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A social–ecological systems analysis of impediments to delivery of the *Aichi 2020 Targets* and potentially more effective pathways to the conservation of biodiversity

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ABSTRACT

The *Aichi 2020 Targets*, under the Convention on Biological Diversity (CBD), aim to halt the loss of biodiversity by 2020, in order to ensure that ecosystems continue to provide essential services. Here we apply a social–ecological systems analysis to provide insight into the diverse system interactions that pose impediments to delivery of the *Aichi Targets*. We applied an analytical framework of pair-wise exchanges along six axes between the social, economic, environmental and political loci of the global social–ecological system. The analysis identified that many impediments result from partial decoupling in the system through phenomena including delayed feedbacks and insufficient information flows. It suggests 15 of the *Aichi Targets* are unlikely to be delivered; 3 are likely to be delivered in part; and 2 in full. We considered how interventions at leverage points may overcome the impediments, and compared these to actions included within the *Implementation Decision* for the *Aichi Targets*, to find gaps. These new leverage points to fill identified gaps involve many aspects of system re-coupling: co-production of knowledge and more equitable food systems governance (environmental–social axis); support for social change movements (social–political axis); an appropriate financial target for biodiversity conservation investment, with a clear means of implementation such as a currency transaction tax (economic–political axis); and co-governance of natural resources (environmental–political axis). The recently released Global Biodiversity Outlook 4 shows that 18 of the 20 *Aichi Targets* are tracking in accordance with our analysis; and that current efforts are unlikely to result in an improvement in the base state of biodiversity by 2020, confirming some of our results. We argue that attention to the interactions within, and the partial decoupling of, the global social–ecological system provides new insights, and is worthy of further attention both for delivery of the *Aichi Targets* and for guiding longer term actions for the conservation of biodiversity.

1. Introduction

Biodiversity loss continues globally, driving major alterations to earth's ecosystems and the services they provide to humans (Cardinale et al., 2012; Hooper et al., 2012). Global commitments made under the *Convention of Biological Diversity* (CBD) to substantially reduce rates of biodiversity loss by 2010 were not met. The new *Strategic Plan for Biodiversity 2011–2020* including the *Aichi Targets* (hereafter *Strategic Plan 2020, Aichi Targets*) sets out two mechanisms to provide a stronger basis for global action: (1) 20 "SMART" (Specific, Measurable, Ambitious, Realistic, Time-bound) targets to be achieved by 2020; and (2) adoption of a specific *Implementation Decision* (Secretariat of the Convention on Biological Diversity, 2010, 2011). The *Strategic Plan* and *Implementation Decision* have been welcomed by some as ambitious, well-targeted and highly relevant, clearly addressing socio-economic factors that constitute the underlying drivers of biodiversity loss (Perrings et al., 2011). Nevertheless, a mid-term analysis found

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that despite accelerating policy and management responses, the condition of biodiversity is trending down (Leadley et al., 2014; Tittensor et al., 2014). These policy initiatives occur in a context of complex social and ecological system interactions where interventions can have unanticipated consequences (Collins et al., 2010; Norris, 2012). In this paper, we apply a social–ecological systems (SES) analysis to provide insight into the diverse system interactions that pose impediments to delivery of the *Aichi Targets* and consider the implications for potentially more effective pathways to the conservation of biodiversity.

Social–ecological systems (SES) science responds to accumulating evidence that society and the environment are strongly coupled and coevolving (Collins et al., 2010; Liu et al., 2007). Planet Earth can be considered as a large, coupled human and natural system including many smaller coupled systems linked through flows of energy, information, matter and evolving through time as a set of interconnected complex adaptive systems, that are referred to as social–ecological systems (SES) (Liu et al., 2015). However, evidence is also accumulating that economic and cultural globalisation is decoupling social and ecological systems, through innovation, and increases in the connectivity, speed and scale of linkages that drive social system change, without evident accompanying environmental change (Young et al., 2006). Raudsepp-Hearne et al. (2010) consider that such partial decoupling in the global SES may explain why human well-being increases as ecosystem services decline, termed the "environmentalists' paradox". The behaviour of any complex system emerges, in part, from the interactions between its components (Newell, 2012; Sterman, 2000). Basic system interactions include flows (e.g. of information and materials), accumulations of stocks (e.g. natural and social capital) and effects such as positive feedbacks loops, thresholds, or lags that dampen and delay flows and connections between components (Newell, 2012; Sterman, 2000). "Leverage points" can exist as a result of such system interactions: places where a small shift in one part can produce large changes in the whole system (Forrester, 1969; Meadows, 2008).

We begin by presenting and justifying our SES framework for representing interactions along six axes between social, economic, environmental and political loci, followed by a description of our methods for analysis. We then present the results of our analysis of how interactions within the SES may impede delivery of the *Aichi Targets*, and the potential leverage points for interventions to overcome these impediments. We then present our analysis to identify gaps where actions are missing or given minimal attention within the *Implementation Decision*, and where additional actions could generate potentially more effective pathways of change. We conclude by discussing how scientific attention to the SES interactions and dynamics is critical to enhance opportunities to deliver the *Aichi Targets* by 2020, and set more effective pathways for the longer-term conservation of biodiversity.

2. Analytical framework

Social–ecological systems (SES) analysis is a rapidly growing field of scientific endeavour, which has led to fundamental discoveries: emergent properties and complexity; interconnections among multiple key issues (such as air, climate, energy, food, land, and water); assessment of multiple, often conflicting, objectives; and synergistic interactions such as between economic efficiency and environmental impact mitigation. In addition, systems analysis allows for clarification and reassignment of environmental responsibilities among actors, reduction of conflicts and design of conservation and development policies and practices that minimise trade-offs (Liu et al., 2015). Nevertheless, very few SES analytical frameworks and approaches specifically consider *interactions* between system components (Binder et al., 2013; Hufnagl-Eichiner et al., 2011). Binder et al.'s (2013) examination of how interactions were addressed within ten common SES frameworks found that only three addressed bi-directional interactions between social and ecological components; none consider bi-directional interactions between multiple subsystem components. We identified one SES framework that considers such multiple bi-directional interactions: the four spheres framework for SES analysis in sustainability contexts created by O'Connor (2006) and Maxim et al. (2009). We developed a modified version of this 'four spheres' framework for our analysis of interactions in SES, which they depict as a matrix of pair-wise interfaces between economic, social, environmental and political domains (Fig. 1, Table 1; O'Connor, 2006; Maxim et al., 2009). We defined them as loci rather than spheres as in the original, to avoid confusion with the encompassing planetary sphere.

The pair-wise interactions in the four-loci model are characterised according to the original four-spheres framework. Exchanges of information and resources occur between the loci, which have accumulations that can be considered as social, natural, economic and political "capital" (Maxim et al., 2009; O'Connor, 2006). For example, interactions between the social and economic loci include exchanges of labour and wages; characteristics of these flows include employment conditions and pay levels that are highly diverse and change over both time and space. Interactions between the social and political loci include flows of public participation and returns of legitimacy; characteristics of these interactions include issues of equity and justice. Table 1 summarises the interactions between all four loci, drawing on previous more elaborated descriptions in O'Connor (2006) and Maxim et al. (2009).

3. Methods for analysis

By its nature, social–ecological systems analysis, at the global scale, requires multiple disciplinary perspectives, with diverse epistemologies and conceptual frameworks that are challenging to combine (Jerneck et al., 2011). Newell (2012) provides a systematic approach to structuring integrated analysis in such contexts through a focused dialogue method, which we adapted to a four-step process (Fig. 2). In the first step we identified our multidisciplinary team of nine members with diverse expertise: anthropology; biodiversity; biology; ecology; economics; ecosystem services; governance; human geography; land use modelling; landscape planning; political ecology; and social–ecological systems science. Preparatory documents for a 2-day expert workshop on understanding pair-wise interactions framed our approach to the analysis of impediments to the delivery of the *Aichi Targets* in terms of SES interactions across social–economic–environmental loci with globalization as a key influence. In the second step, we conducted the deliberative analysis at the 2-day expert workshop, through four elements: (i) how pair-wise interactions between the loci could impede delivery of a particular *Aichi Target*; (ii) which pair-wise axis had the most influence on particular targets; (iii) what were the potential leverage points to address these impediments; and (iv) how these could be used to generate potentially more effective pathways for conservation of biodiversity (Fig. 2).

Subsequent to the workshop, a literature review was undertaken to seek confirming and disconfirming evidence for the workshop findings, drawing on validity techniques in qualitative enquiry (Creswell and Miller, 2000). The review focused on the interactions identified as potential impediments to delivery of the *Aichi Targets* (Table 2) and associated leverage points for change to overcome those impediments (Table 3). The review searches were within Web of Science only, and continued until topic saturation was reached; that is, no significant new information was being

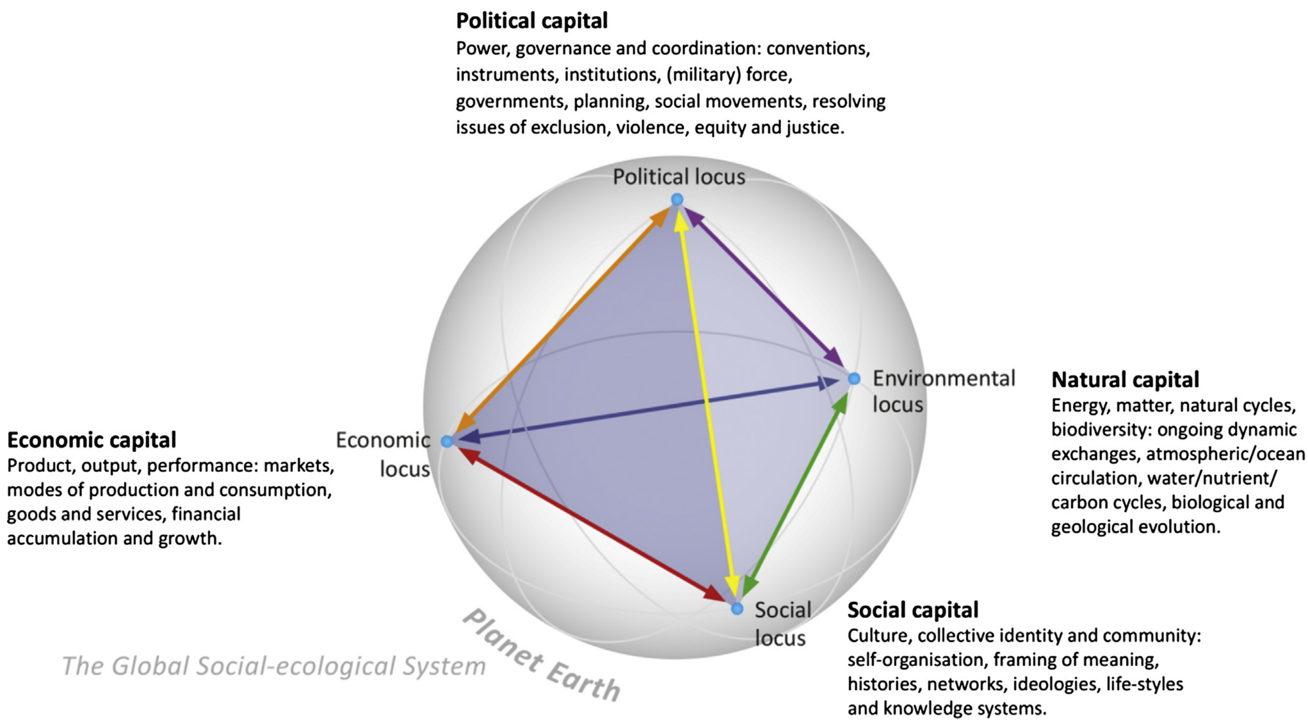

Fig. 1. Analytical framework of social–ecological systems interactions.
Based on O'Connor (2006) and Maxim et al. (2009).

Table 1
The axes and associated exchanges between social, political, environmental and economic loci depicted in Fig. 1.

Axis	Pair-wise exchanges and characteristics of their dynamics	Axis	Pair-wise exchanges and characteristics of their dynamics
Red	**Social-economic** Social and economic interactions include flows of labour, knowledge, innovation with employment, revenue, goods/services; characterised by exploitation, community perturbation, justice; sustainability for whom characterise exchange dynamics.	Yellow	**Social-political** Social and political interactions include flows of capacity of communities, public participation and discourse with, social security and stability; characterised by legitimacy, public confidence, equity characterise exchange dynamics
Blue	**Environmental-economic** Economic and environmental interactions include flows of natural capital and resources as factors of production with goods /services, management/restoration of ecosystems; characterised by environmental condition, resources depletion/ substitution, power differentials between producers/ consumers characterise exchange dynamics.	Orange	**Economic-political** Economic and political interactions include flows of rules/limits of markets, property rights, compliance, information with resources (taxes), supply of infrastructure, innovation support; characterised by distributive justice, market failure, economic growth, credit rating characterise exchange dynamics.
Green	**Environmental-social** Environment and social interactions include flows of natural phenomena as peoples' lived experiences with meaning, symbolic representation and biocultural diversity; characterised by co-evolution, cultural diversity, marginalisation and concepts about rights, duties to nature, future generations characterise exchange dynamics	Purple	**Environmental-political** Environmental and political interactions include flows of regulation of what counts as environmental values, with pressures on and services of the environment; characterised by setting, credibility/ legitimacy of environmental standards, levels, distribution of risks/benefits of pollution, characterise exchange dynamics.

found in relation to the identified impediments and leverage points for change. The analysis was, therefore, bounded by testing the deliberations from the experts in the workshop. In step three, again post-workshop, we compared the potential leverage points with the existing actions within the *Implementation Decision* to identify gaps. The potentially more effective pathways for conservation of biodiversity are, therefore, limited to areas where gaps exist in the *Implementation Decision.* These gaps were found to be related to interactions along four of the six pair-wise axes (Table 3). The SES analytical framework was updated in iterations throughout the post-workshop process. In the final step, we considered our findings in the context of existing theory in the scientific literature relevant to biodiversity conservation policy, to underpin the discussion and conclusions in this paper.

4. System interactions that impede delivery of the *Aichi Targets*

Our analysis identified significant impediments to the delivery of the *Aichi Targets* within the complex mutual interactions taking place between the diverse loci of the SES. The colour coding in Table 2, which is the same as the colour coding in Table 1, indicates the axis that we identified as posing the most significant impediment affecting each target:

- Red for the social–economic axis.
- Blue for the environmental–economic axis.
- Green for the environmental–social axis.
- Yellow for the social–political axis.
- Orange for the economic–political axis.
- Purple for the environmental–political axis.

The second column in Table 2 summarises the targets, the full version of which are presented in S1. The third column of Table 2 summarises the identified impediments arising from SES interactions on which the classification into a particular axis is based. The superscript numerals in this table cite sources from the literature review that sought confirming and disconfirming evidence; these sources are listed in the Supplementary Material. Many of the interactions that impede delivery of the targets can be characterised as forms of partial system decoupling, including delayed

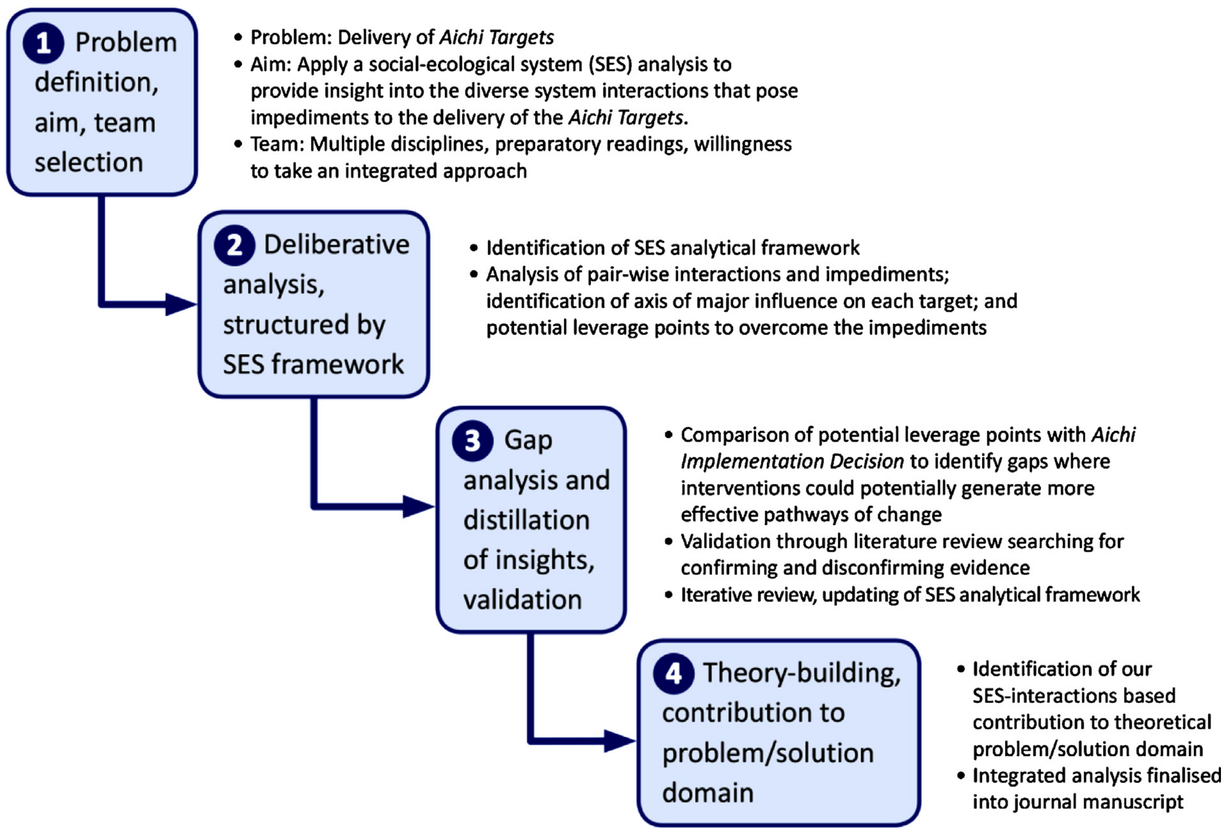

Fig. 2. Steps in the analysis.

feedbacks and insufficient information flows. The influences of these interactions is such that 15 targets are unlikely to be delivered; 3 are likely to be delivered in part; and 2 in full (16 and 18) simply because little change is required for their delivery.

4.1. Red: social–economic axis

Interactions along the social–economic axis were not identified as the major source of impediment to the delivery of any one of the

Table 2
System interactions that pose impediments to delivery of the *Aichi Targets*, together with identification of the major access of influence on each target and likelihood of target delivery: red for social–economic; blue for environmental–economic; green for environmental–social; yellow for social–political; orange for economic–political; and purple for environmental–political.[a]

Aichi Target		Impediments from SES interactions	Major axis of influence	Delivery
#	Focus			
1.	People more aware of biodiversity values	This target implies a deficit model of communication that assumes the publics' perceptions of risks and benefits of biodiversity loss are rooted in ignorance. However, people already have awareness of biodiversity values underpinned by culturally-based world-views, knowledge systems and discourses[1]. These socio-cultural values are blocked from influencing biodiversity outcomes primarily through the political-institutional subsystem[2] and also through pressing needs for provisioning services[3, 4].	Environmental-social; Community capacity/diversity, also the contexts of marginalized peoples	Not likely
2.	Biodiversity integrated into development	Technical barriers exist that impede defining and measuring culturally-diverse biodiversity values[5, 6] which often involves monetizing and privatizing[7]; lack of agreed local-global framework of accounting for natural capital, and for the relationship between biodiversity and ecosystem services[8].	Environmental-economic; Issues of natural resource economics	Not likely
3.	Perverse incentives and subsidies removed	Economic interests impede shifting away from subsidies. The food production system has economic distortions, typically import barriers and subsidies that favour farmers in developed world, and urban populations[9, 10]. New market mechanisms that "enclose" land and natural resources serve in many cases to dispossess the poor rather than slow biodiversity loss[11, 12]. Higher levels of debt service, structural adjustment and primary sector exports are associated with higher levels of environmental degradation in poor nations[13].	Economic-political; Issues of rules of markets, distributive justice, power differentials	Not likely
4.	Sustainable production and consumption	Sustainable production and consumption is impeded by the fundamental issue that the world economy/population is getting larger in scale than the planet[14-16]. Few stakeholders have access to democratic connections to enable actions that reduce power imbalances. Future generations are not represented. Rich countries have 2-5 times the per capita sustainable consumption identified through ecological footprint analysis[17]; new global financial structures support increasing subordination to international economic liberalization[18] .	Environmental-social; Issues of marginalised peoples, rights of future generations suppressed in global power differentials	Not likely

Table 2 (*Continued*)

5.	Rate of loss of natural habitats halved	Human populations and their levels of consumption are both increasing[19]; 850 million people face hunger globally[20]; agricultural expansion is the largest threat to remaining areas of natural habitat globally[21]; conflicting evidence about whether agricultural-intensification (land-sparing) or agro-ecological matrix (land-sharing) offer the best approaches for food security and biodiversity conservation impedes action[22, 23].	Environmental-political; Issues of setting standards that balance risks/benefits of pressures on and services from environment.	Not likely
6.	Sustainable harvests of fisheries	Global trade has effectively masked the successive depletion of fish stocks in industrialised fishing since 1950 and about one-third of current fisheries are probably over-fished[24]; non-compliance is normalized rendering policy settings dysfunctional[25]; duplicity and ignorance undermine fisheries management[26].	Social-political; Issues of equity, undermining of legitimacy of compliance regimes.	Not likely
7.	Sustainable agriculture, aquaculture and forestry	High production costs and collapsing prices for farm products push farmers out of options for trialling sustainable systems[20]; agriculture, aquaculture and forestry produce ecosystem-disservices including soil erosion, pest outbreaks, nutrient and pesticide run-offs[27, 28]; trade-offs between yield and biodiversity appear intractable[29, 30]; agricultural protection continues to favour developed nations at the expense of developing, both net food-importing and net-exporting[31].	Environmental-economic; Issues of environmental condition, power differentials between producers and consumers.	Not likely
8.	Pollution brought to safe levels	Control of diffuse pollution (from intensive farming, aquaculture, urbanization, industrialisation, greater shipping traffic, fishing [32, 33]) impeded by information asymmetries[34] and stochastic effects that render both market and regulatory mechanisms ineffective and slow to respond[35, 36]; time lags between practice change and pollution reduction (e.g. in farming)[37]; point source pollution (e.g. chemicals) control easier but impeded by adhoc arrangements[38] and compliance costs in systematic approaches[39].	Economic-political; Issues of market failure (information, compliance).	Not likely
9.	Invasive species control	Some invasive species' eradication results in increases of provisioning and cultural ecosystem services and is supported by multiple stakeholders[40] while control is impeded by scale and prioritization challenges [15, 41]; the need for biosecurity measures to control trade, mass transport, immigration drivers (e.g. movement constraints) is not widely accepted[42, 43].	Environmental-social; Issues of power differentials between producers and consumers.	Not likely
10.	Climate impacts on biodiversity minimized	Climate change policy initiatives are impeded by growing public scepticism related more to socio-cultural and "affect" factors (e.g. conspiracy theories) than scientific uncertainty[44, 45]; the most critical threats (terrestrial pollution, fishing impacts, climate change) are not well-addressed in even best-managed reefs; policy prioritises development (e.g. ports for export industries)[36].	Environmental-political; Issues of setting standards, credibility, legitimacy.	Not likely
11.	Protected areas cover 17% of terrestrial, inland water; 10% of coastal and marine	85% of protected areas globally are occupied by indigenous peoples and ongoing parks-people conflicts impede expansion[46, 47]; competition for land use that skews protected areas to places "high and far" where they do not oppose the conversion of habitat for human use[48] is institutionalized in the new differential 17/10 target, impeding representativeness; 40% of protected areas in a recent global analysis showed major deficiencies in effectiveness[49]; establishment of protected areas is impeded by marine resource-dependency[50] and indigenous territorial claims[51].	Environmental-social; Issues of marginalized peoples, power differentials.	Likely
12.	Extinctions of threatened species prevented	Time lags between anthropogenic drivers and extinction outcomes, and interactive effects between multiple anthropogenic drivers, impede identification of "those most in decline"[52]; multiple actions needed to prevent extinctions are impeded by drivers for ongoing supply of ecosystem services for humans associated with land use and cover change[53].	Environmental-economic; Issues of environmental condition, producer-consumer power differentials.	Not likely
13.	Genetic diversity of cultivated biota maintained	Genetic diversity increases yields in crops and fisheries[14]; nevertheless genetic erosion continues through homogenizing effects of industrial agriculture involving replacement of landraces by modern cultivars and further breeding[54, 55]; reversing genetic erosion is impeded by lack of recognition and power in the traditional farming, collective property and action systems that establish and maintain land/sea race varieties[56, 57]; sovereign resource rights and private intellectual property rights dominate over communal rights in international regime complex[58].	Social-political; Access to resources structured by gender, class, race and geopolitical power differentials.	Not likely
14.	Ecosystem services restored and safeguarded	Access to essential services for indigenous peoples and local communities is impeded by political, social and economic inequities[59, 60] e.g. export of embedded ecosystem services (e.g. water) to developed countries[61]; restoration efforts in degraded environments are impeded by war, refugee movements, lack of infrastructure and unstable governments[59, 62, 63].	Environmental-social; Issues of distribution structured by gender, class, race and geopolitical power differentials.	Not likely

Table 2 (*Continued*)

15.	Ecosystems' resilience and contribution to carbon enhanced	Incentives necessary to promote restoration are impeded by the lack of effective market and institutional arrangements globally[64, 65]; technical challenges in quantifying the relationship between carbon and restoration remain; effective climate mitigation measures impeded by the power of carbon-intensive industrial actors and nations[66]; fundamental injustices in REDD mechanisms impede their wide uptake[67].	Economic-political; Issues of setting of market rules, standards, distributive justice.	Likely for some
16.	Nagoya Protocol enforced	The Nagoya Protocol can be enforced without achieving access and equitable benefit sharing[68] as key provider nations' points including retroactivity, checkpoints, certification and disclosure were not agreed[69]; indigenous and local peoples' consent only required where nation-state recognises their rights.	Environmental-social; Issues of marginalisation and rights recognition.	Likely, little change
17.	National Biodiversity Action Plans implemented	Adoption and implementation of biodiversity policy is hampered by institutional fragmentation, contested interests, lack of effective participatory methods, and diversity of knowledge systems and world views[70, 71]; participatory implementation requires participatory formulation which is hampered by resource and capacity constraints.	Social-political; Issues of legitimacy, public confidence, equity.	Not likely
18.	Traditional knowledge respected, full participation of indigenous and local communities	Contested constructions of "environment" and deep ontological divides underpinning competing discourses impede indigenous participation[72, 73]; actual full and effective participation impeded by lack of rights-recognition by nation-states, power differentials between local and indigenous peoples and nation-states, elite capture at local levels, ongoing attrition of local languages and knowledge systems[74-76].	Environmental-social; Issues of marginalisation, cultural diversity.	Likely, little change
19.	Science and knowledge shared	Sharing and applying knowledge is impeded by a "deficit model" of science communication[77]; challenge of negotiating boundaries between diverse knowledge systems[78, 79]; science viewed as a colonising project with agendas that limit sharing and favour powerful elites[80].	Social-political; Issues of community capacity, equity.	Likely for some
20.	Sufficient finances mobilized	Donor fatigue, the global economic crisis, competing aid requirements, are impediments to mobilizing resources[81, 82]; the raising of green capital constitutes new threats and new ways of appropriating resources from the poor and marginalized[12].	Economic-political; Issues of distributive justice.	Not likely

[a] For sources cited in Tables 2 and 3, see superscript numbers and their corresponding reference in the list in Supplementary Materials.

Aichi Targets. As elaborated in O'Connor (2006) and Maxim et al. (2009), these interactions are essentially between labour and capital. The characteristics of such interactions were the subject of many 20th Century political contests regarding the relative merits of capital–labour relationships in communist, socialist, free-market and centrally planned economies. Coupling between flows of labour in return for wages appears related to social conditions such as the skill of the workers and their extent of collective organisation, for example through unions. While the diverse characteristics of these arrangements could influence biodiversity-related outcomes, high rates of biodiversity loss are associated with high-wage, high-consumption and low-wage, high poverty contexts (Tittensor et al., 2014). Given this variability, the relatively low importance of social–economic interactions as an impediment to the *Aichi Targets* is perhaps not surprising.

4.2. Blue: environmental–economic axis

Interactions along the environmental–economic axis, in particular time lags that delay the feedback between economic activities and environmental impacts, impede delivery of Targets 7 and 12. In Target 7, time lags occur between changes to agricultural practices and reduction of environmental pollutant loads (Sprague and Gronberg, 2012). In Target 12, time lags occur between anthropogenic drivers and extinction outcomes (Jackson and Sax, 2010). Target 12 is also impeded by insufficient information flows: interactive effects between multiple anthropogenic drivers impede identification of which species can be fairly considered "those most in decline" (Jackson and Sax, 2010). Both time lags and insufficient information flows reflect partial decoupling.

4.3. Green: environmental–social axis

Influences from interactions along the environmental–social axis were identified as posing the major impediment to delivery of *Aichi Targets* 1, 4, 9, 11, 14, 16 and 18. Target 1 seeks to support information flows on a "deficit model" of communication that assumes public perceptions of the risks and benefits of biodiversity loss are rooted in lack of knowledge, and will be changed by additional information (Groffman et al., 2010). However, many people already have awareness of and information about biodiversity that is embedded in socio-cultural worldviews and community capacity. Uptake of new knowledge will be impeded if people are not able to connect it with their existing knowledge system (Howitt et al., 2013). Targets 4 and 14 encounter multiple impediments related to how current interactions and power differentials marginalise some people. For example, exports deliver embedded ecosystem services (e.g. water) to developed countries in ecologically unequal exchanges (Shandra et al., 2009). Through these types of interactions, rich countries are able to generate benefits based on 2–5 times the global per capita consumption, while either not receiving the environmental impacts in exchange, or receiving them only in very delayed means, such as refugee movements from water-depleted regions (Ehrlich et al., 2012). These delays reflect considerable system decoupling. Target 4 also encounters the fundamental issue that the world economy/population is getting larger in scale than the planet's capacity to supply services (Barnosky et al., 2012). Future generations are not represented in any interactions, impeding the system understanding of the long-term consequences of resource depletion, again a form of partial decoupling. Restoration efforts in degraded environments are impeded by war, refugee movements, lack of infrastructure and unstable governments, which again in part result from ecologically unequal exchanges and partial decoupling (Raleigh, 2011).

Feedbacks from impacts on marginalised peoples affect Target 11 particularly, as the expansion (and effectiveness) of protected areas is triggering resistance and ongoing parks-people conflicts due to the perceived inequitable distribution of parks globally (Clark et al., 2013; De Santo, 2013; Hill, 2011). For example, nation-states amongst the lowest Gross Domestic Product per capita globally, including Zimbabwe and Liberia, have more than 15% of their land in protection, while some with very high per capita GDP, including Australia and Canada, have much less (McDonald and Boucher, 2011). The differential targets for 10% of coastal and

Table 3
Gap analysis between the identified potential leverage points for actions to address the impediments and currents actions in the *Implementation Decision*, and axis of influence of the identified gap: red for social–economic; blue for environmental–economic; green for environmental–social; yellow for social–political; orange for economic–political; purple for environmental–political. Colours of the rows here represent the axis where there is an implementation gap for the delivery of that Target, and so are different to the colours of the rows in Tables 1 and 2 and S1.[a]

Target No.	Potential leverage points for actions to address the impediments	Current actions in the Implementation Decision and clause numbers e.g. 1(e)	Implementation gap and associated axis of influence
1	Respect peoples' knowledge and support process of mutual learning about risks and benefits of biodiversity loss[5]. Address provisioning services: food security, education, poverty reduction; increase socio-economic equity[6].	1 (e) enhanced knowledge management, information and technologies; (6) Collaboration with others including UN Develop Prog.	Co-production of knowledge; Environmental –social axis
2	Address the technical gap: more effective indicators[11, 12]; transdisciplinary methods and pluralistic frameworks for "biodiversity values"[13]; ensure the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) implements a transdisciplinary local-global framework that effectively includes indigenous and local knowledge[14].	1 (f) Support to assess, on a scientific basis, the ... values of biodiversity	Co-production of knowledge; Environmental-social axis
3	Include efforts to remove barriers to agricultural trade within an overall equitable food governance approach[16, 20]. Insert requirements for distributive justice and equitable development into biodiversity market arrangements[18]. Decouple power from economic interests through increased attention to gender equity[21, 22], non-government organisations roles[19] and social capital[23].	(2) Parties to establish mechanisms to foster full ... participation; previous CBD decision recognises gender action.	More equitable governance of food systems; Environmental-social axis
4	Recognise political ecology of power differentials and support processes that enable power-shifting e.g. social movements that create narratives and discursive frames to mobilize actors in socio-political change[29, 30]. Increase the democratization of international financial institutions and their harmonization with the UN's biodiversity institutions[19, 31].	*Implementation Decision* refers only to coherence between global biodiversity institutions but *Strategic Plan* recognises partnerships.	Mobilisation of social change to address power differentials; Social-political axis
5	Promote sustainable consumption patterns that lower environmental impact[32, 37]; European scenario modelling demonstrates biodiversity loss slowed most by the adoption of more localised food production and sourcing rather than liberalisation[38]	Text is silent on consumption.	Sustainable consumption; food production localisation;
6	Establish co-governance to re-couple fisheries across jurisdictions[42, 43] and to build social capital, trust and social learning between fishers, managers and scientists[44, 45]; integrate human rights, indigenous claims, adaptive capacity and wealth into co-governance[46-49].	(2) Parties to establish mechanisms to foster full...participation; Partnerships recognised in clause 17 in *Strategic Plan*	Co-governance of natural resources; Environmental-political axis
7	Support localized food systems that produce food where the hungry live[33, 35]; address distributional issues in food security; tailor mixtures of land-sparing, land-sharing, collective management, agricultural protection and local-global supply chains to the socio-economic context[20, 35, 38, 54].	*Strategic Plan* recognises the need for mainstreaming across all sectors.	More equitable food production governance; Environmental-social axis
8	Support development of low-cost monitoring technologies for diffuse pollution[58]; provide incentives and regulations for pollution reduction from farming, urban, industrial systems[63]; increase participatory solution-generation for pollution reduction and social learning to integrate management, address time-lags and bridge knowledge asymmetries[64-66].	1 (b) human resource development; 1 (e) enhanced knowledge management.	Co-production of knowledge; Environmental-social axis
9	Accept some novel ecosystems through co-producing new knowledge about their risks and benefits[71]; integrate socio-economic drivers in risk and control prioritization[72] through long-term, flexible funding, and active public involvement approaches[68].	2 Parties to establish mechanisms to foster full ... participation.	Co-production of knowledge; Environmental social axis
10	Adopt a social-ecological systems approach to risk-assessment and priority setting for management of reefs and other vulnerable ecosystems[75, 76].	1 (e) enhanced knowledge management.	Social-ecological systems approach; All axes
11	Establish national Protected Area Negotiating Tribunals with indicators, definitions, supported negotiations, ability to address legacy issues and overcome power differentials[83] and support great equity[84]; support the principles of Free Prior and Informed Consent for protected area creation (and development) in indigenous customary territories[85].	2 Parties to establish mechanisms to foster the full and effective participation of indigenous and local peoples.	Co-governance; Environmental-political axis
12	Increase focus on linking the charismatic and productive species that are valued for their ecosystem services to the non-charismatic non-productive species[87]; increase focus on socially-designated protection areas[88]; develop new financial arrangements e.g. a currency transaction tax to reduce debt and build secondary and tertiary export sectors [19].	1 (f) support to assess ... values of biodiversity.	Appropriate financial target and means of implementation; Economic-political axis
13	Include Indigenous and Community Conserved Areas (that protect cultivated genetic diversity) into the national protected area systems[88]; support endogenous development that is based on locally conserved biocultural diversity[94]; strengthen traditional systems	2 Parties to establish mechanisms to foster the full...participation.	Co-governance; Environmental-political axis

Table 3 (*Continued*)

	through application of the Nagoya Protocol and other means of achieving access and benefit-sharing[95].		
14	Requires an orchestrated global effort to generate sufficient resources to achieve equitable human development between developing and developed nations[101] .	*Strategic Plan* refers to contributions to the Millennium Development Goals (MDG).	Appropriate financial target and means of implementation Economic-political axis
15	Implement an effective international carbon mitigation agreement with transfers to compensate developing nations[104]; transfer ownership over large forest commons to local communities with payments for improved carbon storage[106]; enhance local and institutional capacities[107].	*Implementation Decision* refers to participation rather than recognition of ownership and rights.	Co-governance; Environmental-political axis
16	Integrate the Nagoya Protocol into national legislation; continue to mobilise actors to gain sufficient democratic power to negotiate for hard-instrument provisions to change national legislation[109].	1 (a) support for updating the national biodiversity strategies...as effective instruments.	Mobilisation of social change to address power differentials; Social-political axis
17	Implement hybrid adaptive governance[112] and collaborative partnerships for both policy formulation and implementation[49, 113]; tailor biodiversity conservation policy to the local context[114] and culture[115].	Partnerships and participation key features of *Implementation Decision* noted above.	Co-governance; Environmental-political axis
18	Inclusion of Indigenous and Community Conserved Areas into national protected area systems; support indigenous governance and co-governance[49, 118] and indigenous driven-planning and knowledge co-creation[84, 120].	As above; *Strategic Plan* recognises support for contributions of knowledge, innovations and practices of indigenous and local communities.	Co-governance; Environmental-political axis
19	Increase the attention to transdisciplinary methods that bridge science and society in IPBES[125]; support the role of NGOs to contest the terms of neoliberal globalisation to democratise information access[126].	Partnerships with civil society recognised in *Strategic Plan.*	Co-production of knowledge; mobilisation of social change; Social-political axis
20	Green economy is viewed as the means of financing sustainable development[129] but structurally embedded power differentials remain a significant barrier to such a transition[29, 30]; global currency transaction tax can raise funds without deepening power differentials	Clauses 4 and 5 of *Implementation Decision* relate to raising finances through donors and the GEF.	Appropriate financial target and means of implementation; Economic-political axis

[a] For sources cited in Tables 2 and 3, see superscript numbers and their corresponding reference in list in Supplementary Materials.

marine areas, and 17% of terrestrial and inland water will further skew protected areas to places "high and far" from key development contexts, where they do not oppose the ongoing conversion of habitat for industrial, urban and agricultural land uses (Hill et al., 2015; Joppa and Pfaff, 2009). This differential Target may be impeded by increasing effectiveness of the resistance to protected area expansion from local and indigenous peoples, as they are gaining power within the *CBD*, for example through the recognition of the requirement for free, prior and informed consent over actions in their territorial domains (Carino and Colchester, 2010). However, the global recognition of indigenous and local peoples' rights is also scaling downwards to some lower-level jurisdictions to enable re-coupling between people and natural systems. Recognition of Indigenous and Community Conserved Areas as able to provide biodiversity protection is enabling people to return to lands from which they were removed in the fortress conservation era, and also supporting the expansion of protected areas without displacing people (Berkes, 2009; Hoole and Berkes, 2010). Targets 16 and 18 represent cases where the likelihood of achievability reflects the low-level of goal setting. The Nagoya protocol only requires consent arrangements in places where indigenous and local peoples' rights are already recognised by the nation-state, and the certification and disclosure arrangements are not considered adequate by many provider nation-states (Kamau et al., 2012). Similarly, the recognition of traditional knowledge and partication of indigenous and local peoples in Target 18 is limited by the requirement that this occurs accordance with existing recognition and participation measures of the nation-states.

4.4. Yellow: Social–political axis

Influences from interactions along the social–political axis were identified as posing the major impediment to delivery of Aichi Targets 6, 13, 17 and 19. Target 6 is impeded by global political arrangements that have masked feedbacks from the successive depletion of fish stocks by industrialised fishing since 1950, as fleets move to different fish stocks, a form of partial decoupling. About one-third of current fisheries are over-fished (Srinivasan et al., 2012). Policies that underpin flows of resources for social needs from developing to developed nations are characterised by higher levels of debt service, structural adjustment and primary sector exports, which are associated with higher levels of environmental degradation in poor nations (Shandra et al., 2010). Target 13 is challenged by the homogenising effects of the flows from industrial food systems, which involve replacement of landraces by modern cultivars and ongoing genetic erosion in key centres of diversity (Dyer et al., 2014). The traditional farming, collective property and action systems that establish and maintain biological race varieties lack recognition and power, impeding feedbacks and attempts to reverse genetic erosion, again a form of partial decoupling (Eyzaguirre and Dennis, 2007). Sovereign resource rights and private intellectual property rights dominate over communal rights in the international regime complex. Target 17 encounters impediments from the lack of effective participatory policy formulation and political recognition of diverse knowledge systems and world views (Hill et al., 2010). Social networks (both national and transnational) of powerful economic agents, that enjoy influence on governments (and so on institutions and policies) and media through a variety of mechanisms, frequently capture the regulatory agenda, and impede implementation of effective national biodiversity strategies (Katic and Kim, 2013; Orsini and Dampagnon, 2011). Target 19 encounters challenges in negotiating boundaries between diverse knowledge systems (Robinson and Wallington, 2012).

4.5. Orange: Economic–political

Influences from interactions along the economic–political axis were identified as posing the major impediment to delivery of Targets 3, 8, 15 and 20. Target 3 encounters the multiple economic distortions in the global political arrangements for trade, typically market rules that protect subsidies for developed-world farmers, fishers and foresters and urban consumers (Moon, 2011). New market mechanisms that "enclose" land and natural resources in many cases end up dispossessing the poor rather than preventing biodiversity loss, as lack of political recognition of the rights of the poor prevents feedbacks, again a form of partial decoupling (Fairhead et al., 2012). Target 8 is impeded by dampened feedback, for example time lags between market mechanisms and reduction of environmental pollutant loads (Sprague and Gronberg, 2012).

Target 15 encounters the power differential between carbon-intensive industrial actors and global arrangements for rule-setting driven through the United Nations, so that proposed policy initiatives to address current environmental feedbacks, such as displacement of people on small island nations through sea level rise, are suppressed in global negotiations, and effectively decoupled from their intended impacts (Mathys and de Melo, 2011). Target 20 encounters impediments from the economic and geopolitical power differentials that underpin the global economic crisis and competing aid requirements so that even existing, inadequate, commitments to contributions are not met, without punitive consequences. Meanwhile, the proposed solution of raising green capital constitutes new threats and new ways of appropriating resources from the poor and marginalised, further decoupling the connection between benefits in the developed world and impacts in the developing world (Fairhead et al., 2012).

4.6. Purple: environmental–political

Influences from interactions along the environmental–political axis were identified as posing the major impediment to the delivery of Targets 5 and 10. Target 5 is affected by impeded information flows from conflicting evidence about whether agricultural-intensification (land-sparing) or agro-ecological matrix (land-sharing) offer the best approaches for food security and biodiversity conservation and, therefore, about how to set context-relevant environmental standards that balance the risks and benefits of biodiversity loss (Hill et al., 2015; Ramankutty and Rhemtulla, 2013). Target 10 is also impeded by information flows that feed public scepticism about climate change impacts, related more to cultural diversity and belief systems (e.g. conspiracy theories) than scientific uncertainty (Smith and Leiserowitz, 2012). Climate awareness enhances adaptive capacity and the supply of environmental standards is negatively affected by the absence of relevant information (Marshall et al., 2013).

5. Leverage points for generating potentially more effective pathways for the conservation of biodiversity

Our analysis has identified that many of the impediments to delivery of the *Aichi Targets* arise from impeded information flows, delayed feedbacks and other forms of partial decoupling, such as between benefits delivered from biodiversity change in consumer nations, and impacts on ecosystem services in producer nations. We identified multiple leverage points, and the associated axis of influence, where interventions could help shift the system towards potentially more effective pathways for the conservation of biodiversity (Table 3, column 2). We compared our identified leverage points with the actions within the *Implementation Decision* (full text in Table S2), to highlight gaps where new actions could generate change (Table 3, column 3). We found that there is not always a direct correspondence between the axis of impediment to achieving a target, and the axis of intervention to overcome this impediment; sometimes the leverage to move an impediment comes from a different axis. As a result, two axes are absent in Table 3. No leverage points that would remove impediments to any of the *Aichi Targets* were identified along the social–economic (red) axis. In contrast, many leverage points were identified along the economic–environmental (blue) axis, but were found to be already well represented in the *Implementation Decision*. Leverage points where gaps exist with the *Implementation Decision*, and where actions could generate potentially more effective pathways for conservation of biodiversity, were identified along four axes:

- *Green* environmental–social interactions where co-production of knowledge and more equitable food systems governance are potential leverage points to generate more effective information flows.
- *Yellow* social–political interactions where support for social change movements is a potential leverage point for shifting power imbalances that dampen system feedbacks.
- *Orange* economic–political interactions where an appropriate financial target for biodiversity conservation investment and a clear means for its implementation (such as a currency transaction tax) is a potential leverage point towards more effective political structuring and connections with economic interactions.
- *Purple* environmental–political interactions where co-governance of natural resources is a potential leverage point for structuring more effective feedbacks from the environment to policy interventions.

5.1. Green *environmental–social interactions: co-production of knowledge and more equitable food systems governance*

Leverage points along the environmental–social axis can help remove impediments to Targets 1, 2, 3, 5, 7, 8 and 9. Information flow initiatives are already in the *Implementation Decision* but focus on the public deficit model of providing information from the scientific frame of "biodiversity", rather than building on and respecting people's existing knowledge. Co-production of knowledge, through linking science with peoples' existing knowledge systems, and ways of framing 'biodiversity' as 'nature' or 'country', generates positive feedbacks and more effective coupling (Maclean and Cullen, 2009; Robinson and Wallington, 2012). For example, increased focus on linking the charismatic and productive species (that are valued locally for their ecosystem services) to the non-charismatic non-productive species in the same habitats can help overcome lags in environmental feedbacks to the social system (Hill et al., 2010). Evidence is growing about the worth of transdisciplinary methods and pluralistic frameworks for "biodiversity values" as an effective means of triggering information flows in ways that address a diverse array of sustainability problems (Lang et al., 2012). The Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) has recognised this need for diverse frameworks to underpin information flows in their conceptual framework for assessments (Díaz et al., 2015).

More equitable food systems governance is critical to overcoming the impediments posed by ecologically unequal exchanges, as discussed in Section 4.3. Support for localised food systems that produce food where the hungry live could help address such distributional injustice. Improvements in information flows about food supplies are also a leverage point. For example, the recent Niger food crisis is argued to have resulted more from institutional failure that impeded information flows than from lack of food production (Juhola, 2012). Mechanisms to allow agreement amongst stakeholders about the severity of the situation, to incorporate farmers' knowledge and trigger (free) food distribution outside the market arrangements have been identified as food systems governance interventions that could help avoid future famines, and represent improvements in system coupling (Juhola, 2012). Requirements for distributive justice and equitable development could be inserted into existing agricultural market and emerging biodiversity market arrangements, overcoming the barriers that currently block feedbacks to consumer nations from the producer nations about environmental and social costs of production (Fairhead et al., 2012). Transfer of ownership over large forest commons to local communities combined with payments for improved carbon storage could also remove current blockages to feedbacks from ecologically unfair exchanges, whilst continuing to generate biodiversity conservation outcomes (Chhatre and Agrawal, 2009).

5.2. Yellow *social–political interactions: support for social change movements.*

Leverage points along the social–political axis can help remove impediments to Targets 4, 16 and 19. The relative powerlessness and marginalisation of many social actors in the developing world results in many biodiversity conservation challenges: structural adjustment packages associated with environmental damage; inability to protect biodiversity through traditional farming systems and corporate capture of regulatory instruments (Section 4.4). Promoting processes that enable empowerment and power-shifting offers a leverage point to strengthen feedbacks. Social movements that create narratives and discursive frames to mobilise actors can move biodiversity as an issue into a more powerful governance context (Hill et al., 2013). Non-government organisations are key actors that can contest the terms of neoliberal globalisation; comparative analysis has shown that higher levels of non-government organisations are associated with lower numbers of threatened mammals and birds (Shandra et al., 2010). Supporting network linkers, including social entrepreneurs and leaders, and information-flow processes including shared visions, learning platforms, bridging and boundary organisations, can strengthen coupling between various system components and help shifts towards adaptive institutions with the potential to solve the problem of biodiversity decline (Boyd and Folke, 2012). Social movements' current mobilisation around greater recognition of common property rights, greater democratisation, and opposition to unfettered trade provide potential leverage points for a number of system impediments. Greater democratisation could aid power shifting and mobilise feedbacks to leverage institutional adaptation (Kim and Mackey, 2014).

Inclusion of hard-instrument regulatory provisions into the CBD mechanisms is a potential pathway towards equalising power differentials between the international conservation, development and finance instruments which currently masks feedbacks such as those from climate change impacts and infrastructure development (Boisvert and Vivien, 2012; Laurance et al., 2015). The World Trade Organization (WTO) and Agreements have enforceable powers, for example for breaching rules of the WTO, whereas *Aichi Targets* have no penalty imposed for failure (Jóhannsdóttir et al., 2010). Trade Agreements could be modified to allow nation-states to put biodiversity before free trade, when they deem it necessary, and remove the power of corporations to sue governments that implement legislation that enhances biodiversity protection. More generally, criteria based on social, economic, and environmental sustainability goals should be used for redesigning and applying multilateral trade rules. The Nagoya Protocol could be strengthened through voluntary application (regardless of status in the nation-state's formal institutions) while negotiations continue for hard-instrument provisions that will require changes in national legislation and greater recognition of indigenous and local peoples' rights, again overcoming impediments to feedbacks, and strengthening system coupling (Oberthuer and Pozarowska, 2013).

5.3. Orange *economic–political interactions: improved food systems governance and an international currency transaction tax*

Leverage points along the economic–political axis can help remove impediments to Targets 12, 14 and 20. Raising an appropriate level of financial resources to implement actions for conservation of biodiversity was identified as a key leverage point to overcome impediments to several targets, and a key gap in the current plans (Table 3). While Target 20 recognises the need to increase resources, a specific target detailing the amount of finances necessary is absent. Specific financial targets now accompany development plans; for example the G20 nations in 2014 committed to invest US$60–70 trillion worldwide in new infrastructure by 2030, thereby more than doubling the current value of global infrastructure (Laurance et al., 2015). Similar commitment to a clear financial target for biodiversity conservation investment, with a means for its implementation, is a key leverage point for overcoming the current financial impediments.

The financial challenge of funding *Aichi Targets*' delivery has been estimated at $76.1 billion annually (McCarthy et al., 2012). An international currency tax of 0.005 percent would yield around $40 billion annually, and support for this at an appropriate level (e.g. .02) to fund global human development and sustainability concurrently is growing (Klugman et al., 2011). This tax can also re-couple the economic activities of global corporations with the political system, currently decoupled as many corporations appear able to pay little tax by operating across diverse nation-state tax regimes. Other funding mechanisms relevant to biodiversity conservation, such as the Clean Development Mechanism, REDD+, and debt relief for poor countries, do not display these characteristics (i.e. clear financial target with means for implementation, stimulating recoupling) but are worthy of consideration (IMF, 2014; Schroeder and McDermott, 2014; UNFCC, 2014). Nevertheless,the tax would allow resources to be channelled from richer to poorer contexts without the debt and structural adjustment arrangements that have been shown to be associated with higher numbers of threatened mammals and birds and without the governance, rights and tenure contests that have challenged REDD+ and the CDM (Schroeder and McDermott, 2014; Shandra et al., 2010).

5.4. Purple *environment–political: co-governance of natural resources*

Leverage points along the social–political axis can help remove impediments to Targets 6, 11, 13, 15, 17 and 18. Co-governance is a means of integrating human rights and indigenous claims into biodiversity conservation that can lead to more effective system linkages, and overcome impediments to decision making in contexts of partial information, such as in the land-sharing vs landsparing debate discussed in Section 4.6 (Boyd and Folke, 2012). Co-governance arrangements that re-couple fisheries across jurisdictions are recognised as a means to build social capital, trust and social learning between fishers, managers and scientists, leading to more effective resource management (Fidelman et al., 2012). Tailoring biodiversity conservation policy to the local context and culture builds social support, and could be a means to negotiate context-specific mixtures of land-sparing and land-sharing (Ramankutty and Rhemtulla, 2013; Waylen et al., 2010). An increased focus on socially designated protected areas, with co-governance arrangements, such as Community Conserved Areas, helps overcome resistance to expansion of the protected area estate associated with feedbacks from those whose territories are affected (Davies et al., 2013). Adhering to Free Prior and Informed Consent in indigenous customary territories and addressing legacy issues resulting from a history of forced evictions are also highlighted as useful mechanisms for overcoming impediments to protected area expansion (Hill, 2011).

6. Conclusion

Our application of social–ecological systems (SES) analysis has provided insight into diverse system interactions that pose impediments to the *Aichi Targets*, many of which are related to partial decoupling between SES components. The Global Biodiversity Outlook 4 (GBO-4), which provides a mid-term assessment of progress towards implementation of the *Aichi Targets*, was released while this paper was in review (Leadley et al., 2014; Secretariat of the Convention on Biological Diversity, 2014; Tittensor et al., 2014). GBO-4 found that 18 of the 20 *Aichi Targets* are tracking in accordance with our analysis (Table 4). Only Target 16 is fully on track to be achieved; our analysis identified that this Target is likely to be achieved in full because the conditionality of the Nagoya Protocol means that it can be achieved with little change.

A further mid-term analysis of progress towards the targets using 55 indicator data sets, also published while this paper was under review, found that recognition of the biodiversity crisis is increasing, and growing efforts are being made to address it, but these efforts appear unlikely to result in an improvement of the base state of biodiversity by 2020 (Leadley et al., 2014; Tittensor et al., 2014). This projected acceleration of societal actions, without change in biodiversity conditions, is recognised as possibly due to time lags, or alternatively to inappropriate or insufficient responses relative to the pressures (Tittensor et al., 2014).

In response to the lack of progress shown in the mid-term analysis, Tittensor et al. (2014) recommend "efforts need to be redoubled" (p. 244), while also noting the current efforts may be inappropriately directed and discussing the potential need to consider the impact of time lags. Marques et al. (2014) argue that the poor progress means that prioritisation of actions within the current plans is now critical. Kok and Alkemade (2014) present details of relevant priority actions across food and wood production, water and fisheries management, and in mainstreaming biodiversity. The analysis here presents a complementary option: rather than just prioritising among existing actions, we can focus on new areas of action. Our analysis highlights new leverage points, currently not within the global biodiversity plans and policies, which can generate potentially more effective pathways for the conservation of biodiversity.

The gap analysis showed that the current *Implementation Decision* focuses on the economic–environmental axis, perhaps reflecting the influence of market-based solutions, and initiatives such as The Economics of Ecosystems and Biodiversity (TEEB, 2009). However, interventions on this axis have little impact on key impediments associated with the context of marginalised peoples, issues of distributive justice and equity, and entrenched global power inequities. Interventions along environmental–social, social–political, economic–political, and environmental–political have the potential to influence pathways that overcome these sorts of impediments (Table 3).

Many of our suggested actions to generate potentially more effective pathways for the conservation of biodiversity align with the emerging concept of adaptive institutions for sustainability, with its emphasis on multi-level co-governance, entrepreneurial activism to lead change, networks and cross-scale learning to overcome obstacles to adaptation arising from overly rigid institutional and cultural frameworks (Boyd and Folke, 2012). The expansion of the global human ecological footprint is inducing the growth of socio-environmental conflicts worldwide, but particularly in regions with ecologically vulnerable ecosystems, intensive human occupation and high levels of social organisation. On the other hand, social movements of resistance are able, sometimes, to stop, or at least delay, the expansion of the extraction frontier, and to re-draw its limits. In this context, an increasing number of communities are reacting, searching for information and experiences. Stimulating actions that recognise

Table 4
The assessment of likelihood of delivery of each target from this analysis compared with the findings of Global Biodiversity Outlook 4 (Leadley et al., 2014; Secretariat of the Convention on Biological Diversity, 2014; Tittensor et al., 2014).

Target #	Focus of target	Our assessment of achievability	GBO-4 findings
1.	People more aware of biodiversity values	Not likely	Not on track
2.	Biodiversity integrated into development	Not likely	Not on track
3.	Perverse incentives and subsidies removed	Not likely	Not on track
4.	Sustainable production and consumption	Not likely	Not on track
5.	Rate of loss of natural habitats halved	Not likely	Not on track
6.	Sustainable harvests of fisheries	Not likely	Not on track
7.	Sustainable agriculture, aquaculture and forestry	Not likely	Not on track
8.	Pollution brought to safe levels.	Not likely	Not on track
9.	Invasive species control	Not likely	Not on track
10.	Climate impacts on biodiversity minimised	Not likely	Not on track
11.	Protected areas cover 17% of terrestrial, inland water; 10% of coastal and marine	Likely	On track to meet 17%, not on track otherwise
12.	Extinctions of threatened species prevented	Not likely	Not on track
13.	Genetic diversity of cultivated biota maintained	Not likely	Not on track
14.	Ecosystem services restored and safeguarded	Not likely	Not on track
15.	Ecosystems' resilience and contribution to carbon storage enhanced.	Likely for some	Not on track
16.	Nagoya Protocol enforced.	Likely, little change	On track.
17.	National Biodiversity Action Plans implemented.	Not likely	Not on track
18.	Traditional knowledge respected, full participation of peoples.	Likely, little change	Not on track
19.	Science and knowledge shared	Likely for some	On track on one of two indicators
20.	Sufficient finances mobilised	Not likely	Not on track

and support this challenge to the current trajectory may help global civilisation to break out of the pattern where institutions constrain behaviours, which in turn prevent institutional change towards sustainability (Fischer et al., 2012).

Our SES analysis provides some support for Raudseep-Hearne et al.'s (2010) contention that partial decoupling in the global SES may explain why human well-being increases as ecosystem services decline, termed the "environmentalists' paradox". For example, the global political arrangements that have masked feedbacks from the successive depletion of fish stocks by industrialised fishing since 1950, as fleets move to different fish stocks, a form of partial decoupling, may contribute to human well-being increasing as biodiversity declines (Srinivasan et al., 2012). Similarly, human well-being may be raised through exports that deliver embedded ecosystem services (e.g. water) to developed countries in ecologically unequal exchanges, whereby recipient countries raise the per capita consumption of many, and provider countries receive the environmental impacts in exchange, in regions with lower human population densities (Shandra et al., 2009). Further attention to multi-dimensional aspects of system interactions, coupling and de-coupling may explain why human well-being increases while ecosystem services decline.

The insights from this SES analysis into the interactions between human social systems and the environment have assisted in understanding impediments and leverage points where interventions could potentially assist to achieve the *Aichi Targets* by 2020, and set more effective pathways for longer-term conservation of biodiversity. We argue that further scientific attention to the interactions and dynamics associated with biodiversity in social–ecological systems is critical to move beyond analysing and measuring the problem towards the generation of realistic context-specific pathways towards halting biodiversity loss. New actions are urgent to reverse the current trajectories that show the *Aichi Targets* are unlikely to be delivered by 2020 and biodiversity condition continue to trend downwards.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2015.04.005.

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