Supplementary Material

Nicholson et al. (2018) Scenarios and models to support global conservation targets. Trends in Ecology & Evolution. *DOI: 10.1111/cobi.12918*

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Table S1: List of all Aichi targets summarising how their formulation, implementation and review could be informed by scenarios and models, and the degree to which that potential has been met to date, with examples from local to global scales; the interactions between the Aichi targets, showing the strong influences of each target on other targets, and the strong influences of other targets on each target, as identified by [1]; and linkages with SDG targets [2] (where ★ refers to a weak relationship, ★★ refers to moderate relationship and ★★★ refers to a strong relationship). Quantitative elements of targets are underlined (our emphasis).

In this table, we address targets that relate to the application of quantitative biophysical models of biodiversity and ecosystem services, including models of interactions between humans and their environment (e.g. linked social-ecological models) with biophysical models included. Thus, we have not evaluated the roles of scenarios and models in Targets 1, 2, 16, 17, 18, 19, 20 (shaded in grey), to which such models have limited use for scenario projection [3, 4]; we note however that other types of models and theory may be applicable to these targets, including uptake of knowledge, human behavioural responses, governance, and marketing [5-11]. The numbers in the table refer to the literature exemplifying how scenarios and models have or could be used; the references are indicative not comprehensive. Studies that examine all targets include Tittensor et al. [12], with statistical projections of indicators for 16 of the 20 targets based on current trajectories, Global Biodiversity Outlook 4 [3, 4], which also includes scenario analysis, and Hill et al. [5], who analyse the likelihood of each of the targets being met based on a social-ecological analysis.

The level of development ranges from: the need for development of theory to support a target's formulation and implementation; to targets with many relevant examples in the literature but little evidence of application; to targets where there is some evidence or examples of influence of scenarios and models in a target's formulation, implementation and review, suggesting that models and scenarios are an accepted tool within the related disciplines. Where theory and models exist, there is great opportunity for collaboration between policy-makers, managers and modellers to maximise uptake and use of scenarios and models. Targets with few examples highlight opportunities for collaborative research between policy-makers and modellers to develop the theory needed for use and influence.

This summary table excludes the Agenda-setting phase of the policy cycle, as models and scenarios used in that context tend to have a broad scope that is beyond the specific targets. We focus on the potential for influencing reformulation of targets, though do highlight some examples where models and scenarios may have influenced targets. Models and scenarios may be developed and used for several purposes: to assist understanding of the response and dynamics, including analysis of past data, exploratory scenarios, evaluation of indicators of change, risk assessment; for policy screening and target seeking, including optimisation approaches and specific strategy or policy evaluation; and to analyse past trends and provide counterfactuals for comparison with current or past, to evaluate actions.

Aichi Target	(re) Formulation	Implementation	Evaluation and Review	Strong influence on targets [1]	Strongly influenced by targets [1]	Links with SDGs [2]
Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society						
1. *By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.*	Model impacts of increased awareness on behaviour.	Use goal seeking and policy screening models and scenarios.	Counterfactual around differing levels of awareness and action.		17, 19, 20	★ 4.7 ★★ 12.8
2. *By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.*	Model impacts of accounting requirements on behaviour and compliance.	Explore effects of different implementation mechanisms (reporting requirements) on uptake and effect; Impacts of governance structures and policies [13, 14].	Counterfactual around differing levels of accounting requirements.	3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20	3, 17, 20	★★★ 15.9
3. *By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio-economic conditions.*	Generate data on subsidies and incentives; Use policy screening to assist wording of target for maximum effectiveness, e.g.: Identifying subjects of positive subsidies [15, 16], Identifying trade-offs/synergies/conflicts between different targets/policies [17] such as biofuels [18-20].	Screen potential effect of different levels of subsidies and incentives; Seek optimal combinations, and explore alternative scenarios on, e.g.: carbon pricing [21], agriculture [22-24], biofuels [25], fisheries [26, 27], dam construction [23], REDD and REDD+ [28, 29].	Explore impacts of current (perverse) subsidies and compare against incentive-based policies, hindcasting and counterfactuals, e.g.: in fisheries [26], agriculture [30] and land-use [29], measuring progress toward target under imprecise information [31].	2, 4, 5, 6, 7, 8, 10, 14, 15	2, 4	★★ 14.6
4. *By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.*	Explore levels of change required to achieve aim of sustainable production; Pathways to achieving targets [32, 33]; Identifying sustainable levels of consumption [34].	Projecting future levels of sustainability (in relation to biodiversity) under different scenarios of, e.g.: Consumption [35], International trade [36], Identification of trade-offs between different policies (e.g. emission reduction via bioenergy vs. habitat	Counterfactual based on relationship between resource use and biodiversity loss; Consider implications of alternative population growth scenarios [29].	3, 5, 6, 7, 8, 10, 13, 14, 15	2, 3, 6, 7	★★ 8.4, 9.4 and 12.2

Aichi Target	(re) Formulation	Implementation	Evaluation and Review	Strong influence on targets [1]	Strongly influenced by targets [1]	Links with SDGs [2]
		protection) [29, 34, 37, 38] and pathways [39].				
Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use						
5. By 2020, the rate of loss of all natural habitats, including forests, is <u>at least halved</u> and where feasible brought <u>close to zero</u>, and degradation and fragmentation is significantly reduced.	Consider interaction with other targets [40-42]; development of harmonised scenarios and intermodal comparison protocols [43]. Evaluate implications of alternative wording, definitions, and quantitative targets.	Consider rates of habitat conversion and costs under different policies and scenarios [14, 21, 23, 29, 40-42, 44-47], e.g.: Protected areas [48], reduced or no meat diet [48, 49], agricultural efficiency [48, 50-52], climate mitigation [53], agricultural expansion [54], economic incentives [55], effect of GHG emissions scenarios on distribution of trees [56, 57], estimating habitat loss [58].	Analyse existing trends and assess scenarios accounting for uncertainties in plausible futures [45, 59]; Review and projection of progress under business as usual [60]; Protected area counterfactuals [29, 59].	7, 10, 11, 12, 14, 15	2, 3, 4, 7, 10, 11, 15, 17,20	★★★ 15.2 and 15.5
6. By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.	Current formulation incorporates terms that can be interpreted as quantitative reference points [61], typically defined using models (see Box 1); Further development could explore implications of alternative exploitation and management regimes for biodiversity (species and ecosystems) [61-65].	Simulate potential policy changes and whether they deliver on objectives or have unintended consequences [66]; Define reference points [6, 65, 67-70].	Consider best possible performance given the global, national, local context etc.; Models to examine recent trends, projected progress [71], status and indicators [70, 72-76], potential effects of climate change on recovery plans [77].	4, 10,12, 13, 14	2, 3, 4, 11, 14, 20	★★★ 14.4 ★ 14.7
7. By 2020 areas under agriculture, aquaculture and forestry are managed	Assess alternative management schemes,	Evaluate impacts of different management and industry	Counterfactuals, e.g.: Sustainable grazing [87];	4, 5, 8, 10, 12, 13, 14, 15	2, 3, 4, 5,14, 15 20	★★ 2.4 and 12.2

Aichi Target	(re) Formulation	Implementation	Evaluation and Review	Strong influence on targets [1]	Strongly influenced by targets [1]	Links with SDGs [2]
sustainably, ensuring conservation of biodiversity.	production implications, potential trade-offs, and whether target is attainable, under which circumstances [14, 46, 78]; Effects of different or multiple priorities or objectives on biodiversity, sustainability [79] or ecosystem services [80].	practices, policies, subsidies, land-use choices [14, 46, 78, 81, 82], e.g.: Multi-action pathways [83], land use (protection, bioenergy, plantations) [84], economic agricultural policy [85, 86], grazing intensity [87], meat consumption [88].	Reviews, e.g.: Impacts of sustainable agriculture on biodiversity across the world [89].			
8. By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.	Determine detrimental levels of pollutants (individually and interacting) e.g.: projecting N to 2020 [90], planetary boundaries of pollution [91, 92].	Screen costs and benefits of alternative management and policy scenarios, regulatory and monitoring schemes, e.g.: Removal of perverse agricultural subsidies [23], Nutrient reduction run-off [23], Nitrogen and sulphur deposition at regional [93] and global scales [94]; Identify freshwater systems [95], protected areas [94, 96] and biodiversity hotspots [97] at risk from nutrient pollution.	Scoping cost of meeting targets under scenarios [23].	10, 14	3, 4, 7	★★★ 14.1
9. By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.	Use models to undertake the prioritisation [98-101].	Develop quantitative criteria for assessment of impacts; Use of bioeconomic and risk models to identify potential pathways and prioritisation of biosecurity measures [98, 99]; Evaluation of eradication strategies [102]; Identification of key drivers and areas at high risk of invasion (e.g., global shipping [101]); Effects on invasive	Examine recent trends [106] or assess management effectiveness with counterfactuals [107, 108].	10, 12, 14		★★★ 15.8

Aichi Target	(re) Formulation	Implementation	Evaluation and Review	Strong influence on targets [1]	Strongly influenced by targets [1]	Links with SDGs [2]
		species arising from different scenarios of, e.g.: Greenhouse gas emissions [103, 104] or Socio-economic priorities [105].				
10. By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.	Determine impacts of cumulative pressures and minimum requirements for resilience, e.g.: setting quantitative limits [109].	Screen policy options via integrated global scenarios coupled with process-based (data-driven) models; Effectiveness of different or combined management approaches or policies of local water quality [110], or fishing [110, 111]; Practical incorporation of models into conservation planning [112], economic policies [113]; Impacts of greenhouse gas emissions scenarios on instrumental values [114, 115], fish health [116], ecosystem properties [117].	Consider degree of degradation if existing schemes were not in place, or under alternative scenarios.	5, 11, 12, 14	2, 3, 4, 5, 6, 7, 8, 9, 11, 14, 20	★★ 14.2 ★ 14.3
Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity						
11. By 2020, <u>at least 17 per cent</u> of terrestrial and inland water, and <u>10 per cent</u> of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and	Influence on current wording and concepts [118-121], but current quantitative thresholds politically derived [122, 123]; Explore concepts and threshold reserve coverage needed to achieve aims [67, 119-121, 123-130].	Explore thresholds of reserve coverage and placement needed to achieve aims [14, 41, 128, 129, 131-134]; Goal-seek the reserve design under alternative reserve expansion and management scenarios [12, 129, 130, 135-141]; Examples exist of models and planning tools being used in real planning (e.g. The Great Barrier Reef in Australia, South	Trends in reserve expansion [129, 135, 141]. Impacts and of reserve placement [40, 59, 145-149]; Counterfactuals and opportunity costs of alternatives. [150, 151].	5, 6, 10, 12, 13, 14	2, 5, 10, 17, 20	★★ 11.4 ★★★ 14.5

Aichi Target	(re) Formulation	Implementation	Evaluation and Review	Strong influence on targets [1]	Strongly influenced by targets [1]	Links with SDGs [2]
integrated into the wider landscapes and seascapes.		Africa and China [140, 142-144]), but still greatly under-utilised.				
12. By 2020 the extinction of known threatened species has been <u>prevented</u> and their conservation status, particularly of those most in decline, has been <u>improved</u> and sustained.	Quantify key concepts, terms and indicators [152] [153-157]; Explore feasibility of target levels through scenarios [158]; Assess extinction debt [159]; Consider means of preventing additional extinctions under plausible futures.	Explore what drives extinction; Undertake policy-screen and goal seeking to determine what is required at species-level and costs [67, 133, 136, 137, 139, 160-166], including screening land use policies [84, 167, 168]; Use of scenarios to identify: Priority regions for conservation [169, 170]; Effects of agricultural intensification [171]; Effects of meat consumption [171]; Impacts of greenhouse gas emissions scenarios on: loss of vertebrate species [172], vulnerability of marine biota [67, 173] effect of protected area placement on extinction levels and influence of spending on target progress [174, 175].	Analysis of trends and effectiveness, models for hindcasting [133, 164, 166]. Counterfactuals around degree of implementation and success [133, 176-178]	13	2,5, 6, 7, 9, 10, 11, 20	★★★ 15.5 and 15.7
13. By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.	Explore levels of genetic erosion likely under alternative regulatory and incentive structure scenarios; Quantifying effect of animal genetic diversity in spread of infectious disease.	Explore levels of genetic erosion likely under alternative regulatory and incentive structure scenarios; Methods of prioritisation to maximise genetic diversity [179]; Conceptual frameworks for choosing management tools [180, 181]; Prioritising areas suitable to act as genetic	Counterfactual of level of loss if regulations not in place.		2, 4, 6, 7, 11, 12, 16, 20	★★★ 2.5

Aichi Target	(re) Formulation	Implementation	Evaluation and Review	Strong influence on targets [1]	Strongly influenced by targets [1]	Links with SDGs [2]
		'storehouses' [182], or species to be included in gene banks [183]; Impacts of greenhouse gas emissions scenarios on, e.g.: Distribution and vulnerability of valuable crops [184, 185] and wild relatives [183].				
Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services						
14. By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.	Improve definition of 'restored'; Explore the consequence of a range of targets and scenarios in terms of ecosystem services, health, well-being [186].	Consider interaction between services, level and type of restoration, its degree of success and reach across communities (i.e. well-being), and trade-offs between ES [187, 188], e.g.: assessment of water use by African agriculture [189], sea level rise scenarios to identify [190], participatory scenario planning tools for social-ecological systems [191].	Counterfactuals around interventions (in terms of health, well-being etc.); Effectiveness of Payment for Ecosystem Service (PES) schemes [192], policies [193], and ecosystem service quantification [194]; Alternative pathways and back-casting to meet goals [195].	6, 7, 10,15	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 18, 20	★★★ 6.6 ★★ 15.4
15. By 2020, ***,*** *ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of <u>at least 15 per cent</u> of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.*	Explore implications for other targets of different levels of degradation or restoration [40]; Determine effective assessment methods; Calculating investment thresholds for effective restoration [196]; Arguments for using future prediction to guide restoration targets [197].	Policy screening around measurement schemes under alternative scenarios; Optimisation of restoration activities vs objectives [198]; Explore implications of different policies or management [14, 21, 40, 41]; Identifying circumstances which might allow for revegetation of abandoned farmland [199]; Using	Counterfactuals around management schemes [40, 107, 108] and targets [206]; Use social-ecological models to measure benefits of restoration [207].	5, 7,14	2, 3, 4, 5, 7, 14, 20	★★★ 15.1 and 15.3

Aichi Target	(re) Formulation	Implementation	Evaluation and Review	Strong influence on targets [1]	Strongly influenced by targets [1]	Links with SDGs [2]
		conceptual models to determine pathways towards restored state [200]; Identifying sites which are economically and environmentally suitable for restoration [201-203]; Conceptual models for incorporating pollinators into restoration [204]; Identify sites with high carbon storage [205].				
16. By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation		Counterfactual around degree of success; Explore implications of success and failure.	Counterfactual scenarios around degree of implementation success; Explore where these failed and why.	13, 18,	2, 20	★★★ 15.6
Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building						
17. By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan	Model impact of timing on implementation; Explore implications of alternative patterns of effectiveness and spatial variation across nations.	Consider effectiveness of participatory inclusion on compliance and uptake; Model governance and policies [13].	Consider impact of timing on implementation; Level of effectiveness and spatial patterning across nations.	1, 2, 5,11, 20	2, 20	★ 15.9
18. By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of	Consider impacts of use types on ecosystems; Explore compliance implications of cultural respect.	Consider response functions covered in traditional knowledge; Explore uptake responses when respected; Tools and approaches for including local and indigenous knowledge into models [208].	Consider effectiveness of other targets with and without inclusion of traditional knowledge.	14, 19	2,16, 20	★ 1.4 and 16.7

Aichi Target	(re) Formulation	Implementation	Evaluation and Review	Strong influence on targets [1]	Strongly influenced by targets [1]	Links with SDGs [2]
indigenous and local communities, at all relevant levels.						
19. By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.	Scenarios about transfer of information across domains, world views and cultures; Consider implication of wording and engagement on compliance and uptake.	Compare different means of data sharing, influence of context and impacts of improved knowledge on decisions ('value of information theory').	Explore effectiveness of different knowledge sharing approaches; Consider value of data and how it modifies land-use decisions etc.	1	18, 20	★★ 17.18 and 17.6
20. By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011-2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization, should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.	Consider the implications of timing of resource mobilization.	Model alternative models of adoption and financing to explore feasibility.	Counterfactual on outcomes associated with differing levels of financing and investment.	1, 2, 5, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,	2,17	★★ 1a, 10b, 17.3

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