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Structured analysis of conservation strategies applied to temporary conservation

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ABSTRACT

We present a novel framework for the structured analysis of conservation strategies, concentrating on their conceptual, causal, logical and qualitative aspects. The analysis both increases our understanding of conservation strategies and provides a tool for supporting their use in decision making. It facilitates answering such questions as: What are the basic characteristics of the strategy? What are its biological targets? What are its aims, paths of influence and expected benefits? Where should the strategy best be applied and by whom? How should the strategy be applied over time? What are the data needs? What major assumptions underlie the strategy? Which are the major costs, constraints, and uncertainties that might influence its feasibility and application? How does the strategy relate to other conservation strategies? Are there viable alternatives? We also examine the emergent properties of the strategy, asking what the world would be like if the strategy was applied extensively. We examine the usefulness of structured analysis by applying it to the strategy of temporary conservation, which incorporates dynamic reserves and temporary conservation contracts, either to maintain a regional distribution of successional habitats or to facilitate climate-change induced range shifts of species. This application showed that these strategies have appeared under various names, that they require extensive data, that implementation involves significant uncertainties, and that associated uncertainties increase through time. Applying the proposed framework to a range of conservation strategies would improve our ability to identify most appropriate paths of conservation when many alternatives exist.

1. Introduction

Many conservation problems are complex. Choosing an appropriate response strategy to resolve a complicated problem necessitates identifying the problem correctly (Caughley and Gunn, 1996), interpreting evidence for the effectiveness of different strategies (Sutherland et al., 2004; Dicks et al., 2013), and adequately implementing the chosen action or strategy (Knight et al., 2006, 2010). Basic understanding of the qualitative and quantitative features of the conservation problem, and possible responses to it, are fundamental to the decision. In this paper, we present a novel framework for the structured analysis of conservation strategies, concentrating on their conceptual, causal, logical and qualitative aspects. It allows partitioning a conservation strategy functionally and behaviorally into a logical representation, such as those used to design information systems (Grady, 2009; Pressman, 2009; Wieringa, 2011). The analysis involves classifying and comparing conservation strategies according to their properties. We also use graphical tools to clarify complex relations.

Structured analysis comprises a group of techniques in software engineering and systems analysis used for dealing with complex, multifaceted problems, such as controlling air traffic safely at busy airports (Grady, 2009), or energy management in the engines of electric vehicles (Marco and Vaughan, 2012). Typical tools used in structured analysis include concept diagrams and flowcharts, with the principal aim being to aid implementation. We adopt the term structured analysis from this literature, although there are necessarily some differences in the analysis methods for information systems and conservation strategies, due to the different nature of the complexity. The present work can be seen as one way of organizing complexity inherent in conservation decision making: creatively adopting methodologies from other sciences will broaden the options available in conservation science (Game et al., 2013).

Structured analysis can be applied to any conservation strategy or group of strategies, such as those listed in Heller and Zavaleta

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(2009). To demonstrate the application of this framework, we analyze a conservation strategy frequently called dynamic reserves (although it has multiple aliases), in which conservation shifts between areas and so is only temporary in a given site. The initial suggestion for dynamic reserves relates to the maintenance of a stable regional distribution of successional habitats. Pickett and Thompson (1978) proposed the concept of minimum dynamic area, defined as the smallest area with a natural disturbance regime that would maintain internal recolonization sources, thereby minimizing regional extinctions; this concept was later called minimum dynamic reserve size by Leroux et al. (2007). This idea has been extended to incorporate human management, with a planned dynamic shift in management over time, to include cases where natural landscape dynamics might not suffice alone.

Cumming et al. (1996) proposed a dynamic strategy for maintaining reserve systems over time within a managed landscape. Under this 'floating reserve' strategy portions of the system are periodically replaced in response to the aging of components, expected large-scale disturbance and refinements in conservation objectives. Bengtsson et al. (2003) elaborated this concept with 'temporary conservation zones', designed to provide periodic protection of fixed areas that could be moved in both time and space to track spatiotemporal dynamics of interest. Temporary forest conservation has recently been applied in Finland, where the South-Central Finland forest biodiversity program allows 'temporary conservation agreements' to be made as voluntary measures initiated by the landowner (Juutinen et al., 2008, 2012). Such conservation agreements have been studied by several authors (e.g., Hoctor et al., 2000; Knight et al., 2006; Mikusinski et al., 2007; von Hase et al., 2010).

Static and dynamic reserves (in the successional context) were compared in detail by Rayfield et al. (2008), with the objective of sustaining sufficient mature forest to maintain American Marten *Martes americana* populations in an area of managed Canadian boreal forest that experienced irregular disturbance through wild fire and logging. They found that it was possible to maintain an approximately stable distribution of successional stages, but that the performance of dynamic PAs (protected areas) was constrained by the disturbances in unprotected areas in between PA relocations. They conclude that a key component in dynamic PAs is to manage the surrounding matrix so that options remain when it comes to re-planning. Using a similar approach, Kattwinkel et al. (2009) investigated temporary conservation in an urban brownfield setting. They term the concept 'temporary conservation' as it generates mosaic cycles and excludes only some areas from development at a time, while accepting the destruction of habitat at one location but with the creation of new habitat elsewhere. One significant difference between this study and Rayfield et al. (2008) is the focus on early instead of late successional stages.

Game et al. (2009) investigated dynamic reserves in the context of marine protected area design. They found that the optimal rotation of dynamic protected area depends on the tradeoff between the recovery rate of newly protected areas (coral reefs) and the deterioration rate of newly opened areas. While this study did not find improvement in biomass across the entire reef system, they argue that large protected areas may be socially more acceptable if they are periodically open for subsistence fishing.

The second major usage proposed for dynamic reserves is adaptation to climate change, which could drive species out of reserves (Araujo et al., 2004; Coetzee et al., 2009; Hole et al., 2009). Monzón et al. (2005) showed that climate change presents an immense challenge to protected areas, but also suggest it as an opportunity to shift from managing for static, historical community composition toward managing for dynamic and novel assemblages. Hannah et al. (2007) investigated the expansion of the conservation area network of Mexico and found that climate change could result in species range dynamics that reduce the relevance of current fixed protected areas in future conservation strategies. Finding that climate change might drive species out from Europe's conservation areas, Araújo et al., 2011 noted that it would imply a major paradigm shift in current conservation policies if designation of new areas and integrated management of the countryside would be used for facilitating movement of species between conservation areas.

In their review of conservation responses to climate change, Heller and Zavaleta (2009) proposed that increased conservation effort outside reserves would be a sensible response to expected climate change. Even so, they recognized that the strategy of targeting land purchases to predicted future 'hotspots' is only suitable for risk-tolerant decision makers. The prospect of dynamic reserves has been explicitly recognized in the context of facilitating range shifts of species. One approach is to use so-called temporal corridors to connect populations through space and time (Rose and Burton, 2008). In a related work, Phillips et al. (2008) adopted a, somewhat confusingly named, concept of 'dispersal corridors', by which they mean a dynamic conservation area network of minimum size. They proposed a formalization of a minimum range size (for many species) moving, amoeba-like, through space and time, and used network flow to achieve persistence targets with the minimum possible protected area. While terminology varies, the common denominator in all these studies is repeated relocation of conservation effort as a response to predicted climate change. Outside the context of climate change, Fuller et al. (2010) proposed that a more radical approach to expanding protected area systems would be to reverse the protection status of the least cost-effective sites and use the resulting capital to establish and manage new protected areas. In summary, the present study concerns analysis of strategies in which conservation is temporary and reserves therefore spatially dynamic.

Another type of dynamic conservation area has also been both proposed and implemented for species with wide yearly movements, such as migratory birds (Martin et al., 2007) or migratory fish (Hyrenbach et al., 2000). Such species follow a regular yearly migration route and protection of the species can therefore be implemented with protection measures that move following the species. Feeding/resting/breeding grounds of the migratory species stay the same year after year, thus enabling a yearly recurring static pattern of dynamic protection. This is different from the cases we consider in our structured analysis, where habitat suitability may shift in a non-recurrent and uncertain manner.

Dynamic reserves should not to be confused with the technique called dynamic reserve site selection, whose other names include scheduling of conservation action, dynamic reserve selection, dynamic reserve design, sequential reserve selection and incremental reservation (Costello and Polasky, 2004; Snyder et al., 2004; Turner and Wilcove, 2006; Moilanen and Cabeza, 2007; Visconti et al., 2010). In this approach there are dynamics of site availability (conservation opportunity), and habitat deterioration may impact individual areas, but reserves, once established, are static. As put by Spring et al. (2010), this is about permanent protection under dynamic threats that develop through time.

We chose to focus on temporary conservation to demonstrate the structured analysis approach because it represents a relatively complex strategy, with numerous possible parameters or characteristics that could be interpreted differently. Many broad conservation strategies are similarly complex, inviting further study adopting this methodology.

2. Methods

We introduce a framework for structured analysis of any single conservation strategy or group of strategies. The main analysis comprises the classification and comparison of strategies according to properties that can be evaluated based on review and logical deduction. First, we summarize relevant operational entities and describe relations between them using an entity–relationship diagram. Second, we describe the flow of events and influence paths in a strategy using flowcharts. Third, we summarize and evaluate strategies by asking an extensive set of questions that clarify basic properties of strategies, underlying explicit and implicit assumptions, risks and uncertainties in their application, and feasibility of implementation.

2.1. Entity–relationship diagrams and flowcharts

Mappings that are commonly used in management science to arrange concepts include concept mapping (Novak and Gowin, 1984), semantic mapping (Sowa, 1999), and conceptual analysis (Snelting, 1996). Here we adopt an entity–relationship (ER) diagram (also called relational mapping), variants of which are commonly used in computer science and data base design (Chen and Pin-Shan, 1976; Teorey et al., 1986; Thalheim, 2010). Here, an ER diagram defines the meaning of, and relationships between, the operational entities used in the description of a strategy. First, the diagram serves to reduce semantic uncertainty in discussion (see Kujala et al. (2013) for a summary of classes of uncertainty). Second, ER-diagrams have the fundamental characteristic and purpose that they directly support design of data storage structures; they describe a direct and concrete linkage to data that can be collected to underlie decisions (Codd, 1979). ER-diagrams are extensively discussed in computer science text books about data base or information systems design. For example, Elmasri and Navathe (2010) discuss both conventional and enhanced ER models. Thalheim (2010) summarizes modern developments of ER models. For the present purpose we only use basic components of the conventional ER model.

Developing an entity–relationship diagram is an iterative process (Elmasri and Navathe, 2010). Entities relevant to the application at hand must be identified and described. Then, relationships between entities are described. When describing a detailed model, attributes of entities must also be described – but this step can be omitted when developing a high-level conceptual model, as we do here. The aim is to develop a diagram with all relevant entities included. It should be normalized by removing entity replication. The diagram also needs to be logically consistent internally, implying that relationships between entities join up logically in terms of their cardinalities. Cardinality, the mathematical term for the number of items that comprise a set, is used in this context to refer to the number of ways an entity can be linked to another entity (see below for further explanation). It is possible that the same entities could be arranged in several slightly different but nevertheless logical arrangements. Alternative names for entities can also frequently be chosen: for example, area, site, planning unit, or patch could be used for describing a physically bounded region of the landscape. Here we used 'area', as it is a neutral term. The alternative term 'patch' may in a spatial ecological context have the connotation of having a uniform vegetation type that separates it from the surrounding habitat matrix.

Entities in an ER diagram can be divided into three types: independent, characteristic, and associative. Independent entities, such as species, can exist on their own as single entities. Characteristic entities only exist to describe further information about other entities. 'Species distribution' is an example of a characteristic entity; it does not exist without the entity 'species'. Associative entities are used for removing many-to-many relationships from the diagram. To illustrate, it is obvious that any species can occur in zero to many areas and that an area can host zero to many species. Most areas would have many species and most species would occur in many areas. This potential many-to-many linkage is removed by the associative entity "occurrence of species in area", which links one specific area with one specific species. Entities should not be confused with attributes, which specify details about instances of entities. Name (of species) or mean elevation (of area) are examples of attributes. In database design entities link to structural elements (tables) of the database and attributes represent the information that is fed into the table.

ER diagrams use a so-called min–max notation to describe the cardinality of linkages between entities. The minimum is always either zero or one, and the maximum is either one or many. For example, a climate change scenario generates exactly one set of environmental conditions in an area, but a given set of environmental conditions can be generated by more than one climate change scenarios. As example of another type of relationship, a species has one, and only one, species distribution; a species distribution belongs to one and only one species. A common further way of classifying entities is between supertypes and subtypes. In the present case 'area' is a supertype entity that has several subtypes including 'protected area' and 'temporary conservation area candidate'.

While entity–relationship diagrams describe relationships between entities, the dynamics of systems, computational algorithms, or sequences of events are better described using other types of diagram that are able to convey the temporal order and potential repetition of events. Thus, we use a flowchart to describe the influence path of the strategy.

Flowcharts are a tool extensively used in computer science, engineering and management science to describe an algorithm or process (Damelio, 2011). Flowcharts usually include inputs, processing steps (also called activities) and decisions. Decisions are if-then-else type conditional statements, which can lead to loops and thus describe repeated activities. Elements of the chart are connected by arrows that describe the order in which activities and decisions take place. Implementation of a conservation strategy must be either a sequence of activities or a repetitive continuous process, which implies that a flowchart is an appropriate method for visualizing operational aspects of the strategy. Flowcharts are described in many computer science and management science text books (e.g., Damelio, 2011).

2.2. Strategy description tables

In addition to the standard diagrams of structured analysis, we summarize and evaluate strategies by asking two sets of questions that we expect to be relevant in the context of conservation strategies. The first set identifies properties that can be interpreted as basic properties of strategies (Table 1). The second set of questions delves into additional topics that may require further interpretation. The tables are aimed at clarifying the assumptions underlying strategies, the risks and uncertainties in their application, and the feasibility of implementation (Table 2). Tables 1 and 2 are provided as templates for later studies about structured analysis of conservation strategies; references included in them summarize relevant background information. They can be filled by literature review and logical deduction, as we did here. Further input could be sought from conservation practitioners.

A further component that we propose would be useful is examination of the emergent properties of the strategy (or group of strategies). Emergence is a well-known phenomenon in the study of complex systems (e.g., Frei and Di Marzo Serugendo, 2011), or

Table 1
Questions about basic properties of conservation strategies. "Applicability" refers to the types of strategies that each question can be used to evaluate, where "Info", "Pol." and "Impl." refer to information, policy and direct implementation strategies, respectively.

Question	Applicability	Explanation
Name and aliases	All	(i) Most common names of the strategy (ii) What aliases and small variants of the name can be found?
Type	All	(i) The broad type of the strategy on the information–policy–implementation axis (ii) The relationship of the strategy to accommodating change, i.e. the resistance–resilience–transformation axis (Heller and Zavaleta, 2009; Poiani et al., 2011).
Why	All	Primary aims of the strategy considering the multitude of possible goals and objectives in conservation (Lindenmayer et al., 2008; Mawdsley, 2011).
What	(i) Info, Impl. (ii) All	(i) Biological targets, ranging from genes, populations, individual species, ecological communities/ecosystems, to all of biodiversity. Also threats can be targets (ii) Expected benefits: reduced loss of biological targets, recovery of biota or ecosystem services (Lombard et al., 2003; Brooks, 2006)
Where	(i) All (ii) Impl.	(i) Where should the strategy be applied; is it best applicable locally, regionally, or globally (Opdam and Wascher, 2004)? (ii) Are its effect locally concentrated or diffuse through space (Dauber et al., 2005; Gaston and Fuller, 2008)?
Who	(i) All (ii) Pol., Impl.	(i) Who might be interested in applying such a strategy; private people, scientists, local organizations, national administrators, international collaborative bodies or global NGOs, etc.? (ii) To what extent should stakeholder involvement be expected (Knight et al., 2006)?
When	Impl.	(i) Is it an implement-in-one-go type of a strategy or does it require sustained effort over a longer period of time (Knight et al., 2006)? (findings of information strategies can be considered permanent) (ii) How long is the duration of its influence (e.g. Bengtsson et al., 2003)?
How	All	How is the strategy implemented and what are its paths of influence, possibly described using a flowchart
Defining characteristics	All	Main defining characteristic(s) that separate the strategy from other approaches to conservation

Table 2
Fundamental properties and feasibility of strategies.

Topic	Applicability	Explanation
Major underlying assumptions	All	The major explicit or implicit assumptions or postulates that underlie the strategy (Meir et al., 2004).
Direct and opportunity costs	(i) All (ii) Impl.	How costly would one expect the strategy to be in terms of (i) direct and (ii) opportunity costs; would there be high spatial variance (Faith and Walker, 2002; Watzold and Schwerdtner, 2005; Naidoo et al., 2006)?
Data needs and availability	All	Data needs of the strategy, and, if possible, assessment of data availability (Hannah et al., 2002; Brooks et al., 2006)
Other constraints	All	Other constraints (in addition to costs) on the application of the strategy, e.g. in terms of human resources, administrative boundaries, and socio-political or ethical objections (Sarkar et al., 2006; Knight et al., 2006)
Risks, unintended consequences	Pol., Impl.	Risks in the application of the strategy (e.g. Ricciardi and Simberloff, 2009), in particular from the perspective of (i) stakeholders and (ii) biodiversity
Uncertainty	All	High-level uncertainties associated with the strategy as classified by Kujala et al. (2013) under categories of semantic, epistemic and human decision uncertainty
Conflicts	All	(i) Conflicts with other land uses (ii) Conflicts with other strategies
Synergies	All	(i) Co-existence with other land uses (ii) Synergies with other strategies
Overall feasibility	All	An estimate of how feasible the implementation of the strategy would be in general, accounting for the constraints above
Related alternatives	All	(i) Are there related alternative strategies that might be considered? (ii) Could the strategy be potentially confused by some other strategy, keeping in mind that usage of terminology may sometimes be unstable in rapidly developing literature?

for example in the study of schooling behavior of fish (Parrish et al., 2002). Repeated application of even a simple rule can lead to an outcome that appears organized and coordinated in a broader context. It is our expectation that conservation actions could also display such emergent behavior. What would the world be like if a specific strategy was applied extensively? This question might be illuminated by logical analysis, mathematics or even empirical observation: details would depend on the strategy in question and, in complicated cases, might be best answered by separate study. With respect to analysis, here we analyze the emergent properties by thinking through worst-case and best-case scenarios. Worst-case and best-case analyses are usually much easier to implement than analysis of average case, which requires that distributions of inputs are both fully known and tracked through evaluation (Jiang et al., 2000).

2.3. Linkages to other decision making in conservation

Our description of structured analysis bears superficial similarity to structured decision making (SDM), means-end networks used in SDM, and to results chains used following the guidelines of the Conservation Measures Partnership (Conservation Measures Partnership, 2013). SDM is about collaborative and facilitated application of multiple objective decision making (reviewed by Gregory et al. (2013)). It is about combination of science, human values and societal considerations, aiming to identify demonstrably effective plans that can survive broad scrutiny across stakeholders. A results chain is a tool that provides a graphical depiction of how conservation actions or strategies are expected contribute to reducing threats and achieving conservation targets (Conservation Measures Partnership, 2013). They link how many factors, processes and intermediate objectives can contribute to the achievement of a broader conservation goal. Both these methodologies resemble the present structured analysis for example in that the problem is partitioned and that diagrams may be utilized to describe chains of events. But, the scope of these analyses is different. SDM, means-end diagrams and results chains are about a specific real-world case where a sensible outcome needs to be reached. In contrast, the present analysis is about conceptual-logical analysis of a conservation strategy in general. In essence, we do a detailed analysis of one tool that could be utilized as one component within SDM or results chains.

3. Results

We present the results of applying structured analysis to the strategy of temporary conservation, to demonstrate how the method can be applied in practice. The first component of our analysis is construction of an entity–relationship diagram to identify entities about which data could be generated/stored to underlie analysis. In our interpretation (Fig. 1), a landscape consists of one or many areas, which could be permanent protected areas, other conservation areas, existing or candidate temporary conservation areas. Conservation objectives can be set to species. Conservation performance of the corresponding objective is evaluated from the distribution of the species, consisting of occurrences in areas through time. Temporary conservation agreements influence the disturbance regime or succession in an area, which influences environmental conditions (incl. connectivity and habitat structure and condition) in the area, which in turn influence habitat suitability for a species in the area, which influences the expected occupancy of areas by species. Note that we use species instead of the more general term biodiversity feature because much of the literature on temporary conservation comprises species-level analysis. Feature could be used instead of species without any structural change in thinking. Likewise, agreement could be replaced by contract.

The process of drawing the entity–relationship and influence path diagrams (Fig. 2) to identify the structural features of the temporary conservation strategy made it obvious that this strategy should be treated as two separate sub-strategies with different aims: *A1*, where temporary conservation serves to maintain a representative set of successional habitats in the context of ongoing ecological succession; *A2*, where temporary conservation provides for movement of species through landscapes in the context of large-scale environmental change, particularly climate change. The mechanistic influence paths of sub-strategies *A1* and *A2* are approximately as follows (Fig. 2): (*A1*) either habitat management or disturbance (natural or human) produces successional dynamics in which typically either early or late successional stages are critical for many species. Conservation measures are applied regionally to ensure a sufficient density (and possibly spatial pattern) of these successional stages. Conservation areas are then relocated periodically as succession or contract termination makes an old area unsuitable or succession makes new areas candidates available for (temporary) conservation. (*A2*) Ranges of species are predicted to shift due to climate change. Species distribution models coupled with climate change models predict a (directional) movement of suitable habitat through time. Resources are insufficient to protect

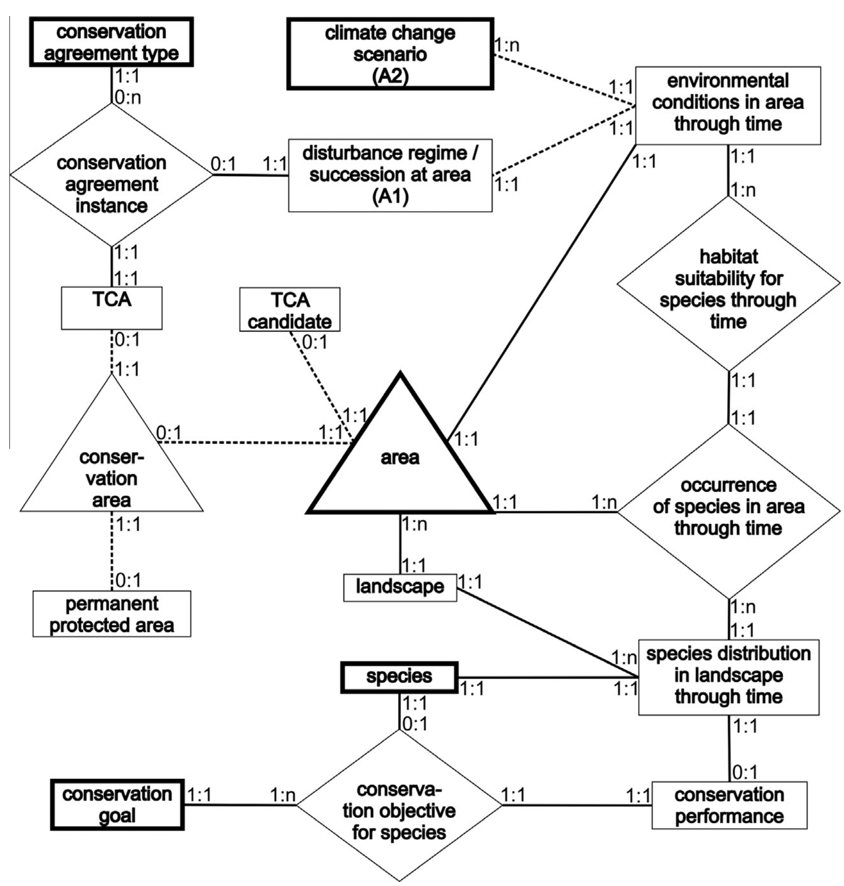

Fig. 1. Entity–relationship diagram, showing the order of relations between main entities used in the description of the conservation strategy. Independent entities are marked in boxes with thick lines, characteristic entities with thin lines, and associative entities with diamonds. 'Area' is a supertype entity (marked by a triangle) with several subtype variants deriving from it. Linkages to subtypes are marked with a dotted line. The numbers marked next to a relationship indicate the minimum:maximum cardinality of the relationship denoted by following the line towards (not away from) the numbers. To illustrate, a landscape includes one or many areas and each area belongs to exactly one landscape; similarly, an area can be, but does not have to be, a conservation area but a conservation area is always exactly one area. TCA = Temporary Conservation Area. (*A1*) and (*A2*) refer to two alternative aims of the strategy: (*A1*) To maintain sufficient successional habitats regionally, or (*A2*) to facilitate range shifts of species due to climate change.

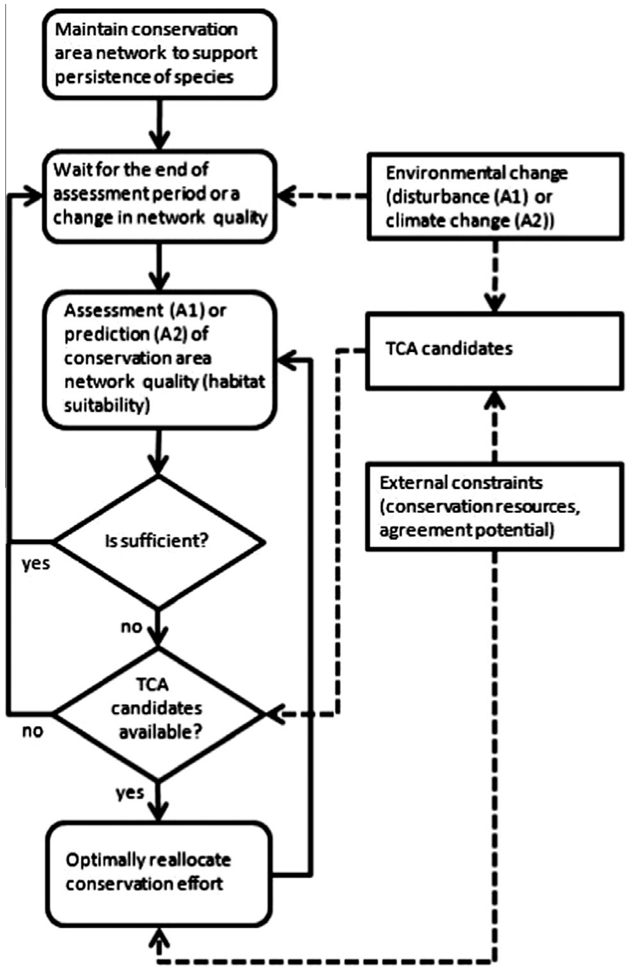

Fig. 2. Influence paths of temporary conservation presented as a flowchart. Rectangles denote external entities, rounded rectangles denote processes, diamonds denote conditionals; solid arrows denote the decision flow and dashed arrows denote constraints. The starting point is the upper left-hand corner (maintenance of the reserve network). There is no end point as temporary conservation will continue to alternate between assessment of the network quality and reallocation of conservation effort triggered by changes in habitat quality or availability. Site selection is constrained by habitat dynamics and resources. The diagram applies to both aims *A1* and *A2*. TCA = Temporary Conservation Area.

large and sufficiently continuous areas to allow species to shift range through high-quality habitats (early or late successional, as appropriate). Therefore, a scheme is devised in which temporary conservation effort flows through the landscape with the aim of facilitating range shifts.

Table 3 summarizes the basic properties of temporary conservation, including both "dynamic reserves" and "temporary conservation agreements" as sub-strategies. Table 4 further interprets their fundamental properties and feasibility. The temporary nature of this strategy leads to uncertainty about the permanence of gains. Repeated retargeting of conservation management or protection also requires continued commitment of political will, human capital and funding resources. In the case of facilitating range shifts (*A2*), high-quality information is needed about the expected dynamics of species/habitats, and co-operation is hoped from nature so that inherently stochastic dynamics take a course close to what was expected (Table 4).

Instead of a thorough analysis of emergent properties, we summarize worst-case and best-case analyses of the strategy. For the worst-case analysis, it is apparent that temporary conservation is burdened by (realistic) potential for outright failure, meaning that conservation gains turn out nonexistent or much smaller than expected. This is because (i) this strategy relies upon the continuity of effort and resourcing to maintain the conservation program. (ii) In the case of temporary conservation contracts, there is potential for outright failure, especially with late-successional habitats that also have high economic value (e.g., old growth forests) as landowners may choose not to renew the contract and instead to exercise their legal rights to extract resources from the area (e.g., cut the forest), thereby effectively causing a complete loss of prior conservation investment.

Furthermore, examination of local versus regional gains may give a contrasting view about the effectiveness of conservation action in the case of maintaining late-successional stages. A temporary contract may lead to a reasonable expectation of a local biodiversity gain in the area. However, such gains may be illusory from a regional perspective if there is leakage and habitat loss simply relocates elsewhere. If this is the case, the resources put into temporary contracts end up being a mere windfall subsidy to landowners, suggesting overall inefficient use of conservation resources.

For the best-case analysis, it is possible that repeatedly relocated habitat management or protection could, in the regional context, successfully maintain a stable distribution of successional stages (aim *A1*, Table 3). The case is, however, different for aim *A2* (Table 3), which with even the best case would partially fail. To explain this strong assertion, consider the following. In any region there are numerous species, but for many of them the distributions and population dynamics are largely unknown. There is substantial uncertainty even for those species for which there is sufficient data for them to be included in the analysis. Predictions of moving habitat suitability will then depend on relatively uncertain predictions about the progress of climate change (Kujala et al., 2013). Expectations about the range shifts of species are compromised by uncertainty of species dispersal and, perhaps more importantly, uncertainty about their ability to invade local communities and establish populations during the range shift. Consequently, it will be easy to overestimate how well dynamic reserves facilitate range shifts, especially if the dynamically moving areas are small. Some species will inevitably fail to move as expected, so, at best, only partial success for aim *A2* should be expected.

4. Discussion

We describe a method for structured analysis of conservation strategies, aiming at improving our conceptual understanding about their properties and correct usage. The benefits of structured analysis include the clarification of concepts, terminology, and influence paths of the strategy (Figs. 1 and 2). We also added the requirement to answer a comprehensive set of questions that summarize the properties of the strategy (Tables 1 and 2). To examine the utility of this approach, we applied structured analysis to strategies that have the dominant property that conservation is temporary. As protection is just one out of many forms of conservation, dynamic reserves can be understood as a special case of temporary conservation.

The usefulness of this approach is illustrated by the revelation of a number of important policy-relevant insights about the strategy of temporary conservation that may not otherwise be obvious. For instance, the structural features of the strategy differ according to the main objective, and this affects what underlying information is important. It was quickly apparent in the analysis that here are two likely objectives in this case. If the objective is maintenance of successional habitats, it is operationally relevant whether the

Table 3
Basic properties of the strategy of temporary conservation. (*A1*) and (*A2*) refer to the two alternative aims of the strategy.

Question	Distinctive features
Name and aliases	(i) Most commonly: "dynamic reserves" or "temporary conservation agreements". (ii) Aliases: may include combinations of (temporary/dynamic/floating/moving/adaptive) + (reserves/reserve networks/conservation areas/protected areas); conservation contracts/agreements
Why	Alternative aims: (*A1*) To maintain sufficient successional habitats regionally, or (*A2*) to facilitate range shifts of species due to climate change
Type	(i) Strategy type: implementation. An adaptive element can be engineered into these strategies, making them implementation–information strategies. (ii) Mental framework: (*A1*) Resistance–resilience, maintenance of habitats and species in the region. (*A2*) Resilience–transformation: facilitating range shifts and, unavoidably, emergence of novel communities
What	(i) Targets: individual species or ecological communities. (ii) Expected benefits: reduced loss of species or populations
Where	(*A1*) Regional. (*A2*) From regional up to national and continental.
Who	This strategy requires coordinated action across a larger spatial area. Therefore, the most likely coordinating body would be a national administrator or a multinational organization. There may be a strong dependency on stakeholder and landowner cooperation
When	(i) Timing of implementation: long-term, regularly recurring activity. (ii) Duration of influence: always temporary for a single area. Semi-permanent for the entire reserve system, assuming that effort can be maintained
How	Paths of influence (Fig. 2): (*A1*) Temporary protection of successional habitats that have been generated by natural disturbance or by habitat management. (*A2*) Recurring relocation of conservation areas, following predicted or observed spatial dynamics of species or ecological communities
Defining characteristics	The defining characteristic of this strategy is that the conservation or protection status of an area is temporary, and may be discontinued after the landscape changes, species move or the contract period ends

Table 4
Fundamental properties and feasibility of the strategy of temporary conservation.

Topic	Distinctive features
Major underlying assumptions	(i) Permanent conservation areas will not be adequate, because environmental conditions and/or habitat quality in the candidate areas will become unsuitable in the future. Alternatively, resources are insufficient for establishing permanent PAs extensive enough to maintain natural spatial dynamics. (ii) Dynamic reserves will be more cost-effective than permanent reserves, even when uncertainties are taken into account. (iii) Long-term, regularly recurring conservation effort can be maintained and coordinated. (iv) Information is sufficient for well-informed implementation of a dynamic system of conservation areas
Direct and opportunity costs	(i) Direct costs: large because of recurring operations that require planning and implementation. (ii) Opportunity costs: significant due to large land areas impacted, but nevertheless limited, because areas stay protected only for a limited time, thus easing constraints on alternative activities
Data needs and availability	(*A1* and *A2*) High, including information about habitat dynamics, dispersal and colonization of habitats as well as land uses and availability. (*A2*) Additional information about expected climate change in the region
Other constraints	High skill levels are required for confident design and evaluation of dynamic reserve systems. High resources needed in implementation. In the case of aim *A2*, implementation might span multiple countries or other administrative units, therefore requiring collaboration between multiple parties and reducing confidence in positive outcome. Overall, a "high maintenance" strategy
Risks, unintended consequences	(i) To stakeholders: high risk of conservation activity failing to produce expected benefits. This is because of the long time frame of implementation and continued need of resourcing. (ii) To biodiversity: can realistically only be implemented for a small number of species, leaving consequences uncertain for most of biodiversity
Uncertainty	(*A1* and *A2*) Major uncertainty about the continuity of sufficient resources for recurrent planning and implementation. (*A2*) Major epistemic (knowledge) uncertainty about how species will respond to climate change and about the reliability of dynamic reserves in facilitating range shifts. Following the terminology of Kujala et al. (2013), major human decision uncertainty about what are the species and habitats whose dispersal will be facilitated
Conflicts	With permanent protection. Indirect conflict between strategies that would aim to maintain species locally instead of using resources for facilitating range shifts. (*A2*) Possible conflicts about costs of implementation between different administrative regions
Synergies	(*A2*) Can provide additional information about species responses to climate change
Overall feasibility	Low feasibility because of high uncertainty and high demands for data, human resources and money. Depending on perspective, complexity might either support (=based on cutting edge science) or hurt (=too complex to work) credibility of temporary conservation
Related alternatives	(i) Maintenance of natural succession regimes by permanent protection of large enough areas (*A1*). (ii) Conservation easements, which differ from aim *A1* in that they have generally been used as permanent protection measures (Main et al., 1999). Unlike the adaptive measures of aim *A2*, they are primarily aimed at static goals (Greene, 2005; Richardson, 2010). Furthermore, they usually allow development to take place alongside protection (Rissman et al., 2007). (iii) Incentive schemes which in general, lack direct conservation effects (Ferraro and Simpson, 2002). (iv) Dynamic reserve site selection, in which a permanent conservation network is built incrementally over many years, accounting for expected habitat deterioration and dynamics of land availability for protection (Costello and Polasky, 2004). (v) Facilitation of the local adaptation of species to climate change (*A2*). (vi) Adjustment of reserve boundaries to capture small-scale distribution shifts of species (Welch, 2008)

question is about early or late successional habitats. Early successional habitats need constant renewal, making temporary conservation strategies useful. If the question relates to (economically valuable) late successional habitats, the objective is avoidance of land conversion. If the objective of dynamic reserves is facilitation of range-shifts of species, high data demands and major uncertainty will enter the scheme, because the ultimate degree of climate change and the subsequent responses of species are largely unknown (Millar et al., 2007; Table 4). The rate and scale of projected climate change make apparent our lack of knowledge on ecosystem, community, and species range dynamics, quite plausibly overwhelming any ability to manage effectively using this strategy (Monzón et al., 2005).

It is apparent from analyzing the basic features of temporary conservation as a strategy (Tables 1 and 3) that is important to monitor its effects at regional or landscape scale. The ecological effects of a conservation strategy can be examined via its net effects on habitat area, habitat quality and connectivity for many biodiversity features (Hodgson et al., 2009, 2011). It is not sufficient to consider only the local effects of the strategy, but an overall assessment of the effects across the landscape is required. Taking a simple example, temporarily protecting a plot of mature forest does not have much net effect if forest clearance just shifts to other mature forest – a process often called leakage or displacement (Pence et al., 2003; Ewers and Rodrigues, 2008; Brooks et al., 2009), and the plot itself becomes available for resource extraction after the temporary protection ends. Temporary local gain can become a long-term regional loss.

One major underlying assumption identified by the structured analysis is that dynamic reserves are more cost-effective than permanent reserves (Table 4). This assumption needs to be carefully examined for individual cases. For temporary conservation, the transaction costs of establishing and maintaining contracts are an important aspect of the direct costs (Table 3). These depend on whether an administrator can move reserves freely or whether fixed-term contracts have to be recurrently negotiated with landowners. The area under conservation may increase if temporary contracts (agreements) are much less expensive than permanent ones (Lennox and Armsworth, 2011). Signing contracts for larger areas may be relatively more cost-efficient as the price of establishing the conservation contract may be only weakly dependent on land area (Knight et al., 2010). On the other hand, recurrent costs of maintaining, communicating, monitoring and enforcement of the contracts can become much higher than expected (Ando and Getzner, 2006; Game et al., 2009; von Hase et al., 2010), thus reducing what remains for on-the-ground operations.

The optimal contract length for temporary conservation depends on how the length of the contract influences both ecological effects and the willingness of landowners to participate (Armsworth and Sanchirico, 2008; Ando and Shah, 2010; Lennox and Armsworth, 2011). Longer contracts lead to greater ecological benefits, while landowners are generally more willing to accept short contracts (Guerrero et al., 2010). Lennox and Armsworth (2011) similarly find that long contracts should be preferred when future site availability becomes more unlikely – an argument in favor of permanent protection when site availability is unknown.

Unlike permanent conservation areas, a temporary conservation program is particularly sensitive to reduced funding. This problem is highlighted as an assumption and as a risk in Table 4. The strategy *assumes* long term conservation efforts can be maintained, and *risks* future loss of resources. In temporary conservation, increased conservation now is potentially paid for by reduced conservation in the future, which could be justified when temporary measures are only needed to help a population through a temporary bottleneck (Phillips et al., 2008; Vos et al., 2008; van Teeffelen et al., 2012). Rayfield et al. (2008) found that the effectiveness of dynamic reserves compared to permanent ones was limited by a regional limit on the density of mature forest stages.

If reduced human impacts lead to increasing habitat quality through time, as it does for maturing and old-growth forests, temporary protection has worrisome aspects if failure to renew a contract can cause an outright loss (Skaggs et al., 1994; Juutinen et al., 2008). It has also been observed that existing protected areas are good in facilitating range shifts of species in the context of climate change (Thomas et al., 2012), counteracting the argument about the need for dynamic reserves in the rest of the landscape. While existing protected areas might not be spatially optimally positioned, their overall habitat quality is relatively good for many species due to long-term reduced human impacts. On the other hand, if habitat quality is highest during an early successional stage, and if natural disturbance generates insufficient habitat densities, then there is hardly any alternative to temporary conservation via active habitat management. In traditional agricultural vegetation types, abandonment of habitat management leads to loss of biodiversity (Bolliger et al., 2011).

The operational logic of dynamic reserves largely aims at facilitating range shifts of species as response to climate change, but connectivity to colonization source areas is also important in the maintenance of successional habitats (Rayfield et al., 2008; van Teeffelen et al., 2012). This is particularly relevant when the spatial properties of a conservation area network can be influenced by management decisions. Van Teeffelen et al. (2012) review how network properties and habitat turnover influence population persistence. As dispersal characteristics and connectivity vary widely between species it is difficult to propose solutions that would be ideal for most species simultaneously. This consideration is identified by the structured analysis as a risk in Table 4. For biodiversity, an appropriate temporary conservation strategy can only be implemented properly for a small number of species, because of the data requirements.

So what does our structured analysis tell us about whether temporary conservation strategies are useful? In our subjective opinion, the answer is clearly positive for the maintenance of early successional habitats. For the maintenance of late successional habitats, permanent protection may be considered instead, so as to avoid loss of investment after the end of the contract period. Considerable uncertainty and potential loss of investment are problematic also for the facilitation of range shifts of species, suggesting that dynamic reserves should be applied with care, if at all.

There are limitations to the present analysis. While it may reliably tell whether a strategy is a poor fit to a specific conservation planning case, it cannot tell if a strategy is the best alternative among many. It does not address what combinations of strategies make most sense in general or in a specific case. It does not tell us how to come up with sensible candidate strategies in the first place. It does not provide original empirical evidence as to how successful the strategy has been in application. It does not in its basic form go into deep analysis of the emergent properties of a strategy – this would in many cases require additional work.

As a final consideration, the structured analysis of conservation strategies we propose here fits very well into the evidence-based conservation framework that has been developing over the last 10 years, with the aim of improving the effectiveness of conservation management decisions (Sutherland et al., 2004; Pullin and Knight, 2009; Keene and Pullin, 2011; Dicks et al., 2013). Evidence-based conservation is a set of developing methods for incorporating empirically observed evidence into conservation decisions. So far, it happens through systematic review (Pullin and Stewart, 2006) and synopsis (Williams et al., 2013), sometimes combined with expert evaluation to summarize evidence at a level of detail and format useful to decision makers (Sutherland et al., 2011; Dicks et al., 2013). When comparing conservation actions, the evidence-based approach can be applied to detailed individual actions or large scale overarching strategies. It records and synthesizes whatever evidence is available, but it does not consistently consider the underlying assumptions, emergent properties, risks or feasibility of different strategies. Yet such considerations are crucial in decision making (Segan et al., 2011). The present approach is intended as a logical top-down investigation of the properties of conservation strategies, to complement bottom-up synthesis of the empirically observable effects of individual conservation actions. While the present approach is predominantly theoretical, conservation practitioners should ideally be involved in completing the questions tables (Tables 1 and 2). This would help capturing important elements of practice and knowledge that are poorly documented in scientific literature.

To conclude, the closely related pair of strategies evaluated here are but a small fraction out of dozens of strategies that have been proposed as solution to present-day conservation problems (Heller and Zavaleta, 2009). Replicating structured analysis for each strategy would improve our understanding about its fundamental properties and applicability, thereby facilitating well-informed choice between conservation strategies.

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