et al., 2015). No net loss (NNL) is commonly used to describe the goal of offsetting, full compensation for all ecological damage (e.g. Gibbons and Lindenmayer, 2007; Maron et al., 2018). Net Positive Impact (NPI; Gibbons and Lindenmayer, 2007) means that offsets produce an outcome that is ecologically better than NNL. Net Gain (NG) is a similar concept (Bull and Brownlie, 2017), with the difference in flavor that it is primarily used for in-kind offsets whereas NPI is more associated with trading-up situations (Section 2.4.2). In this work, we use NPI/NG for an outcome that is better than NNL, whether in- or out-of-kind. We use impact area and offset area for areas in which ecological losses and gains take place, respectively. There are two major ways of producing offset gains, habitat restoration (Section 2.5.2) and so-called avoided (averted) loss (Section 2.5.3), which typically means protection of an area to avoid ecological losses in

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it – the avoided losses are then counted as offset gains. Different forms of land (habitat) management can produce gains alike those produced by restoration or avoided loss. We use the term multiplier (offset ratio, compensation ratio; Moilanen et al., 2009) to indicate the size of the offset areas compared to the size of impact areas; for example, a multiplier of five means that five area units of land are needed to offset one area unit of loss.

There is widespread and globally expanding interest in offsetting (Boisvert, 2015; Bonneuil, 2015). The purpose of this work is not to exhaustively review concepts, principles, case studies, offsetting activities in various regions or countries, or concerns about offsetting, as these have been extensively discussed in prior literature (e.g. IUCN, 2016 and references therein; Wende et al., 2018). Rather, it is to describe a framework that allows systematic and transparent examination of the main design decisions that significantly impact the meaning of and outcome expected from an offset plan. The following presentation builds on Finnish and English language grey literature reports by the same authors, Moilanen and Kotiaho (2017) and (2018).

## 2. The fifteen decisions and their impacts

The ecological reality of the World can be expressed in terms of three main dimensions: what biodiversity (features) you have, where (space), and when (time) (Wissel and Wätzold, 2010). Ecological losses and gains can be expressed through these dimensions: what and how much is damaged or lost, where and when? What offsets gains are generated, where and when? Operationally important decisions about offsets can be grouped around objectives, actions and these three major axes of ecology (Fig. 1).

Table 1 summarizes why these questions/topics impact offset design. We note effects on several different factors of interest to parties involved in offsetting. (i) Options for offsetting. How many alternatives will there be for implementing the offsets? (ii) Feasibility. How easily, if at all, can offsets be implemented? (iii) Credibility. How credible is the compensation plan in delivering NNL or better? (iv) Multipliers. How would decisions influence multipliers and hence implementation costs? (v) Costs. Costs accumulate from design and administrative expenses, land purchase (or rent) and implementation of habitat restoration or other conservation actions. (vi) Complexity of design and implementation is increased by stricter requirements and size of the project. (vii) Local satisfaction. How satisfactory are the offsets likely to appear from the perspective of locals, who suffer losses of ecosystem services and biodiversity in their neighborhood? Table 2 summarizes expected effects, with major ones discussed in the following sections. Note that depending on their objectives with respect to the proposed offsetting effort, different stakeholders (developer, regulator, local inhabitant, etc.) might hold varying opinions about whether some type of effect is “good” or “bad”.

Having set the stage, Sections 2.1–2.5 examine each of the fifteen factors in increased detail.

### 2.1. Objectives

#### 2.1.1. Degree of adherence to the mitigation hierarchy

The degree to which the mitigation hierarchy is followed is a partially heuristic decision, because there probably are no clear rules for how much effort a business or other developer must spend on impact avoidance and local minimization before embarking on offsetting. Who says how much avoidance is possible? Who defines how far minimization can and has to be taken? From the perspective of the developer, this is primarily a question of costs and secondarily about credibility. It is quite plausible, that minimization and impact avoidance can come out as more expensive than offsets, in which case there may be a tendency to skip avoidance and to go direct to offsets (Quétier et al., 2014; Spash, 2015; Schoukens and Cliquet, 2016).

How far avoidance and minimization are taken will influence both options for local restoration (step 3 of the hierarchy) and options for offsetting. Stricter adherence to the hierarchy will reduce environmental damage done, which leads to lesser requirements for offsetting, which implies increased feasibility and credibility and reduced costs for the offsetting phase (but higher costs in avoidance).

Decision to be made: how far is the developer required to take impact avoidance and minimization before embarking on offsetting?

#### 2.1.2. Definition of NNL

One might expect the meaning of NNL - a basic concept - to be clear, but it is not. First, gains are counted in relation to a reference scenario, which can be generated and used in various ways (Maron et al., 2018; Section 2.5.4). Second, there is a question of levels of certainty required. Assume for the sake of illustration that an area has 7423 individuals of a given species (not that you'd ever be able to know the exact number). When aiming at NNL compensation, the expectation

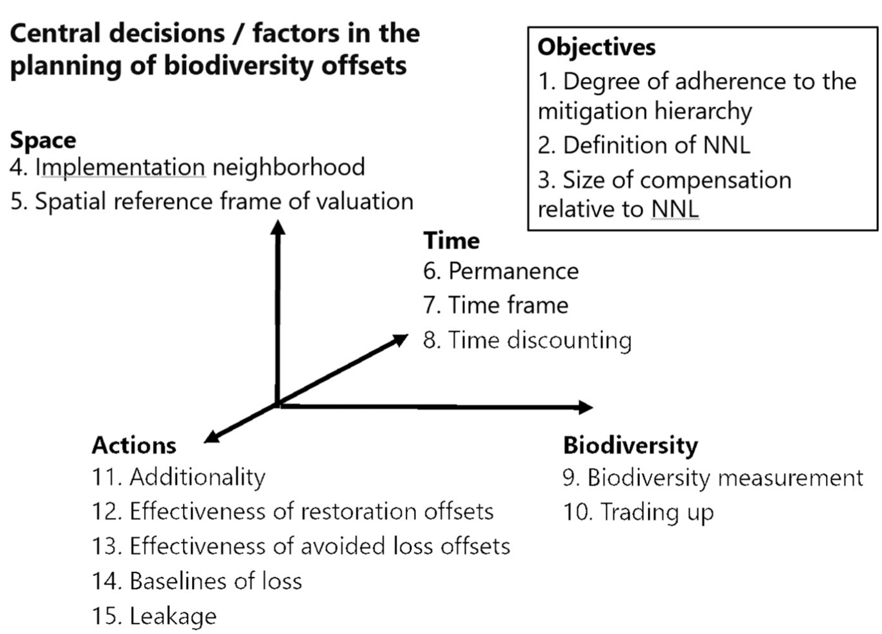


**Fig. 1.** Important decisions/factors of biodiversity offsetting grouped around objectives, offset actions and the three major axes of ecological reality.

**Table 1**
Summary of the fifteen decisions. Details are provided in separate sections for each.

| Decision/factor | Brief characterization |
|---|---|
| Degree of adherence to the mitigation hierarchy | Defines how much offsetting will need to be done. |
| Definition of NNL | More detailed definition and higher emphasis on uncertainty leads to higher requirements for offsets. |
| Fraction of NPI/NG targeted | Directly influences the size of the ecological compensation/offset needed. |
| Implementation neighborhood | Allowing a larger neighborhood brings more options and reduces costs. |
| Spatial reference frame of biodiversity valuation | Impacts biodiversity valuation and hence indirectly requirements for measurement and possibly options for trading up. |
| Permanence | Lack of permanence is a serious issue for credibility. |
| Evaluation time frame | Influences, e.g., gains estimated from habitat restoration. |
| Time discounting | How delayed gains are valued. Increases area required from offset. |
| Biodiversity measurement | Influences operational definition of NNL, credibility and complexity. |
| Trading up | Major influence on options if allowed. Increases complexity. |
| Additionality | Lack of additionality should increase size of offset required. |
| Effectiveness of restoration | Critical component influencing the estimate of gains and hence size of offset required. |
| Effectiveness of avoided loss | As the previous item. |
| Avoided loss baseline of decline | Influences gains achievable from avoided loss offsets. |
| Leakage | Can reduce gains from avoided loss offsets to a variable degree. |

**Table 2**
Linkages between factors and types of impact. Different impacts follow from the fifteen factors that impact offset design. This table summarizes major pathways of how these factors lead to direct or indirect impacts. Awareness of impact pathways facilitates well-informed discussion about offset design and implementation. The table in not intended to be exhaustive and additional project-specific effects can exist.

**Pathway from factors to impacts**

Stricter requirements for offsets increase credibility, complexity and design costs, multipliers, implementation costs, and probably local stakeholder satisfaction. However, there is a reduction in options and feasibility, which may counteract credibility.

**Linkages between impacts, which mediate indirect effects**

Increased options imply increased feasibility.
Increased options imply reduced per-unit costs, due to ability to pick and choose.
Increased feasibility implies increased credibility.
Increased credibility implies increased local stakeholder satisfaction.
Increase in multiplier implies increased credibility.
Increase in multiplier implies increased costs.
Increase in complexity implies increased costs and possibly reduced credibility.

**Examples of major linkages from factors to impacts**

*Increased options* follow from increased adherence to the mitigation hierarchy (less offsetting needed), an increased implementation neighborhood, and allowing of out-of-kind offsets and trading up. *Reduced options* follow from many factors that tighten the requirements and constraints placed on offsets.

*Increased feasibility* follows from anything that increases options, reduces offsets needed, or loosens requirements set for offsets. Vice versa for *reduced feasibility*.

*Increased credibility* follows from increased feasibility, increased offset area (multiplier) and higher standards (requirements) for offsets, including permanence and more detailed biodiversity measurement. *Reduced credibility* follows from factors such as lack of permanence, lack of time discounting, lack of additionality, significant leakage, and uncertainties about restoration success and effectiveness of avoided loss.

*Increased multipliers* follow from any factors that increase partial multipliers, summarized in Section 2.6.

*Increased costs* follow from increased multipliers and to a smaller extent, from increased complexity design restrictions.

*Increased complexity* follows from lack of permanence, partial lack of additionality, requirements for detailed biodiversity measurement, leakage, and uncertainties about effectiveness of offset actions.

*Increased local stakeholder satisfaction* follows from reduced implementation neighborhood and higher multipliers, conditional on (avoided loss) offsets not reducing access to ecosystem services.

would be an addition of 7423 individuals into the average population size of the same species elsewhere. Getting exactly this increase would in fact be an incredible coincidence, and you would almost surely get something more or something less. What does NNL mean then? Does it mean a result, which on average achieves NNL, implying that 50% of species (or other biodiversity features) fail NNL and the other 50% of species receive NPI/NG? One could also argue in the spirit of "in-kind NNL" that everything needs to be fully replaced for sure, which would imply 100% confidence of all 100% of features receiving 100% compensation (NNL) or better. It should be obvious that the size of the offset required to achieve the latter is massively larger than the size of the offset needed to achieve the first.

Decision to be made: specify what is meant by NNL?

#### 2.1.3. Size of compensation required relative to NNL

The size of ecological compensation implemented can obviously vary on a scale from partial compensation to NNL to NPI/NG, depending on the size of the area used as offset. Here, we take offsetting to mean anything that is NNL or better. We use 'partial compensation', when compensation is less than NNL. (Partial compensation is acceptable, e.g., if the compensation effort is voluntary, but it cannot be called an NNL offset.)

Decision to be made: what fraction of NNL is required?

### 2.2. Decisions around space

#### 2.2.1. Implementation neighborhood

This is another easy decision to understand: how far from the impact area is implementation of offsets allowed? This question is important, because implementation near the impact area may be difficult or even plain impossible due to lack of suitable (and available) offset sites. Reflecting this decision against Table 2, the logic goes as follows. When the implementation neighborhood allowed increases, there is likely to be an increase in options for implementation. Consequently, feasibility of doing offsets improves and credibility of achieving NNL is likewise improved. A major side-effect is decrease in per-unit offset costs, which follows from the ability to pick from amongst an increasing set of options. The multiplier is not directly affected. However, if the developer negotiates increased spatial flexibility to gain more options, the environmental administration could ask for an increased multiplier in the trade, which would counteract the decrease in per-unit implementation costs. As a downside of an increased implementation neighborhood, local communities will suffer greater losses of ecosystem services since compensation happens further away. ESS available to locals might also become reduced due to the offsets themselves, if for example protection measures limit the usage of some areas. Overall, ecosystem services (ESS) might be better considered in a separate process that accounts for local preferences between services (Griffiths et al., 2018).

Decisions to be made: (i) What is the implementation neighborhood of biodiversity offsets? (ii) What is implementation neighborhood for offsetting of ESS? (iii) Is a multiplier needed for elevated spatial flexibility, and if so, how large is it?

#### 2.2.2. Spatial reference frame of biodiversity valuation

The spatial reference frame is one of the most abstract questions around the design of offsets. The question arises from the fact that what is rare in one spatial reference frame (e.g. province, country) might be common in another. This factor influences what biodiversity may need to be measured or what may be accepted as trading up, with consequences to options available. Hence, it can make a big difference whether biodiversity is valued in a local, regional, national, continental or global context, or some combination of these. The contexts utilized should be stated explicitly to avoid misunderstandings in communication (Moilanen and Kotiaho, 2017, 2018).

There is a point to be made about spatial frames for biodiversity conservation and for the maintenance of ESS. Agreements about biodiversity, such as the Convention on Biological Diversity, tend to be international. In Europe, the Natura 2000 network is European, and environmental laws are national/EU-wide. This implies that biodiversity conservation (including offsetting) should perhaps be seen as a regional or national undertaking, not forgetting global commitments. In contrast, ESS should preferably be compensated locally or regionally, so that the flow of services to local people is maintained.

Decision to be made: explicitly state the spatial reference frames used in the planning of offsets.

### 2.3. Decisions around time

#### 2.3.1. Permanence of offsets

Permanence of conservation actions and protected areas are major questions in conservation biology including offsetting (McKenney and Kiesecker, 2010; van Oosterzee et al., 2012; Moilanen et al., 2014). If temporary offsets are offered, there will be increased uncertainty about the offsetting effort as a whole, complexity of design will increase and credibility will consequently be harmed. Multipliers should increase significantly to compensate for lack of permanence – after all, all gains could be lost after the temporary offsets comes to the end of its term. If a development project is effectively permanent (roads, housing, etc.), it is hard to see how a temporary offset could achieve NNL in a credible manner. Note that offsetting using land management implies recurrent management action, which can become very expensive over time if maintained permanently.

At the operational level, more options might be available for temporary offsets compared to permanent ones, because some land owners might find temporary agreements more agreeable. While the minimum requirement is that the duration of gains equals the duration of losses, it is (in our opinion) within the interests of an environmental administration to primarily endorse permanent offsets so that uncertainties are reduced. Credibility demands that permanent offset areas are voluntarily and permanently protected without monetary compensation from the state.

Decision to be made: is permanence required from the offsets?

#### 2.3.2. Time frame of evaluation

The time frame of evaluation influences multipliers in a possibly counterintuitive manner. As a starting point, full gains from habitat restoration or avoided loss can take decades or even centuries to mature (Section 2.5.2). Therefore, the time period over which gains are evaluated makes a difference to the gains expected. Ecological gains are zero or minor at first and develop slowly over time: a short evaluation interval limits evaluation to early years when restoration or avoided loss gains are comparatively small (see Section 2.5.5 for illustration). As a consequence, shorter time frames imply higher multipliers for NNL to be achieved, because average gains achieved over the evaluation time frame become reduced. Also, very long timeframes will decrease the credibility of offsets due to increased uncertainties about estimations over long time frames (see Laitila et al., 2014 and references therein). Note that if the evaluation time scale is short but offsets permanent, offsets that are NNL at the end of the time frame may turn into NPI/NG in the long run (Moilanen and Kotiaho, 2018). The length of the evaluation time frame is a subjective decision.

Decision to be made: how long is the time interval over which the balance of losses and gains is evaluated?

#### 2.3.3. Time delays and time discounting

Delayed payment (compensation) is generally not accepted as equally valuable to immediate compensation, which is demonstrated by the existence of financial interest rates and expectations about return on investment (Green and Myerson, 2004; Carpenter et al., 2007). The same principle applies to ecological compensation: a net present value calculation should be performed upon them delayed offset gains. In effect, time discounting implies an elevated multiplier for achieving NNL (Moilanen et al., 2009; Laitila et al., 2014). Because time delays are inherent in both habitat restoration and avoided loss, time discounting should be routinely applied on both. Technically, time discounting is a weighted average in which yearly weights come from the time discounting function that declines by time. Hence, early years influence net present value more than later years. Separate evaluation time frame and time discounting are apparent in offset calculators (Pouzols et al., 2012; Laitila et al., 2014; Gibbons et al., 2016).

Subjective decisions associated with time discounting include the time discounting function and coefficient. Time discounting can significantly influence (increase) both multipliers and the credibility of offsets. Discounting of even a couple of percent per year leads to almost complete perceived loss of value after a few decades, which emphasizes the importance of impact avoidance in habitats that are slow to recover after restoration. A habitat bank stockpiles offsets that have been generated in advance, which eliminates the need for time discounting (Bekessy et al., 2010). However, it may be difficult to ensure adequate stocks of all habitats in all regions, which implies pressure to replace flexibility in time with flexibility in space and biodiversity.

Decision to be made: what yearly time discounting percentage (and discount function) is used in net present value calculations?

### 2.4. Decisions about biodiversity

#### 2.4.1. Measurement of biodiversity and ecosystem services

Currencies of measurement for biodiversity and ecosystem services influence the outcome of offsetting because they specify the resolution at which the gains and losses are balanced (Gamarra et al., 2018). Detail could vary from coarse (habitat hectares; Parkes et al., 2003) to very detailed, like when population size estimates are required for many species. Biodiversity measurement impacts the outcome of an offsetting project. If compensation is done only, say, for one protected species, the offset is not ecologically NNL as losses are allowed for a host of common biodiversity. A NNL outcome is not guaranteed for biodiversity that is not measured either directly or indirectly via some proxy. Ecological losses can be hard to measure at a high degree of resolution. The real challenge, however, is the difficult and uncertain prediction of restoration and avoided loss gains. Consequently, employing very high resolution in the measurement of losses adds only false credibility to an offsetting effort.

Ecosystem services are a further question in measurement (Jacob et al., 2016). In principle, NNL biodiversity offsetting should also provide NNL outcome for ecosystem service supply because ecosystem services are produced by the ecosystem processes maintained by said biodiversity. However, there are three major additional questions with ecosystem services, stakeholder preferences between services, flow and equitable availability. Preferences determine how much people value different services, which might influence measurement and satisfactory compensation. Also, flow between supply and demand is harder to compensate than supply only – ESS tend to become redistributed as consequence of offsetting (Gordon et al., 2015; Levrel et al., 2017). (But location has less significance for some services such as carbon sequestration.) In effect, a separate compensation process for ecosystem services might be an appropriate addition to NNL compensation for biodiversity (Griffiths et al., 2018).

The real decisions: How much simplification, and hence flexibility, is allowed in the estimation of losses and gains? Does this simplification merit application of an additional multiplier? Are ecosystem services also evaluated in offsetting? If they are, is only ecosystem service supply considered or are flow between supply and demand and equitable accessibility also addressed?

#### 2.4.2. Trading up

Trading up means swap of impact areas into offset areas of some other habitat types that are thought to be more valuable from the perspective of biodiversity conservation (Habib et al., 2013). Trading up implies flexibility, as impacts and gains occur to different sets of species (features). It is an inevitably subjective decision whether trading up is allowed and what multipliers are used in the action. If trading up is allowed, options are increased, feasibility is improved, credibility may be impacted positively or negatively, complexity of offsetting is increased, and costs increase or decrease depending on how large a multiplier is applied in trading up and how expensive operation in the other environment is. Implementation might become feasible closer to the impact area, implying increased satisfaction by local parties (Section 2.2.1). Overall, trading up would seem to make sense when clear gains can be achieved for biodiversity conservation, but pay attention to the maintenance of sufficient multipliers.

Decision: are some forms of trading up allowed? If so, with what multipliers?

### 2.5. Offsetting actions and their properties

#### 2.5.1. Additionality

Additionality is a core concept in offsetting and means that double-counting of the ecological gains is not allowed (van Oosterzee et al., 2012). If an area is to be restored due to some other commitment, it cannot be a restoration offset also for a construction project. Likewise, offsets should not be counted towards national environmental goals (IUCN, 2016; Maron et al., 2016). This is because offsets are meant to compensate the negative impacts of a development project and would not usually improve the state of the landscape as a whole. If an area has already been protected, and thus cannot be harmed, it cannot be counted as an avoided loss offset, as there are no pressures to remove.

To do: Examine and estimate the degree of additionality for all proposed offset actions. Account for partial lack of additionality in the calculation of multipliers.

#### 2.5.2. Effectiveness of restoration offsets

Habitat restoration changes the abiotic or biotic environment of a location by restoration actions, following which the environment sets on a trajectory that gradually takes it closer towards natural state (e.g. Dobson et al., 1997; Suding, 2011). The most defining characteristics of restoration are partial recovery, uncertainty and time delays (Dobson et al., 1997; Suding, 2011; Maron et al., 2012), which also significantly influence offset gains that can be expected from habitat restoration. Recovery is partial because (i) habitat restoration is almost never applied to a fully lost environment and (ii) restoration is unlikely to recover the ecosystem to natural state. Uncertainty arises from the somewhat unpredictable outcome of restoration (e.g., Suding, 2011). The EU court of justice has recently stated restoration uncertainty as reason why local restoration action cannot be relied upon when expected environmental damage is evaluated in Natura 2000 areas (Schoukens and Cliquet, 2016). Time delays are inherent in the ecological recovery process and can be even up to centuries long with late-successional habitats (e.g. Dobson et al., 1997; Curran et al., 2014; Spake et al., 2015). Even modest time discounting applied to such long delays results in very high additional multipliers, suggesting impact avoidance to begin with. Restoration can be prohibitively difficult, e.g. for chemically significantly altered environments or because of regional loss of key species, which prevents the recovery of the original ecology

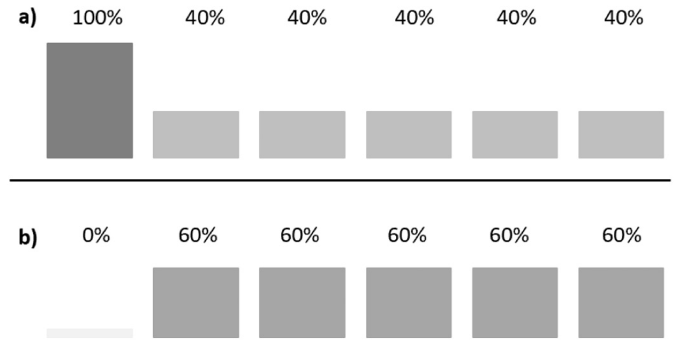


**Fig. 2.** a) Complete loss of one area balanced with b) partial (20%) gains in five areas.

(Maron et al., 2012). Note that calculations for offsetting using land management are structurally identical to those for restoration, when management actions generate improvements in habitat quality. The difference between the two is that restoration can be a once-off effort whereas management typically requires recurrent action.

Because restoration success is only partial, but losses are often complete, it is expected that the restoration multiplier is significantly larger than 1. In the illustration of Fig. 2, complete loss (100%) of one area unit requires partial gains ("restoration from 40% to 60% condition") in five area units (multiplier = 5). Note that the temporal development (recovery function) of habitat quality impacts the perception of what is correct compensation. If in the present example habitat condition improves linearly from 40% to 60% over the evaluation time frame, then average improvement over the evaluation time frame is only 10%, which implies a multiplier of 10 instead of 5. Using a time discounted average would further increase this multiplier. See Section 2.5.5 for illustration of time development of partial gains, leakage and time discounting.

It is expected that generalist species, ecosystem function and ecosystem services will likely recover easier than specialist species, which may need very specific conditions (e.g., Haapalehto et al., 2017). The full original ecological community may be impossible to recover, as some species may have gone regionally extinct (Maron et al., 2012). It is also expected that generalist species, specialist species, ecosystem function and ecosystem services will recover at different rates. When selecting restoration areas, one should seek synergies in the restoration of biodiversity and ecosystem services, accounting for accessibility, connectivity and other such factors as needed. Connectivity to pre-existing high-quality conservation areas is of benefit for the recovery of a habitat.

Information to be obtained: estimates of habitat recovery functions are needed for the time frame used and the biodiversity and ecosystem service components measured. An additional multiplier can be applied to counteract uncertainty.

#### 2.5.3. Effectiveness of avoided loss offsets

Offsetting via protection is usually called avoided loss or averted loss offsetting (ten Kate et al., 2004; Gibbons and Lindenmayer, 2007; Bull et al., 2014). The logic of this approach is that protection (or some other measure to the same effect) reduces human pressures in the newly protected area, thereby leading to environmental gains compared to the situation without the protection. Avoided loss may be better in producing gains for specialist species than restoration (which is applied to degraded areas), because it is applicable also to areas that still are in good ecological condition and hence retain populations of specialist species. Avoided loss can also be generated via land management, when management actions prevent or slow down degradation of habitat quality.

As with restoration, avoided loss produces only partial gains, again implying multipliers (significantly) larger than one. Full avoided loss

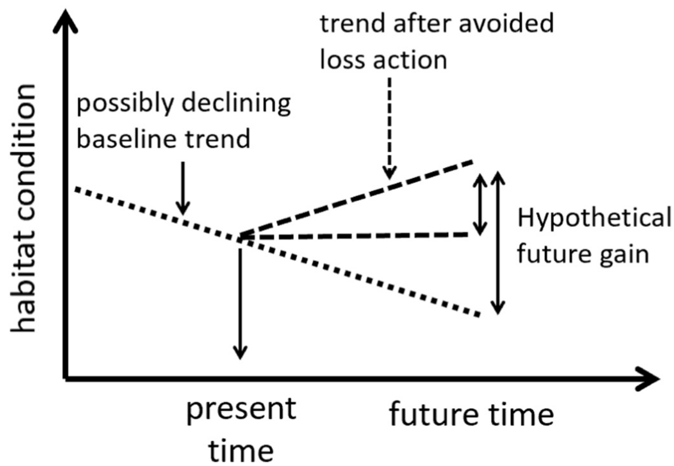


**Fig. 3.** Declining baseline trend (dotted) and two alternative future trends after protection (dashed).

gains only come about over a longer time period and so need to be time discounted. There are two major factors relevant for calculation of avoided loss offsets, baselines of decline and leakage, which are described in the following two sections.

To do: establish that there are pressures that avoided loss action (protection, etc.) could credibly alleviate.

### 2.5.4. *Avoided loss baseline of decline*

Baseline of decline. When considering avoided loss, it is not the full ecological value of the avoided loss area that can be counted as a gain, but rather, the gain is evaluated between what is expected to happen following offset action compared to absence of action, a.k.a. the counterfactual, crediting baseline, or reference scenario (Ferraro, 2009; Bull et al., 2014; Maron et al., 2018). In other words, only the additional difference made by protection or any other conservation action should be counted towards offset gains (Bull et al., 2014). Estimation of the baseline decline is one of the most uncertain and risky parts of offsetting (Section 3.4).

Fig. 3 illustrates the baseline assumption. Protection changes the trend of an area so that expected habitat quality is better than what it would be without protection: the difference made by protection is counted as an avoided loss gain. It is a subjective decision whether speculative declining trends are allowed in avoided loss calculations. To reduce uncertainty and speculation, it may be desirable to only allow calculation of gains from between the present state of the area and an improving future state. (Compare alternative gains marked in the figure.) Maron et al. (2018) summarize alternative ways of generating and using reference scenarios.

There are additional issues to pay attention to with respect to baselines. If the offset area candidate is high-quality environment, there may be reasons why the area has maintained its quality so far (e.g. poor accessibility). The same reasons might maintain the area into the future as well, implying that there is no declining baseline to improve upon via protection. If there is a declining baseline due to expanding land use, use of offsets will not improve upon that trend. Rather, it solidifies the trend because additional losses and gains balance around the declining trend, not around a stable state (Maron et al., 2015). Overall, optimistic (from the developer side) speculation around avoided loss seems to offer a pathway to poor offset outcome. It may well be that true observable gains from habitat restoration offer a categorically more credible route to an NNL outcome.

Information to be obtained: a baseline needs to be specified so that avoided loss gains can be estimated. The trajectory of potential improvement in ecological condition following protection needs to be estimated as well.

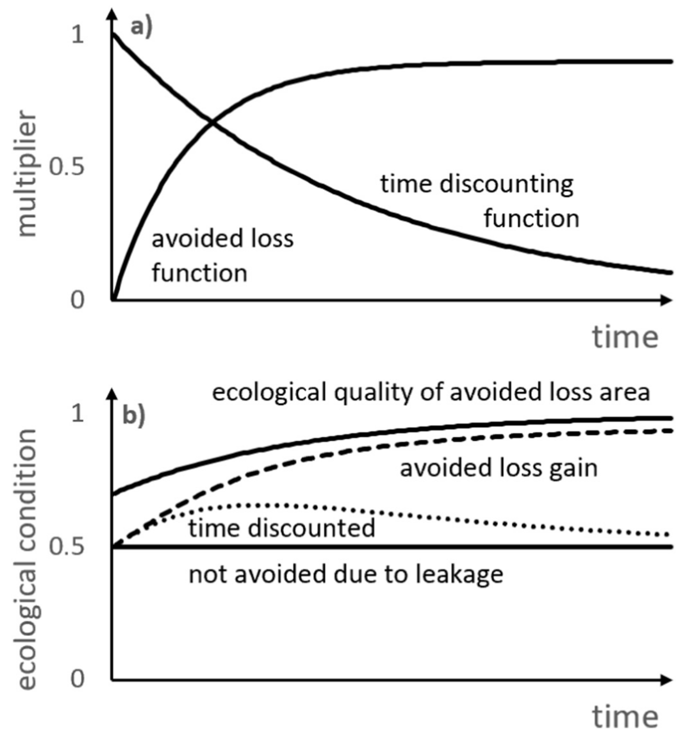


**Fig. 4.** Illustrating time-discounted avoided loss gains and leakage. a) A declining time discounting function, and an avoided loss function, which models the cumulative probability of the area being lost before that time. b) An ecologically high-quality area is approaching natural state (condition 1). It is protected, but not all ecological value can be counted as a gain. First, the example assumes that pressures leak to areas of on average 0.5 condition, which means that only condition above 0.5 is a gain. This gain is first multiplied by the avoided loss function, to arrive at an avoided loss gain (dashed), which is time discounted to arrive at net present value of avoided loss gain after leakage (difference between dotted and lower solid line). In this example, the true gain is in the order of 10% of the ecological condition of the avoided loss area: avoided loss multipliers can well become large.

### 2.5.5. *Leakage*

Avoided loss gains materialize via the removal of human pressures on the offset area. Leakage happens, when the pressures are not neutralized but move to other locations that are then harmed (Ewers and Rodrigues, 1998; van Oosterzee et al., 2012; Moilanen and Laitila, 2015). Potential for leakage is most apparent in environments that are under high resource extraction pressures. Leakage can significantly reduce gains achievable by avoided loss offsets. It reduces both feasibility and credibility and increases multipliers and costs. Options may be reduced as well, because some offset actions may become unviable due to lack of credibility. Fig. 4 illustrates avoided loss gains in the presence of time discounting and leakage.

To do: estimate the degree of leakage for all proposed avoided loss offset actions. Calculate corresponding multipliers.

## 2.6. *Partial and total multipliers*

The considerations summarized above produce several independent multipliers that are then multiplied to provide a total multiplier (Table 3; Moilanen and Kotiaho, 2018). A credible multiplier could easily come out as 10:1 or larger (Gibbons et al., 2016: Moilanen and Kotiaho, 2018).

**Table 3**
Reference table of partial multipliers. All these are expected to be greater than 1.0, with the exception of the trading up multiplier, which could in some special case be 1 or even less.

| Partial multiplier | Applies to | Explanation |
|---|---|---|
| Restoration success | Restoration | Comes from the partial nature of restoration gains, compared to often complete losses. Conceptually separate but handily calculated together with time discounting. |
| Avoided loss success | Avoided loss | From difference made in the avoided loss areas, comparing baseline trend and what is expected after protection. Easy to overestimate. |
| Leakage | Avoided loss | Account for reduced effectiveness due to relocation of pressures. Multiplier depends on the fraction of pressures that leak and where the leakage goes to. |
| Time discounting | Both | Comes from time discounting restoration or avoided loss gains, which produces a multiplier that accounts for both delayed and partial development of gains. |
| Lack of additionality | Both | Only the additional fraction can be counted. Effect can be separated or subsumed into the restoration or avoided loss gain functions. |
| Uncertainty | Both | Additional multiplier to reduce uncertainties, e.g., for species that are not directly measured. |
| Trading up | Both | When replacing one environment with another, some conversion factor (partially subjective multiplier) is inevitably needed. |
| Elevated spatial flexibility | Both | Additional multiplier to compensate for elevated spatial flexibility if such is negotiated by the developer to gain additional options for offset implementation. |
| Simplified biodiversity measurement | Both | Additional multiplier to compensate for simplified biodiversity measurement. |
| Change in connectivity | Both | Additional multiplier to compensate for lower connectivity of offset areas compared to impact areas. |
| NPI/NG | Both | Additional multiplier for NPI/NG. When applied on top of an NNL solution, produces a specific fraction of NPI/NG. |
| TOTAL | | Take the partial multipliers that were relevant for your case and multiply them. |

## 3. Discussion

### 3.1. Unavoidable subjective decisions and data needs

While offsets can be partially based on science, there are surprisingly many inevitably subjective decisions involved, including at least the following: application of the mitigation hierarchy, definitions of in-kind and NNL, the implementation neighborhood, spatial reference frame of valuation, whether permanence is required, time frame of evaluation, strength of time discounting, resolution of biodiversity measurement, relative importance placed on different biodiversity features, whether trading up is allowed, and how reference scenarios are generated and used. We put forward a couple observations. First, temporary offset measures (or conservation measures in general) are a bad idea and permanence should be strongly favored by environmentally minded parties, because temporary offsets run the risk that ecological losses remain while gains vanish after the duration of offsets runs out (e.g., McKenney and Kiesecker, 2010; van Oosterzee et al., 2012; Moilanen et al., 2014; Laitila et al., 2014). Second, ecological losses and gains don't care about costs. Cost efficiency is of interest to the developer, but not so much to regulators and administration. Third, declining avoided loss baselines should be treated with caution (Bull et al., 2014; Maron et al., 2015, 2018). There is the additional consideration that several international agreements, including the UN Convention on Biological Diversity, already require stop of biodiversity losses and even habitat restoration: how come can there even be declining baselines then? Fourth, due to the speculative nature of avoided loss reference scenarios, habitat restoration should be seen as the more certain way forward with offsets.

Examining the factors summarized in Section 2 allows a systematic approach to offsets. Nevertheless, additional information will be needed before numerical values can be estimated for multipliers. Some of this information can be difficult to obtain. The more significant subproblems include (i) measurement of losses, (ii) prediction of gains, including development of restoration recovery functions and avoided loss functions, (iii) verification of the degree of additionality of actions, and (iv) quantification of leakage. When this information has been compiled once, at least some of it can be reused in projects that concern the same environment in the same region (Moilanen and Kotiaho, 2018).

### 3.2. Flexibility and other conceptual issues

The ecological reality of measuring ecological losses and predicting ecological gains fits poorly with the phrasing of the often-stated goal of offsetting, in-kind NNL compensation. A degree of flexibility is unavoidable and in-kind NNL can only be achieved at some simplified level of measurement (Quétier and Lavorel, 2011; Maron et al., 2012; Bull et al., 2013). Even the very definition of NNL turns out to be subjective (Section 2.1.2). There will be flexibility in space, time and biodiversity (Bull et al., 2015; Moilanen and Kotiaho, 2018). Flexibility in space is unavoidable, because the offsets simply cannot be done at the development site itself. There will be flexibility in time because losses are almost immediate but full restoration and avoided loss gains only materialize after a time delay of up to decades or even centuries (Moilanen et al., 2009; Maron et al., 2012; Spake et al., 2015). There will be flexibility in biodiversity and ecosystem services, because what you lose cannot be replaced exactly: individual animals are unique and so are ecological communities. Flexibility is therefore unavoidable, and the question is not whether it should be allowed or not. Instead, the real question is active decision about the degree of flexibility allowed (Bull et al., 2015).

Also suspect is the mitigation hierarchy, which is in reality more of a web than a hierarchy. The steps of the mitigation hierarchy are typically described as apparently separate hierarchical stages, but it is obvious that they are in reality strongly linked. This is because development plans simultaneously influence the amount and type of ecological damage, options for local restoration, and what needs to be offset. What is done at higher levels of the hierarchy impacts requirements and options for latter levels, which suggests that all levels of the hierarchy would, in fact, be best viewed together as a package.

### 3.3. Measurement of biodiversity and ecosystem services

Biodiversity measurement drives the operational reality of offsetting, but subjective decisions are again involved. You get what you measure, which suggests measuring everything that you value. However, it is reality that accurate measurement of losses for hundreds or even thousands of species inhabiting any given hectare is infeasible. And even if losses could be measured, gains cannot be predicted exactly. So, what to do? Effectively, measurement of biodiversity and ecosystem services has to be simplified if offsetting is to be done at all (Quétier and Lavorel, 2011; Maron et al., 2012; Bull et al., 2013). Hence, the question becomes what simplification is acceptable. We suggest the following.

First, deal with generalist species, ecosystem function and ecosystem service provision using some habitat hectares (Parkes et al., 2003) type approach, effectively operating on condition-weighted area. Second, deal separately with specialist species, which have much more specific ecological requirements. Due to lack of detailed ecological knowledge, group-level estimates could be preferable to detailed analysis for individual species. Single-species analyses should only be added when legislation demands or when the species has some critical role in the ecosystem. An additional multiplier can be applied to compensate for simplified biodiversity measurement, thereby increasing confidence in the adequacy of the offset (Moilanen and Kotiaho, 2018). Excessive simplification can lead to failure in representing biodiversity in a balanced manner so care clearly needs to be taken (Walker et al., 2009; Bekessy et al., 2010)

The split between generalist and (demanding) specialist species will significantly influence the outcome of offsetting, because these groups can well have rather different recovery functions. The expectation is that generalist species return comparatively rapidly and reliably after habitat restoration. In comparison, return of specialist species may be very slow and uncertain (Suding, 2011; Maron et al., 2012; Curran et al., 2014; McAlpine et al., 2016). Consequently, the higher the emphasis on specialist species, the higher the multiplier needed. Again, there is subjectivity involved in the relative valuation between generalist species and ecosystem services vs (often rare) specialist species.

### 3.4. About design and implementation risks

If offsets are inappropriately designed, then NNL will fail even if implementation is done honestly and completely, which emphasizes the importance of getting the design right and accepting whatever actions and multipliers come out. Additionally, it is necessary to caution about widespread failure in the implementation of offsets. A study in Australia found that less than 37% of offsets led to any offset actions at all (May et al., 2017), implying complete implementation failure in 2/3 of cases. In Canada, it was evaluated how well the mitigation hierarchy and ecological compensation achieved NNL in 558 projects in wetland environments during years 1990–2011 (Poulin et al., 2016): they found a staggering 99% net loss of ecological values. In Sweden, there has been an evaluation about ecological compensation in the context of transport infrastructure projects (Persson et al., 2015), and it was found that over 90% of communes had never used ecological compensation, and when used, they targeted small environments with a 1:1 offset ratio, which clearly cannot deliver anything even ballpark close to NNL (Section 2.6). Avoided loss baselines have been based on demonstrably false assumptions (Maron et al., 2013), and one study found that baseline declines had been estimated five times steeper than plausible based on scientific evaluation (Maron et al., 2015). In France, offsets have been adopted widely due to new legislation, but deployment has been extremely difficult (Quétier et al., 2014). Likewise, in England deployment of offsets has run into serious disagreements when implementation has been attempted (Lockhart, 2015).

Even if a single offset project is credibly NNL, there may be indirect negative effects that reduce the overall net benefits of offsetting (Gordon et al., 2015; Ives and Bekessy, 2015; Spash, 2015; Levrel et al., 2017). These include the following. (i) Voluntary nature conservation may become reduced when the new possibility for profiting from conservation becomes public knowledge (Gordon et al., 2015). (ii) False public confidence in biodiversity offsetting when offsets seem to guarantee NNL almost by definition (Gordon et al., 2015). (iii) Replacement of other mechanisms of nature conservation when new market-based mechanisms take hold (Gordon et al., 2015). (iv) Utilitarian ethics increasingly replace ethical-moral arguments in the relationship between people and nature (Ives and Bekessy, 2015). Rights of species become reduced (e.g. Apostolopoulou and Adams, 2017). (v) Reduced importance given to place-based values (Gordon et al., 2015; Apostolopoulou and Adams, 2017; Levrel et al., 2017). Local people can suffer irreplaceable (non-economic) damage. Ecosystem services become redistributed; losses are born and benefits gained by different people and stakeholders (Levrel et al., 2017). (vi) Financialization of nature brings potentially significant but difficult to evaluate long-term risks. Taking biodiversity offsets into use is a big step in this process (Spash, 2015). (vii) Potential for fraud is greater than usual in the context of biodiversity offsets business. Poor measurability, difficult valuation, complexity of determining offsets, difficulty of monitoring, and potentially large monetary interests might plausibly attract fraudulent activity (Moilanen and Kotiaho, 2018). (viii) Use of inexpensive partial compensation to benefit (greenwash) the image of a business. (ix) Overall economic activity becomes increased. Indirect environmental damage though the life cycle of new products would typically not be accounted for in offsetting.

### 3.5. To conclude, what is the right question to ask?

We conclude with thoughts about whether offsets can be made work? First, yes offsets can be made work in some environments. With proper design, large enough area and effort in implementation, and perhaps utilizing NPI/NG and trading up, there will be cases in which offsets can work. Can they fail? Yes, absolutely, and there are plenty of examples and reasons for failed offsets (previous Section). The worst case is if incompetent design principles are adopted at a national level, after which all offsets from now to eternity fail NNL. There will also be environments, including late-successional habitats that take centuries to develop, in which in-kind offsets are not credible. Opening up ecologically high-quality areas for development and getting back a pittance from degenerate offsets is a poor outcome for the environment.

But are these the correct questions? One could also ask whether offsets are better than the present business-as-usual, which can allow development without any ecological compensation at all (this of course varies between countries)? Yes, offsets probably can improve upon the present, especially if offsets are voluntary and hence additional compared to business as usual. Importantly, they might also guide activity towards environmentally less damaging practices. A lot will depend on how the regulation of offsets is implemented in legislation and administration.

However, the real question is perhaps whether offsets are the best we could have? To that our opinion is that probably not. As a negative for offsets, they are complex to understand, design, and implement, which places a huge burden on officials if offsets are deployed large scale (Quétier et al., 2014). Also, economic growth and associated increasing resource use is the major environmental burden on our planet (Rockström et al., 2009). Simpler than offsets would be, e.g., real taxes on the use of resources and energy, the income from which would be channeled back specifically to the maintenance of our environment.

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## Author contributions

A.M. originated the structure of this study. A.M. developed the material and prepared the text with contributions from J.S.K.

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