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An integrative research framework for enabling transformative adaptation

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37 ABSTRACT

38 Transformative adaptation will be increasingly important to effectively address the impacts of
39 climate change and other global drivers on social-ecological systems. Enabling transformative
40 adaptation requires new ways to evaluate and adaptively manage trade-offs between
41 maintaining desirable aspects of current social-ecological systems and adapting to major
42 biophysical changes to those systems. We outline such an approach, based on three elements
43 developed by the Transformative Adaptation Research Alliance (TARA): (1) the benefits of
44 *adaptation services*; that sub-set of ecosystem services that help people adapt to
45 environmental change; (2) The *values-rules-knowledge perspective (vrk)* for identifying those
46 aspects of societal decision-making contexts that enable or constrain adaptation and (3) the
47 *adaptation pathways approach* for implementing adaptation, that builds on and integrates
48 adaptation services and the *vrk* perspective. Together, these elements provide a future-
49 oriented approach to evaluation and use of ecosystem services, a dynamic, grounded
50 understanding of governance and decision-making and a logical, sequential approach that
51 connects decisions over time. The TARA approach represents a means for achieving changes in
52 institutions and governance needed to support transformative adaptation.

53 1. Introduction

54 The IPCC Fifth Synthesis Report stated it is *very likely* that surface temperature and sea
55 levels will continue to rise and extreme weather events become more frequent (IPCC, 2014).
56 By 2050 the global population is projected to increase from 7.2 to 9.6 billion, with mounting
57 pressures on terrestrial, marine and freshwater resources. Global networks of commerce,
58 technology and information have produced unstable systems that are vulnerable to
59 uncontrollable failure, posing considerable threats to society (Helbing, 2013; Streek et al.,
60 2016). Climate change combines with other drivers to synergise rates and extent of change to
61 social-ecological systems. Dealing with synergistic effects of other global change drivers and
62 climate change requires transformative approaches to adaptation.

63 Adaptation to global change presents a profound challenge because it requires the tackling
64 of short- and long-term threats, changes and uncertainty that transcend sectors and scales.
65 Over the past decade, efforts to understand the impacts of climate change on biodiversity
66 have led to new concepts and approaches to support adaptation of biodiversity (Mawdsley,
67 2011; Cross et al., 2012; Reid, 2015). Conservation policy and practice have focussed on

68 ecosystems, species and maintenance of biophysical integrity but tended to neglect
69 institutional contexts: the people and organisations responsible for implementing adaptation
70 (Armsworth et al., 2015). Smith (1997) emphasised the need for adaptation to be *anticipatory*
71 rather than reactive, aimed at reducing social vulnerability to climate change and with policy
72 criteria based on institutional attributes of flexibility, adaptability, resilience, and where
73 benefits exceed costs. Almost 20 years later, anticipatory action has been limited. There
74 remains a compelling need for researchers and practitioners to work together to identify how
75 to put concepts of anticipatory transformative adaptation into practice.

76 Adaptation has been framed as a continuum of resilience, transition and transformation
77 (Pelling, 2011). At one end of the spectrum are incremental responses to proximate causes of
78 vulnerability, while at the other is transformative adaptation to long-term, large-scale, non-
79 linear, uncertain changes (Wise et al., 2014). Yet, most adaptation practice is reactive, local
80 and short-term (Hodgkinson et al., 2014). Such actions are likely to be maladaptive (Barnett
81 and O'Neill, 2010) because effects of long-term environmental change are marginalised and
82 the interactions between decision lifetimes, uncertainties about the nature of biophysical
83 change and possible adaptation options, tend to be downplayed (Stafford Smith et al., 2011).
84 Proponents of short-term adaptation may not acknowledge that ecosystems are likely to
85 transform (Park et al., 2012; Wise et al., 2014). But even when ecosystem transformation is
86 acknowledged, societal transformation is considered beyond the capacity for adaptation
87 because of a perceived lack of new options (Dow et al., 2013). The alternative view is that
88 transformative adaptation of social-ecological systems is both necessary and possible, based
89 on anticipatory approaches in which new options are co-created, explored and experimented
90 with (Rickards and Howden, 2012; Rickards, 2013).

91 We define a social-ecological system as a coupled biogeophysical entity (e.g. an ecosystem,
92 landscape or bioregion) with social actors and institutions that has properties of complexity,
93 adaptiveness and multiple cross-scale feedbacks (Fischer et al., 2015). Transformation of a
94 social-ecological system may be initiated by changes in ecosystem drivers (e.g. temperature
95 regime, water availability, nutrient balance), followed by ecosystem changes (e.g. in extent
96 and composition of vegetation communities and their and associated biota), leading to
97 adaptation by social actors including altered use of ecosystem services, livelihoods and
98 governance arrangements for natural resources (Box 1). Changes in ecosystem drivers may be
99 due to climate change or other anthropogenic pressures including transformations in social

100 systems such as establishment of an irrigation system. Such changes have occurred at Lake
101 Faguibine, Mali (Djouidi et al., 2013) and the Murray-Darling Basin, Australia (Colloff et al.,
102 2016a) where complex, non-linear transformative ecological and social changes have followed
103 declining inflows to rivers caused by climatic drought and high water diversions for irrigation.

104 Climate change may limit societal choices over which ecosystem services can be supplied by
105 changing ecosystems. But new knowledge gained from experimenting with adaptation may
106 provide some influence on the direction of ecosystem change, if participants in adaptation
107 decisions and actions are willing and able to use this knowledge in participatory and
108 deliberative ways to alter interests, values and rules that constrain implementation (Chapman,
109 2011). Co-evolving systems of societal values, rules and knowledge define the decision
110 contexts of individuals, groups, organisations and societies which can be purposefully shifted
111 (e.g. Voss et al., 2007) to enable anticipatory transformative adaptation based on co-creation
112 of options and learning by doing. Such an approach can help overcome limited problem
113 awareness leading to low public support for adaptation that has impeded agents from learning
114 about climate change impacts and the range of actions they can take (Eisenack et al., 2014).

115 The willingness of people to engage in transformative adaptation is not enough. Powerful
116 stakeholders who perceive threats to their interests will attempt to prevent others from such
117 action (Klein, 2014). Global and national institutions will be vital for facilitating and supporting
118 transformative adaptation, which "...will require fundamental transitions in the systems of
119 production and consumption that are the root cause of environmental and climate pressures.
120 Such transitions will, by their character, entail profound changes in dominant institutions,
121 practices, technologies, policies, lifestyles and thinking" (EEA, 2015). Providing evidence of
122 successful transformative responses is critical to overcoming barriers to adaptation (Peterson
123 et al., 2003), which include uncertainty regarding risks, benefits and perceived costs, as well as
124 institutional behaviours that serve to maintain the *status quo* (Kates et al., 2012), such as
125 forced and predatory economic growth (Bhaduri, 2008).

126 In this paper, we outline a framework for enabling transformative adaptation, developed by
127 the Transformative Adaptation Research Alliance (TARA <https://research.csiro.au/tara/>), an
128 international network of researchers and practitioners who study and promote transformative
129 adaptation. The TARA approach provides clear and structured ways of diagnosing and framing
130 complex problems, co-generating innovative solutions and overcoming decision inertia to
131 engender agency for adaptation. The TARA approach is based on a novel, cohesive, operational

132 framework that integrates three powerful existing concepts: (1) the *values-rules-knowledge*
133 perspective on adaptation decision-making, that focuses on reframing current decision-making
134 contexts to enable future adaptation decisions and actions; (2) the *adaptation pathways*
135 approach, for planning and implementing adaptation to transform social-ecological systems to
136 become adapted to the effects of global change, and (3) the *adaptation services* concept, that
137 redefines the relationship between people and ecosystem services based on likely future
138 ecosystem states and changes in the supply of services.

139 **2. Three elements to enable transformative adaptation**

140 We propose that operationalising the three elements listed above provides a basis for
141 adaptation planning and action that moves beyond incremental approaches targeted at
142 proximate causes of vulnerability to those capable of addressing transformative adaptation
143 and strategically tackling long-term, systemic problems.

144 *2.1 The values, rules and knowledge perspective (vrk)*

145 For anticipatory, transformative adaptation to be realised, a new perspective on decision-
146 making is required that reveals the need for transformative adaptation. Decision contexts are
147 informed and defined by interactions between systems of societal values and rules and the
148 forms of knowledge considered salient and legitimate by the decision makers (Gorddard et al.,
149 2016). The *vrk* perspective on decision contexts helps identify how decision making can be
150 constrained by the preferences of decision makers, their institutional context and their
151 understanding of how the world works (Gorddard et al., 2016).

152 ‘Values’ in the *vrk* perspective refers to the set of individual and collective motivations that
153 guide goals and actions, priorities and moral framings (Schwartz, 2012). However, these
154 motivations are expressed in adaptation decision making via the other use of the term ‘value’,
155 to mean ‘importance, worth or usefulness’. In this sense, we recognize the importance of
156 values pluralism –the multiple ways of understanding nature by diverse social actors– under
157 the categories of intrinsic, relational and instrumental values (Diaz et al., 2015). Inclusion of
158 values pluralism in deliberation and decision-making allows for different and novel adaptation
159 approaches (Martín-López and Montes 2015). Such approaches go beyond just instrumental
160 values, where nature is regarded as a source of material benefit and wellbeing, and

161 incorporate intrinsic values (i.e. inherent values, independent of usefulness) and relational
162 values (i.e. desirable, and desired, relationships between people and nature (Chan et al.,
163 2016). ‘Rules’ in the *vrk* perspective refer to both ‘rules-in-use’ (norms, practices, taboos,
164 habits, heuristics and behaviours) and ‘rules in form’ (regulations, laws, treaties, ordinances,
165 directives), which ‘knowledge’ includes evidence-based (scientific and technical) knowledge
166 and experiential and meanings-based knowledge (Gorrdard et al., 2016).

167 Where values, rules and knowledge are considered explicitly in adaptation decision-making,
168 they are often treated as independent, disaggregated entities (Fig. 1a), rather than
169 interdependent components. Treating these components as disconnected obscures how
170 certain forms of values, rules and knowledge and their interactions are excluded from decision
171 making; for example, moral and ethical values relating to distribution of power, consideration
172 of the rules of natural justice, local ecological knowledge and Indigenous knowledge and belief
173 systems. In such situations, adaptation is framed without considering the complex, interactive
174 behaviours of human agents and their social and institutional settings. The result tends to be
175 promotion of short-term technological solutions that do not address dynamic, complex human
176 interactions in circumstances of social-ecological change. In this regard, the diagnostic value of
177 the *vrk* perspective echoes the outlook of Abson et al. (2016) that “biophysical, social,
178 economic and political facets of sustainability are addressed in isolation from each other...A
179 common feature of such framings is that they often imply that sustainability problems can be
180 resolved without consideration of the structures, values and goals that underpin complex
181 problems at deeper levels.” Abson et al. (2016) draw upon the deep leverage points model of
182 Meadows (1999): the places in a complex system where small shifts may lead to large system
183 changes. The *vrk* perspective represents a means of intervening at the deepest leverage
184 points; of system *design*, which include rules, incentives, constraints and capacity for change,
185 and *intent*, which include goals, paradigms and the power to transcend them.

186 Shifts in paradigms, norms, world views, interests and values by decision makers and
187 practitioners are needed to foster changes in societal rules relating to adaptation and the
188 emergence of innovative governance systems for transformative adaptation (Chaffin et al.,
189 2016). And by changing rules, so we may change values. New forms of knowledge and new
190 ways of learning are required to facilitate adaptation decisions and actions, particularly those
191 aimed at systemic causes of problems (Cornell et al., 2013). Triple loop learning involves
192 reflexive enquiry into changes in forms of knowing and learning, including questioning the

193 systems of values, rules, and knowledge inherent to a paradigm or an organisation such as a
194 policy decision-making body (Tosey et al., 2012). Agency for change can then arise from
195 collective learning and decision making. The *vrk* perspective augments triple loop learning by
196 emphasising that agency and scope for change are constrained. For example, the *vrk*
197 perspective reveals that new scientific knowledge does not, on its own, translate to changes in
198 adaptation decisions (Gorrdard et al, 2016; Fernandez, 2016). Researchers have limited agency
199 to achieve change without also considering values and rules in relation to new knowledge.
200 Instead, the *vrk* perspective allows policy decision makers to deliberate of each adaptation
201 decision: “do we know the outcome?” [knowledge] and, if so, having considered knowledge
202 interactions with values and rules, ask “do we want the outcome?” [values] and, if so, having
203 considered knowledge and rules, ask “are we allowed the outcome?” [rules], considering
204 knowledge and values. If the answer is “no” at any stage, then the next step is to identify what
205 needs to change in values, rules and knowledge in order to get to “yes”, or to consider other
206 adaptation options. If the answer is uncertain, this signals that more deliberation is required
207 on the sources of uncertainty and what needs to change to get to “yes” or “no”.

208 The legitimacy of adaptation objectives depends on how people perceive the impacts of
209 change on their interests and values (O’Brien and Wolf, 2010). However, limits to adaptation
210 imposed by such perceptions are not immutable (Adger et al., 2009). Interests can be shifted
211 by new knowledge of the options available, such as the prospects for adaptation of livelihoods
212 based on new adaptation services. Adaptation can be facilitated by changes in rules to help
213 realise those options and through planning, learning and implementation as part of an
214 adaptation pathways approach. For example, threatened species are a key driver of
215 conservation, policy and practice in many countries, in response to legislative mandates and
216 considerable societal values placed on certain species. But shifting from a threatened species
217 focus to ‘climate-ready’ conservation practices will require major shifts in knowledge, values
218 and rules of how we plan and implement conservation under climate change (Wyborn et al.,
219 2016). Barriers to be addressed for adaptation in conservation include lack of resources and
220 political support, poor cross-sector coordination, uncertainty over governance responsibilities
221 (rules); conflicting priorities and interests (values); and shortcomings of expertise or feasible,
222 acceptable solutions (knowledge) (Wyborn et al., 2015).

223 Recently, some authors have considered binary interactions between values, rules and
224 knowledge, such as how rules influence values and norms (Kinzig et al., 2013; Rico García-

225 Amado et al., 2014); how power is used by decision makers to exclude some forms of
226 knowledge (Cash et al., 2003; Termeer et al., 2011), how economic drivers prioritise technical
227 knowledge at the expense of local ecological knowledge that has co-evolved with the
228 environment (Iniesta-Arandia et al. 2014), and how societal interests and values can be shifted
229 by new knowledge (Cornell et al., 2013; Leith et al., 2014). Sequential approaches to *vrk*
230 interactions have begun to be applied to adaptation decision making (Hobday et al., 2015).

231 We consider the interactions of values, rules and knowledge are inseparable and multi-
232 directional. Interactions are co-evolutionary and unique to each context: change in one of the
233 domains of knowledge, vision, process and context of adaptive governance precipitates change
234 in other domains (Wyborn, 2015). We suggest that these interactions can catalyse
235 transformative change in other domains. Part of the TARA research agenda is to develop
236 greater understanding of how interacting systems of values, rules and knowledge can both
237 constrain and enable the decision context for transformative adaptation.

238 *2.2 The adaptation pathways approach*

239 Metaphors structure our sense-making of complex issues such as climate change. Meaning
240 is created for concepts through their relationship with the metaphorical frame (Lakoff, 2014).
241 The adaptation pathways metaphor evokes a narrative journey into an uncertain future (Fig.
242 1b), complementing another climate change metaphor of “never going home again”
243 (Chapman, 2011). On such a path, problems emerge and choices have uncertain, far-reaching
244 consequences. People may strive to be forward-looking, learn and be changed by the journey;
245 though the prospect of change is a source of resistance for many. Options for responding to
246 future uncertainties are enabled or constrained by choices made along the journey, changing
247 the path in ways that may be irreversible. Moral and ethical dilemmas are explored en route;
248 conflicts, resolution and co-operation play central roles. Interactions of decisions, social
249 dynamics and environmental change determine the outcomes. These elements are a rich basis
250 to envision how social-ecological systems may traverse the future: adaptation pathways can
251 play an important role in broadening our thinking and actions for transformative adaptation.

252 As well as metaphor, the adaptation pathways approach can be formalised as an adaptive
253 decision process for ‘exploring and sequencing a set of possible actions based on alternative,
254 uncertain developments over time’ in ways that seek to avoid maladaptation (Wise et al.,
255 2014) (Fig. 1c). This conceptualisation explicitly aims to examine trade-offs between the

256 benefits of maintaining the flexibility to respond to future uncertainties against the costs of
257 attempting to maintain the status quo. Adaptation pathways can aid implementation by
258 revealing elements required for transformative adaptation (Wyborn et al., 2015) by focussing
259 on both social and ecological dynamics (Haasnoot et al., 2013; Wise et al., 2014).

260 The adaptation pathways approach conceptualised by Wise et al. (2015), unlike many
261 futures scenario approaches, enables examination and changes in the decision context at each
262 sequenced decision point (Fig. 3), based on the following attributes: *The diagnosis of the*
263 *adaptation challenge* at a particular time, and over time, relies on the knowledge regarding the
264 magnitude, rate and extent of biophysical change and impacts on ecosystems, livelihoods,
265 economic development or other focal contexts. *The setting of agreed and desirable objectives*
266 for adaptation interventions takes into account the diverse values, rules and knowledge
267 framings of multiple stakeholders, including the use of adaptation services under different
268 scenarios of environmental change. *The sequencing of decisions and actions* for paving the
269 pathway towards new adaptation actions depends on the sequence of decisions and actions
270 according to lead times, the duration that such decisions remain valid (Stafford Smith et al.,
271 2011) and the role of each action in paving the pathway. *The development of governance*
272 *systems* that allow adaptation is based on monitoring, evaluation and learning of the
273 management actions up to that point and allows changes in decision processes to realise
274 objectives. A mechanism – the *vrk* perspective – is critical for examining and changing the
275 decision context at each decision point in an adaptation pathway in order to avoid
276 incremental, short-term, maladaptive and path-dependent (historically determinant)
277 sequencing of adaptation actions. Changes to the decision context are the prerequisite for
278 adaptation actions that are implemented between the decision points that pave the way for
279 ensuring a wider set of options is available at the next decision point.

280 The adaptation pathways approach provides the basis for actors to learn and co-create
281 solutions from doing, experimenting and innovating because as its starting point it requires
282 decision makers to address questions such as: are decisions and actions robust to future
283 scenarios and can they be halted or reversed if conditions change? Will actions prevent the
284 crossing of a biophysical threshold? Framing adaptation pathways in this way (as opposed to a
285 route map or simple plan) is both necessary and more likely to be effective in situations where
286 goals are ambiguous, decisions are contested, social-ecological systems are highly dynamic and
287 trajectories of change are unpredictable (Butler et al., 2014). An example of *vrk* – adaptation

288 pathways interactions is where decision makers in New York transformed their decision
289 context by including increased future risks of climate change into plans for rebuilding after
290 destruction caused by Hurricane Sandy (Rosenweig and Solecki, 2014).

291 *2.3 The adaptation services concept*

292 Adaptation services are a sub-set of ecosystem services that provide benefits to people
293 from increasing their capacity to adapt to environmental change (Lavorel et al., 2015; Colloff et
294 al., 2016a, 2016b). Adaptation services are supplied via the properties of ecosystems to
295 moderate and adapt to change and provide future options and insurance for adaptation (Fig.
296 1c). Benefits accrue from (1) novel provisioning and regulating services that become newly-
297 available due to ecosystem transformation, such as timber, charcoal and forage from a forest
298 that grew on a dry lake bed in Mali (Djouidi et al., 2013); (2) latent services, i.e. ones that were
299 available but not recognised as services or used as such, but which provide options for
300 adaptation. An historical example is feral goats, a pest species in Australia, but now the basis
301 of a profitable rangeland meat export industry by former wool producers (Jones, 2012); (3) the
302 management of supporting and regulating services to underpin provisioning and cultural
303 services and (4) the adaptive capacity of ecosystems to remain more-or-less in the same state
304 and continue to provide existing services, or transform to a new state and provide new ones.
305 Adaptation services alone are not a panacea, but together with ecological restoration and
306 preventing ecosystem degradation, they are critical to the management of changing
307 ecosystems (Colloff *et al.* 2016a, 2016b; Doherty et al., 2016).

308 The adaptation services concept is required for transformative adaptation because of the
309 limits of the ecosystem services concept as it relates to global change, particularly where the
310 predominant resource allocation mechanism is market-based, which inevitably favours
311 provisioning services (and some regulating services) that can be commodified, exchanged and
312 priced, over most supporting and regulating services that cannot (Rausdepp-Hearne et al.,
313 2010). Such a market economics-based approach generally constrains adaptation because the
314 delayed and uncertain effects of climate change on the future production and supply of
315 ecosystem services cannot be accounted for (Norgaard, 2010). Instead, adaptation services are
316 focussed on future options, but there is an explicit requirement for a trade-off framework as
317 part of their management to ensure future options are not compromised.

318 3. Integrating *vrk*, adaptation pathways and adaptation services

319 Integration of the values, rules knowledge perspective and adaptation services within an
320 adaptation pathways approach enables exploration of the interactive dynamics of ecosystems
321 and social systems in their adaptation journey (Fig. 2). In this framing, the adaptation services
322 concept is a new way to evaluate scientific knowledge on changes to ecosystems and evolving
323 societal perspectives on their use and management as part of *vrk*. Adaptation services and
324 their underpinning ecological mechanisms provide new options for adaptation as well as
325 enabling supply of some current ecosystem services to be maintained (Lavorel *et al.*, 2015). By
326 focussing on future options, the adaptation services concept can help individuals and
327 collectives explore how to use adaptation services, together with public institutions (e.g.
328 transport systems, economic freedom, democratic processes, health and education systems,
329 land rights) to engage in transformative adaptation. Administrations can support these
330 capabilities by co-producing acceptable, legitimate transformative policies. Such policies, and
331 the decision contexts related to them, would extend the adaptation services concept beyond
332 its instrumental value in providing future options, and including intrinsic and relational values.

333 Realising the options of adaptation services will often require changing aspects of the
334 decision context, using the *vrk* perspective to diagnose barriers and identify the sequencing of
335 interventions, and purposefully attempt to change the prevailing interactions of *vrk* that
336 constrain response options. Such an approach represents adaptation pathways as possible
337 sequences of strategic interventions aimed at overcoming institutional, cultural or knowledge
338 constraints so that adaptation services can be legitimately considered by future decision
339 makers in conservation or natural-resource management (Fig. 3).

340 The adaptation pathways approach represents a set of sequenced shifts in the decision
341 context, and hence in systems of *vrk* in response to the use of adaptation services and changes
342 to social-ecological systems (Fig. 3). The systems of *vrk* evolve along these pathways as
343 adaptation decisions are implemented over time. But the links are not only one way because
344 *vrk* influences which adaptation services might be used, and hence the particular route along
345 the pathway. Adaptation thus involves influencing the evolution of societal responses to
346 biophysical change so that future decision makers can understand the opportunities and
347 constraints and select options in the adaptive space.

348 By identifying adaptation services and the *vrk* context of a focal social-ecological system,
349 management and decision making to support adaptation services (e.g. habitat protection,
350 connectivity and restoration; Lavorel et al., 2015) is integrated into planning and
351 implementation. Implementing an adaptation pathways approach then requires institutional
352 and community co-learning, including engagement in adaptive monitoring and research, co-
353 producing and trialling new management practices and novel approaches to livelihoods,
354 decision making and governance (Wyborn, 2015; van Kerkhoff and Lebel, 2015). By connecting
355 management actions with policy, planning and learning, the TARA approach provides a basis to
356 identify barriers that extend beyond the scale and context of individual management activities,
357 and helps creating new decision contexts supported by co-diagnosis of constraints on decision
358 making; co-development of a common systems framing and co-creation of futures scenarios
359 supporting the planning and implementation of adaptation pathways in a way that stimulates
360 deliberation, choice and empowerment.

361 **4. How the TARA approach compares and links with other adaptation frameworks**

362 There is an increasing number of adaptation approaches, some with properties in common
363 with the TARA approach. Examples include Ecosystem-based Adaptation (EbA; Vignola et al.,
364 2009; Munang et al., 2013; Doswald et al., 2014); Eco-disaster Risk Reduction (Eco-DRR;
365 Renaud et al., 2013); resilience (Walker et al., 2004) and Community-based Adaptation (CBA;
366 Ayers and Forsyth, 2009; Dodman and Mitlin, 2013). These approaches aim to support
367 sustainable adaptation under global change and focus on ecosystems (except CBA); the
368 prospect of ecosystem transformation (TARA and resilience) and transformative adaptation of
369 social-ecological systems, either as the primary focus (TARA) or as an observed phenomenon
370 (other approaches). Initially, resilience (Tanner et al., 2015), EbA and the precursor to Eco DRR
371 (hazard mitigation) were not primarily focused on governance but rather on technical aspects,
372 such as ecological engineering and biodiversity conservation.

373 The focus on implementation, especially of transformative adaptation, has tended to be
374 stronger in adaptation (e.g. EbA and Eco-DRR) than in resilience (Miller *et al.*, 2010), which
375 emphasises adaptation as the mobilising of adaptive capacity for absorption of stress and
376 maintenance of function in response to environmental and social change (Berkes and Jolly,
377 2001; Pelling, 2011). While resilience addresses social dimensions, it has involved a
378 generalisable, top-down approach that does not address decision contexts (Stone-Jovicic,

379 2015). Resilience is concerned with human agency and the power to act under changing social-
380 ecological conditions, but has been criticised because it does not explicitly address power
381 relations or political realities (reviewed by Boonstra, 2016). In contrast, the TARA approach is
382 bottom-up, with a primary focus on interactions of *vrk* systems and future-oriented reframing
383 of decision contexts. Furthermore, the reframing of decision contexts is a process that
384 deliberately addresses the redistribution of power and agency.

385 Transformation of societal interests and values are inherent to the implementation of the
386 TARA approach: neither EbA or Eco-DRR contain an explicit process for transforming decision
387 contexts and societal values as part of implementation though they (and also resilience and
388 CBA) contain the implicit objective of achieving such transformations. Applying the TARA
389 approach to a reframing of policy and governance can start to shift from a focus on climate
390 impacts in isolation of people and institutions towards holistic approaches to adaptation. Co-
391 learning is embedded at each stage: (1) in the diagnosis of constraints on decision making and
392 the need to change decision contexts, as revealed by the *vrk* perspective; (2) in the co-
393 development of a common systems framing based on environmental change, as enabled by
394 the adaptation services concept; (3) in the co-construction of future scenarios, drawing on the
395 adaptation pathways approach and (4) in planning and implementation of adaptation
396 pathways. CBA and resilience thinking also include co-learning in principle.

397 As these various approaches are modified through cycles of implementation and re-design,
398 they have begun to resolve earlier shortcomings, resulting in a convergence of approaches.
399 While there are areas of overlap between them, the choice of which approach is likely to be
400 useful (or which elements) depends on the adaptation task; the stakeholders involved; the
401 prevailing social-political context and the degree of acceptance of the need for transformative
402 change. Human agents may choose a particular approach or draw on practical, complementary
403 elements from a variety of approaches (such as between EBA and TARA, cf. Box 2). The TARA
404 approach takes the latter option and represents a means to assess advantages and
405 disadvantages of each approach. The example of ecological restoration practice (Box 2) shows
406 how the context of existing approaches can be broadened to include complementary
407 approaches (e.g. EBA and TARA). Such broadening of context highlights how restoration might
408 contribute to other aspects of transformation; for example, how EBA could shift from a focus
409 on adaptation services to a focus on decision context. Such a shift would enable practitioners

410 to work with existing structures and processes, but start to build an understanding of the
411 required changes to governance that can enable transformative adaptation.

412 The linking of adaptation services, *vrk* and adaptation pathways in the TARA approach
413 enables an integrated framework for transformative adaptation that can broaden the framing
414 of adaptation problems. For example, in conservation practice by extending the decision
415 context beyond the assessment of ecosystem changes and short-term maintenance of
416 biophysical integrity, the TARA approach can help conservation policy and governance adapt
417 and change by focussing on biophysical change to re-interpret and reframe the problem and
418 value definition (e.g. by using the questions in Section 2.1: “Do we know the outcome? Do we
419 want it? Are we allowed it?”). This shift then allows examination of the implications of the
420 reframing for conservation policy, management and then governance.

421 **5. Conclusions**

422 Enabling transformative adaptation requires new ways to evaluate and adaptively manage
423 trade-offs between maintaining desirable aspects of current social-ecological systems and
424 adapting to major biophysical changes to those systems. We have attempted to position the
425 TARA framework within the context of linked social-ecological systems and emphasise that we
426 add an adaptation lens to a social-ecological systems approach (Figure 2). Binder et al. (2013)
427 reviewed the different approaches to analysing social-ecological systems and did not mention
428 adaptation or transformation. Fischer et al. (2015) linked the concept of social-ecological
429 systems to the understanding of the dynamics of environmental and societal change and set
430 priorities for research and policy, including inter-regional linkages and governance, long-term
431 drivers, power relations and a stronger science-society interface. In this paper, we attempt to
432 add an enabling transformative adaptation framework to the “lens of analysis that sharply puts
433 in focus humanity’s dependence on nature, our burgeoning influence on it, as well as our
434 ethical obligations towards it” (Fisher et al, 2015).

435 In the TARA approach, the reframing of decision contexts is a process that deliberately
436 addresses the redistribution of power and agency. We consider this redistribution as
437 fundamental to overcoming a major barrier to transformative adaptation. A central premise of
438 the TARA approach is that human agents involved in implementing adaptation to global
439 change can achieve more power and agency, not just if the institutions and decision making
440 systems were organized differently, but from the processes of being actively engaged in

441 questioning, learning, changing, revising and reforming the institutional framework in which
442 adaptation occurs.

443 The challenges of implementing transformative adaptation are formidable and future
444 uncertainty is a key theme (Eisenack et al., 2014). The TARA approach helps address
445 uncertainty in adaptation decision making by taking an integrated, holistic perspective to
446 values, rules and knowledge, but it cannot always ensure knowledge will be adequate to help
447 define the decision context under high uncertainty. Integrated approaches may help mitigate
448 uncertainty, but still require improved understanding of the emergent properties of social-
449 ecological systems (e.g. Liu et al., 2015). We acknowledge that dealing with complexity needs
450 to be circumscribed appropriately, and each situation for transformative adaptation will be
451 different. There will always be the prospect of including certain forms of knowledge in the
452 decision context at the expense of others, or ignoring the emotional attachment that stems
453 from values of identity and culture. Shifts in knowledge will not overcome such values, so we
454 need to find ways that new knowledge can be used to shift individual and collective interests
455 without alienating or discounting societal values of identity. Reframing of adaptation decisions
456 to ones that can be considered as transformative therefore requires transformation of
457 governance arrangements (Type 3 transformations in Box 1).

458 Revealing the need for changes to aspects of human organisation that have been taken for
459 granted hitherto is therefore an important adaptation task, as is supporting what people are
460 already trying to do in order to transform. We consider the TARA approach is a means to
461 integrate between the transformation of ecosystems under global change, shifts in decision
462 contexts that acknowledge the need for societal change and the development of adaptive,
463 transformative governance to enable transformative adaptation.

464 Bennett et al. (2016) considered that current global futures scenarios are often based on
465 simplified world views that can be improved by incorporating “seeds of a good Anthropocene”,
466 which are “diverse examples of good practice, innovations, and experiments...that can help us
467 to understand the different components of a better future that people want, and to recognize
468 the processes that lead to the emergence and growth of initiatives that fundamentally change
469 human–environmental relationships.” Imbued in the concept of “seeds of a good
470 Anthropocene” is the positive feedback relationship between *hope*, in the sense of a
471 pragmatic, positive, forward-looking perspective, and *agency*, entraining empowerment,

472 options for the future and collective motivation. We consider that the TARA approach
473 represents one such contribution to a good Anthropocene.

474 **Author contributions**

475 All authors contributed to developing, interpreting and refining concepts and the research
476 framework during the first and second TARA workshops. M.J.C. led the writing, with major
477 contributions from B.M.-L., S.L., B.L., R.G., P.-Y.L, L.V.K. and C.W. B.L., B.M.-L. and MJC
478 designed and produced the figures; R.G. and G.W. wrote the text boxes. All authors
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489 **References**

- 490 Abson DJ, Fischer J, Leventon J et al. (2016, published online) Leverage points for sustainability
491 transformation. *Ambio* <http://dx.doi.org/10.1007/s13280-016-0800-y>
- 492 Adger WN, Dessai S. Goulden M et al. (2009) Are there social limits to adaptation to climate
493 change? *Climatic Change*, 93, 335–354.
- 494 Armsworth PR, Larson ER, Jackson ST et al. (2015) Are conservation organisations configured
495 for effective adaptation to global change? *Frontiers in Ecology and the Environment*, 13,
496 163–169.
- 497 Aronson J, Alexander S (2013) Ecosystem restoration is now a global priority: Time to roll up
498 our sleeves. *Restoration Ecology*, 21, 293–296.

499 Ayers J, Forsyth T (2009) Community-based adaptation to climate change. *Environment*, 51,
500 22–31.

501 Barnett J, O'Neill S (2010) Maladaptation. *Global Environmental Change* 20, 211–213.

502 Baruah M, Bobtoya S, Mbile P, Walters G. (in press) Governance of restoration at the
503 community level: working with Ghana's Community Resource Management Areas. *World*
504 *Development Perspectives*.

505 Bennett EM, Solan M, Biggs R et al. (2016) Bright spots: seeds of a good Anthropocene.
506 *Frontiers in Ecology and the Environment*, 14, 441–448.

507 Berkes F, Jolly (2001) Adapting to climate change: social-ecological resilience in a Canadian
508 western Arctic community. *Ecology and Society*, 5(2), 18.

509 Bhaduri A (2008) Predatory growth. *Economic and Political Weekly*, 43(16), 10–14.

510 Binder CR, Hinkel J, Bots P, Pahl-Wostl C (2013) Comparison of frameworks for analysing social-
511 ecological systems. *Ecology and Society*, 18(4), 26.

512 Boonstra WJ (2016) Conceptualizing power to study social-ecological interactions. *Ecology and*
513 *Society*, 21(1), 21.

514 Butler JRA, Suadnya W, Puspadi K et al. (2014) Framing the application of adaptation pathways
515 for rural livelihoods and global change in eastern Indonesian islands. *Global Environmental*
516 *Change*, 28, 368–382.

517 Carpenter S, Walker BH, Anderies JM, Abel N (2001) From metaphor to measurement:
518 resilience of what for what? *Ecosystems*, 4, 765–781.

519 Cash DW, Clark WC, Alcock F et al. (2003) Knowledge systems for sustainable development.
520 *Proceedings of the National Academy of Sciences*, 100, 8086–8091.

521 Chaffin BC, Garmestani AS, Gunderson LH, Benson, M.H., Angeler DG, Arnold CA, Cosens B,
522 Craig RC, Ruhl JB, Allen CR (2016) Transformative environmental governance. *Annual*
523 *Review of Environment and Resources*, 41, 399–423.

524 Chan KMA et al. (2016) Why protect nature? Rethinking values and the environment.
525 *Proceedings of the National Academy of Sciences*, 113, 1462–1465.

526 Chapman PM (2011) Global climate change means never going home again. *Marine Pollution*
527 *Bulletin*, 62, 2269–2270.

528 Choi YD (2004) Theories for ecological restoration in changing environment: toward
529 'futuristic' restoration. *Ecological Restoration*, 19, 75–81.

530 Colloff MJ, Lavorel S, Wise RM, Dunlop M, Overton IC, Williams KJ (2016a) Adaptation services
531 of floodplains and wetlands under transformational climate change. *Ecological*
532 *Applications*, 26, 1003–1017.

533 Colloff MJ, Doherty MD, Lavorel S, Dunlop M, Wise RM., Prober SM (2016b) Adaptation
534 services and pathways for the management of temperate montane forests under
535 transformational climate change. *Climatic Change*, 138, 267–282.

536 Cohen-Shacham E, Walters G, Janzen C, Maginnis S (eds.) (2016). Nature-based Solutions to
537 Address Global Societal Challenges. IUCN, Gland.

538 Cornell S, Berkhout F, Tuinstra W et al. (2013) Opening up knowledge systems for better
539 responses to global environmental change. *Environmental Science and Policy*, 28, 60–70.

540 Cross MS, Zavaleta ES, Bachelet D et al. (2012) The Adaptation for Conservation Targets (ACT)
541 framework: a tool for incorporating climate change into natural resource management.
542 *Environmental Management*, 50, 341–351.

543 Diaz S, Demissew S, Carabias J et al. (2015) The IPBES Conceptual Framework — connecting
544 nature and people. *Current Opinion in Environmental Sustainability*, 14, 1–16.

545 Djoudi H, Brockhaus M, Locatelli B (2013) Once there was a lake: vulnerability to
546 environmental changes in northern Mali. *Regional Environmental Change*, 13, 493–508.

547 Dodman D, Mitlin D (2013) Challenges for community-based adaptation: discovering the
548 potential for transformation. *Journal of International Development*, 25, 640–659.

549 Doherty MD, Lavorel S, Colloff MJ, Williams KJ, Williams RJ (2016, published online) Moving
550 from autonomous to planned adaptation in the montane forests of southeastern Australia
551 under changing fire regimes. *Austral Ecology*, <http://dx.doi.org/10.1111/aec.12437>

552 Doswald N, Munroe R, Roe D et al. (2014) Effectiveness of ecosystem-based approaches for
553 adaptation: review of the evidence-base. *Climate and Development*, 6, 185–201.

554 Dow K, Berkhout F, Preston BL, Klein RJT, Midgley G, Shaw MR (2013) Limits to adaptation.
555 *Nature Climate Change*, 3, 305–307.

556 Dudley N, Morrison J, Aronson J, Mansourinan S (2005) Why do we need to consider
557 restoration in a landscape context? In: Mansourian, S. & Vallauri, D. (eds.) *Forest*
558 *Restoration in Landscapes: Beyond Planting Trees*, pp. 51–58, Springer, New York.

559 Eden SE, Tunstall S (2006) Ecological versus social restoration? How urban river restoration
560 challenges but also fails to challenge the science-policy nexus in the United Kingdom.
561 *Environmental Planning C*, 24, 661–680.

562 EEA (2015) *The European Environment — State and Outlook 2015: Synthesis Report*. European
563 Environment Agency, Copenhagen.

564 Eisenack K, Moser SC, Hoffmann E, Klein RT, Oberlack C, Pechan A, Rotter M, Termeer CJAM
565 (2014) Explaining and overcoming barriers to climate change adaptation. *Nature Climate*
566 *Change*, 4, 867–872.

567 Feola G (2015) Societal transformation in response to global environmental change: a review
568 of emerging concepts. *Ambio*, 44, 376–390.

569 Fernandez RJ (2016) How to be a more effective environmental scientist in management and
570 policy contexts. *Environmental Science and Policy*, 64, 171–176.

571 Fischer J, Gardner T, Bennett EM et al. (2015) Advancing sustainability through maintaining a
572 social-ecological systems perspective. *Current Opinion in Environmental Sustainability*, 14,
573 144–149.

574 Gorddard R, Colloff MJ, Wise RM, Ware D, Dunlop M (2016) Values, rules and knowledge:
575 Adaptation as change in the decision context. *Environmental Science and Policy*, 57, 60–69.

576 Guariguata M, Brancalion P (2014) Current challenges and perspectives for governing forest
577 restoration. *Forests*, 5, 3022–3030

578 Haasnoot M, Kwakkel JH, Walker WE, ter Maat J (2013) Dynamic adaptive policy pathways: a
579 method for crafting robust decisions for a deeply uncertain world. *Global Environmental*
580 *Change*, 23, 485–498.

581 Helbing D (2013) Globally networked risks and how to respond. *Nature*, 497, 51–59.

582 Hobbs RJ, Hallett LM, Ehrlich PR, Mooney HA (2011) Intervention ecology: Applying ecological
583 science in the Twenty-first Century. *BioScience*, 61, 442–450.

584 Hobday AJ, Chambers LE, Arnould JPY (2015) Prioritizing climate change adaptation options for
585 iconic marine species. *Biodiversity and Conservation*, 24, 3449–3468.

586 Hodgkinson JA, Hobday AJ, Pinkard EA (2014) Climate adaptation in Australia's resource-
587 extraction industries: ready or not? *Regional Environmental Change*, 14, 1663–1678.

588 IPCC (2014) *Climate Change 2014 Synthesis Report. Summary for Policymakers*. Cambridge
589 University Press, Cambridge.

590 Iniesta-Arandia I, Garcia del Amo D, Garcia-Nieto AP, Piñeiro C, Montes C, Martín López B
591 (2015) Factors influencing local ecological knowledge maintenance in Mediterranean
592 watersheds: Insights for environmental policies. *Ambio*, 44, 285–296.

593 Jones A (2012) *Rangeland Goat Production in Western New South Wales*. New South Wales
594 Department of Primary Industries, Sydney.

595 Kates RW, Travis WR, Wilbanks TJ (2012) Transformational adaptation when incremental
596 adaptations to climate change are insufficient. *Proceedings of the National Academy of*
597 *Sciences*, 109, 7156–7161.

598 Kinzig AP, Ehrlich PR, Alston LJ, et al. (2013) Social norms and global environmental challenges:
599 the complex interaction of behaviours, values and policy. *BioScience*, 63, 164–175.

600 Klein N (2014) *This Changes Everything: Capitalism vs. the Climate*. Simon and Schuster, New
601 York.

602 Lakoff G (2014) Mapping the brain’s metaphor circuitry: metaphorical thought in everyday
603 reason. *Frontiers of Human Neuroscience*, 8, Article 958.

604 Lavorel S, Colloff MJ, McIntyre S, Doherty M, Murphy H, Metcalfe D, Dunlop M, Williams R,
605 Wise RM, Williams K (2015) Ecological mechanisms underpinning climate adaptation
606 services. *Global Change Biology*, 21, 12–31.

607 Leith P, O’Toole K, Haward M, Coffey B, Rees C, Ogiera E. (2014) Analysis of operating
608 environments: a diagnostic model for linking science, society and policy for sustainability.
609 *Environmental Science and Policy*, 39, 162–171.

610 Liu J, Mooney H, Hull V et al. (2015) Systems integration for global sustainability. *Science*, 347,
611 1258832.

612 Locatelli B, Catterall, CP, Imbach P et al. (2015) Tropical reforestation and climate change:
613 beyond carbon. *Restoration Ecology*, 23, 337–343.

614 Maginnis S, Laestadius, L, Verdone, M, De Witt, S, Saint-Laurent, C, Rietbergen-McCracken, J,
615 Shaw, DMP (2014) *A Guide to the Restoration Opportunities Assessment Methodology*
616 *(ROAM): Assessing Forest Landscape Restoration Opportunities at the National Level*.
617 International Union for the Conservation of Nature, Gland.

618 Mansourian S (2016) Understanding the relationship between governance and forest
619 landscape restoration. *Conservation and Society*, 14, 267–278.

620 Martín-López B, Montes C (2015) Restoring the human capacity for conserving biodiversity: a
621 social–ecological approach. *Sustainability Science*, 10, 699–706.

622 Mawdsley J (2011) Design of conservation strategies for climate adaptation. *Wiley*
623 *Interdisciplinary Reviews: Climate Change*, 2, 498–515.

624 Meadows, D. (1999) *Leverage Points: Places to Intervene in a System*. The Sustainability
625 Institute, Harland.

626 Miller F, Osbahr F, Boyd E et al. (2010) Resilience and vulnerability: complementary or
627 conflicting concepts? *Ecology and Society*, 15(3) 11.

628 Mitsch, W. (1996) Ecological engineering: A new paradigm for engineers and ecologists. In:
629 Schulze, P. (ed.) *Engineering Within Ecological Constraints*, pp. 114–132, National Academy
630 Press, Washington.

631 Munang R, Thiaw I, Alverson K, Mumba M, Rivington M (2013) Climate change and Ecosystem-
632 based Adaptation: a new pragmatic approach to buffering climate change impacts. *Current*
633 *Opinion in Environmental Sustainability*, 5, 67–71.

634 Norgaard RB (2010) Ecosystem services: from eye-opening metaphor to complexity blinder.
635 *Ecological Economics*, 69, 1219–1227.

636 O'Brien KL, Wolf J (2010) A values-based approach to vulnerability and adaptation to climate
637 change. *Wiley Interdisciplinary Reviews: Climate Change*, 1, 232–242.

638 Park SE, Marshall NA, Jakku E, Dowd AM, Howden SM, Mendham E, Fleming A (2012)
639 Informing adaptation responses to climate change through theories of transformation.
640 *Global Environmental Change*, 22, 115–126.

641 Pelling M (2011) *Adaptation to Climate Change: From Resilience to Transformation*. Routledge,
642 London.

643 Peterson GD, Beard TD, Beisner BE et al. (2003) Assessing future ecosystem services: a case
644 study of the Northern Highlands Lake District, Wisconsin. *Ecology and Society*, 7(3), 1.

645 Rausdepp-Hearne C, Peterson GD, Tengö M, Bennett EM, Holland T, Benessaiah K, MacDonald
646 GK, Pfeifer L (2010) Untangling the environmentalist's paradox: why is human well-being
647 increasing as ecosystem services degrade? *BioScience*, 60, 576–589.

648 Reid H (2015) Ecosystem- and community-based adaptation: learning from community-based
649 natural resource management. *Climate and Development*, 8, 4–9.

650 Renaud FG, Sudmeier-Rieux K, Estrella M (2013) *The Role of Ecosystems in Disaster Risk*
651 *Reduction*. United Nations University Press, Tokyo.

652 Rickards L, Howden SM (2012) Transformational adaptation: agriculture and climate change.
653 *Crop and Pasture Science*, 63, 240–250.

654 Rickards L (2013) Transformation is adaptation. *Nature Climate Change*, 3, 690.

655 Rico García-Amado L, Manuel Ruiz Pérez M, Barrasa García S (2013) Motivation for
656 conservation: Assessing integrated conservation and development projects and payments
657 for environmental services in La Sepultura Biosphere Reserve, Chiapas, Mexico. *Ecological*
658 *Economics*, 89, 92–100.

659 Rosenweig C, Solecki C (2014) Hurricane Sandy and adaptation pathways in New York: Lessons
660 from a first-responder city. *Global Environmental Change*, 28, 395–408.

661 Schwartz SH (2012) An overview of the Schwartz theory of basic values. *Online Readings in*
662 *Psychology and Culture*, 2(1). Article 11.

663 Smith JB (1997) Setting priorities for adapting to climate change. *Global Environmental*
664 *Change*, 7, 251–264.

665 Stafford Smith M, Horrocks L, Harvey A, Hamilton C (2011) Rethinking adaptation for a 4°C
666 world. *Philosophical Transactions of the Royal Society A*, 369, 196–216.

667 Stanturf JA (2015) Future landscapes: opportunities and challenges. *New Forests*, 46, 615–644.

668 Stanturf JA, Palik BJ, Williams MI, Dumroese RK, Madsen P (2014) Forest restoration
669 paradigms. *Journal of Sustainable Forestry*, 33, S161–S194.

670 Stone-Jovicic S (2015) Probing the interfaces between the social sciences and social-ecological
671 resilience: insights from integrative and hybrid perspectives in the social sciences. *Ecology*
672 *and Society*, 20(2), 25.

673 Streek W, Calhoun C, Toynbee P (2016) Does capitalism have a future? *Social Economic*
674 *Review*, 14, 163–183.

675 Tanner T, Lewis D, Wrathall, D et al. (2015) Livelihood resilience in the face of climate change.
676 *Nature Climate Change*, 5, 23–26.

677 Temmerman S, Meire P, Bouma TJ, Herman PMJ, Ysebaert T, De Vriend HJ (2013) Ecosystem-
678 based coastal defence in the face of global change. *Nature*, 504, 79–83

679 Termeer C, Dewulf A, van Rijswick H, van Buuren A, Huiteima D, Meijerink S, Rayner T, Wiering
680 M (2011) The regional governance of climate adaptation: A framework for developing
681 legitimate, effective, and resilient governance arrangements. *Climate Law*, 2, 159–179.

682 UN (2009) *Risk and Poverty in a Changing Climate: 2009 Global Assessment Report on Disaster*
683 *Risk Reduction* United Nations, New York.

684 UN (2014) *Concise Report on the World Population Situation, 2014*. United Nations, New York.

685 UNEP (2010) Decision Adopted by the Conference of the Parties to the Convention on
686 Biological Diversity at its Tenth Meeting. X/33 Biodiversity and climate change. United
687 Nations Environment Programme, Nairobi.

688 van Kerkhoff LE, Lebel L (2015) Coproductive capacities: rethinking science-governance
689 relations in a diverse world. *Ecology and Society*, 20(1), 14.

690 Vignola R, Locatelli B, Martinez C, Imbach P (2009) Ecosystem-based adaptation to climate
691 change: what role for policy-makers, society and scientists? *Mitigation and Adaptation*
692 *Strategies for Global Change*, 14, 691–696.

693 Voss JP, Newig J, Kastens B, Monstadt J, Nölting B (2007) Steering for sustainable
694 development: a typology of problems and strategies with respect to ambivalence,
695 uncertainty and distributed power. *Journal of Environmental Policy and Planning*, 9,
696 193–212.

697 Walker B, Holling CS, Carpenter SR, Kinzig A (2004) Resilience, adaptability and transformability
698 in social–ecological systems. *Ecology and Society*, 9(2), 5.

699 Wise RM, Fazey I, Stafford Smith M, Park SE, Eakin HC, Archer Van Gardenen ERM, Campbell B
700 (2014) Reconceptualising adaptation to climate change as part of pathways of change and
701 response. *Global Environmental Change*, 28, 325–336.

702 Wyborn C (2015) Co-productive governance: A relational framework for adaptive governance.
703 *Global Environmental Change*, 30, 57–67.

704 Wyborn C, Yung L, Murphy D, Williams DR (2015) Situating adaptation: how governance
705 challenges and perceptions of uncertainty influence adaptation in the Rocky Mountains.
706 *Regional Environmental Change*, 15, 669–682.

707 Wyborn CA, Dunlop M, Dudley N, van Kerkhoff L, Guevara O. (2016) Future Oriented
708 Conservation: knowledge governance, uncertainty and learning. *Biodiversity and*
709 *Conservation*, 25, 1401–1408.

710 **Box 1. Definitions of concepts of the three types of transformation used in the TARA**
711 **approach.**

712 There are multiple uses of the term *transformation* in relation to adaptation to global environmental
713 change (Feola, 2015). We do not consider transformation as a process separate from adaptation that
714 occurs after limits of adaptation are reached (Dow et al., 2013). Three types are defined:
715 transformation as a process of change in a social-ecological system without deliberate intervention is
716 described by Types 1 and 2 below. Transformation as a deliberate process is described by Type 3.

717 (1) *Transformation of ecosystems*: is defined by a permanent shift to an alternative stable state, as
718 in resilience thinking (Walker et al., 2004). But such 'Type 1 transformation' also involves a change in
719 the way a focal ecosystem is viewed from the relevant decision context. This change requires a
720 reframing of how the ecosystem is considered in relation to its core driver and response variables, its
721 attributes that are valued by society, and how people relate to and act within the system, including
722 options for managing and using the ecosystem that are normalised and permitted.

723 (2) *Transformation of decision contexts*: focusses on the recognition that because ecosystems and
724 their drivers are transforming, so transformation to decision contexts supported by evolving
725 governance arrangements is required (Gorddard et al., 2016). Thus, 'Type 2 transformation' represents
726 a major shift in the social arrangements that define the decision context, including: (1) the networks
727 that are formed in the process of decision making; (2) the knowledge and belief systems ("knowledge"),
728 societal values and motivations ("values") and formal and informal rules and governance arrangements
729 ("rules") that define how powers are defined, allocated and used, and (3) how resource allocations flow
730 to empower the decision process and are affected by the focal decision-making group.

731 (3) *Transformation as developing the capacity for adaptive, transformative governance*: the capacity
732 to develop adaptive, transformative governance is relative to the type of change that is intended and
733 the position of the people within the system who are seeking the change. Transformative change in
734 governance (e.g. Chaffin et al., 2016) will be needed to support transformative change in the decision
735 context for adaptation. Like specific resilience, with its requirement to specify resilience *of what, for*
736 *what* (Carpenter et al., 2001), it is necessary to frame 'Type 3 transformation' as developing the
737 capacity for adaptive, transformative governance for *whom*, to enable *what* kinds of changes in
738 governance systems, for *what* purpose.

739 Change in decision contexts relating to Type 1 and Type 2 transformations cannot be separated in
740 practice because Type 2 transformations are a consequence of Type 1 and both require no deliberate
741 human intervention in order to occur. Reframing decisions that can be considered as transformative
742 therefore requires transformation of governance arrangements (type 3).

743

744 **Box 2. Adaptation and ecological restoration under climate change and the contribution of**
745 **the TARA approach**

746 Restoration is now considered one solution to climate change adaptation and mitigation, and an
747 important part of approaches to implementing the United Nations conventions on climate change,
748 desertification and biological diversity (UNFCCC, UNCCD and UNCBD; Aronson and Alexander, 2013).

749 Restoration, including ecological restoration (ER), forest landscape restoration (FLR) and ecological
750 engineering (EE), focuses on restoring elements of ecological conditions and function, and ecosystem
751 services, often for societal benefit (Stanturf et al., 2014). Although ER has focused on restoring
752 ecosystems to past conditions and functions, this approach may no longer be relevant (Choi, 2004).
753 Practitioners of ER now consider how to restore ecosystems under a changing environment (Hobbs et
754 al., 2011; Locatelli et al., 2015). EE focuses largely on addressing future societal issues, such as
755 developing novel ecosystems (Mitsch, 1996) in the context of creating wetlands to mitigate climate-
756 related flooding (Temmerman et al., 2013).

757 These restoration concepts largely focus on ecosystems rather than on the governance context,
758 although it is now recognised that governance is key to making restoration successful (Guariguata and
759 Brancalion, 2014, Mansourian 2016). For example, in Ghana, restoration work conducted by members
760 of a Community Resource Management Area was reduced in effectiveness by issues related to
761 accountability and transparency (Baruah et al. in press).

762 Already, FLR focuses on addressing current societal needs (Dudley *et al.*, 2005) and recently began
763 developing national and sub-national multi-stakeholder restoration discussion processes (Maginnis,
764 2014) which can be tailored to discussions on adaptation. Consideration of how restoration
765 interventions and other nature-based solutions can be improved by forward thinking and decision
766 making process is being proposed (Stanturf et al., 2015, Cohen-Shacham et al. 2016). One concept,
767 Ecosystem-based Adaptation (EBA) uses restoration as part of its toolkit to help societies adapt to
768 climate change (UNEP, 2010). Although restoration approaches are progressing towards helping
769 societies use ecosystems to adapt to climate change, they could benefit from the TARA approach,
770 specifically by identifying adaptation services and shifting management approaches towards enabling
771 their delivery, using the *vrk* and pathways framing.

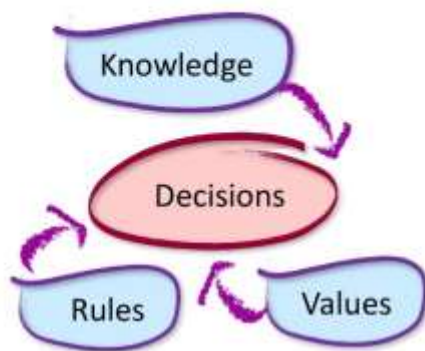
772 Of particular value would be ensuring that restoration decisions include minorities, that multiple
773 values of ecosystems and their uses are included in decision making and that knowledge required for
774 decisions is as inclusive as possible. Some of these outcomes can be achieved by engaging more social
775 scientists in restoration processes (Eden and Tunstall, 2006).

776

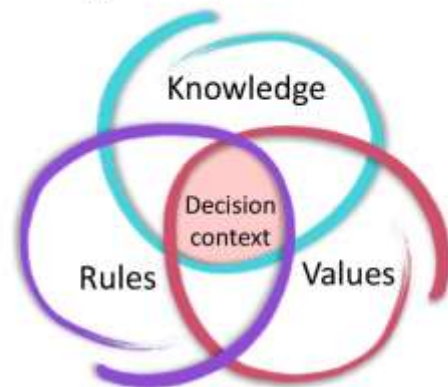
777 Figure 1. The three elements of the TARA approach: (a) values, rules and knowledge (i) in
 778 standard decision making, where values, rules and knowledge are regarded as independent
 779 inputs; (ii) in the *vrk* perspective, where allowable decisions are the product of the *decision*
 780 *context* which results from interactions between the processes in society forming or revealing
 781 values, rules and knowledge. This allows us to ask of each adaptation decision: “do we know
 782 the outcome?” (*k*) and, if so, “do we want the outcome?” (*v*) and, if so, “are we allowed the
 783 outcome (and the means of achieving it)?” (*r*); (b) an *adaptation pathway* for planning and
 784 sequencing decisions and actions for transformative adaptation. Opting for ‘business as usual’
 785 at the first decision point may constrain future options and require further decisions to avoid
 786 maladaptation; (c) *adaptation services*, whereby options for adaptation are created according
 787 to whether ecosystems will persist or transform to alternative states. Where ecosystems
 788 persist, some currently-valued services will continue to be supplied and used. Under
 789 ecosystem transformation, novel services will be supplied and latent services (those not
 790 previously recognised or used), will provide options for adaptation.

(a) Values, rules and knowledge

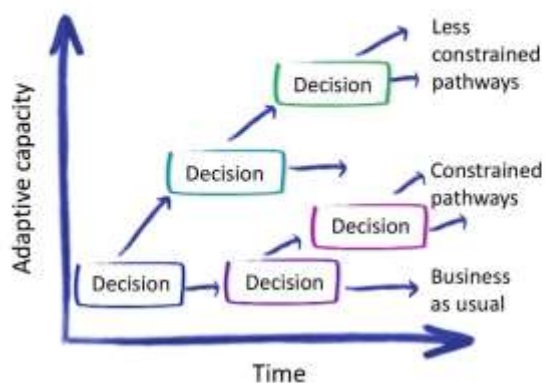
(i) Standard decision making



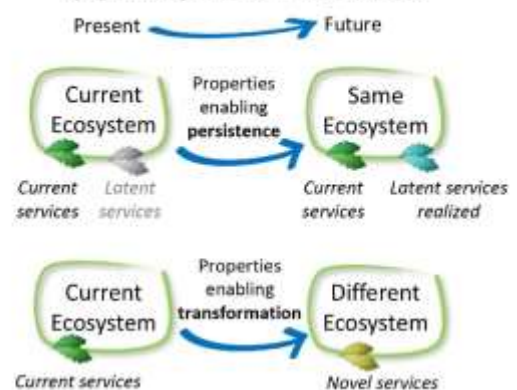
(ii) The *vrk* perspective



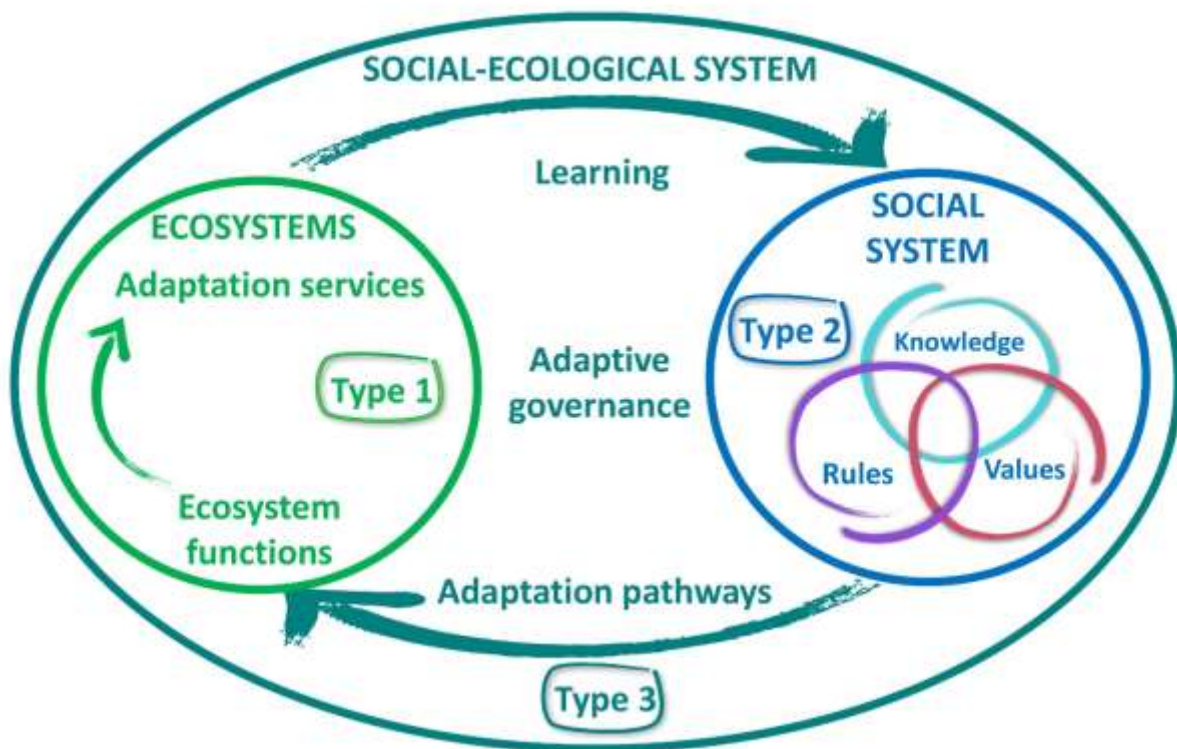
(b) Adaptation Pathways



(c) Adaptation Services



791 Figure 2. Linkages and interactions between adaptation pathways, adaptation services and the
 792 values, rules and knowledge (*vrk*) perspective in the context of transformative adaptation to
 793 global change. The *vrk* interactions define the decision contexts in an adaptation pathway. The
 794 adaptation pathway represents a system of adaptive governance for anticipating and planning
 795 decisions to enable future adaptability, based on changes to ecosystems and the supply of
 796 ecosystem services for livelihoods and wellbeing. Adaptation services—the sub-set of
 797 ecosystem services that provide options for adaptation—form a basis for decisions, integrated
 798 within an adaptation pathway, for the management and use of ecosystems in the future,
 799 considering changes in supply of ecosystem services due to ecosystem change. Type 1, Type 2
 800 and Type 3 refer to types of transformations (of ecosystems, decision contexts and capacity for
 801 adaptive governance, respectively) detailed in Box 1.



802 Figure 3. An adaptation pathway that incorporates shifts in the decision context for adaptation
 803 options enabled by interactions between values, knowledge and rules (*vrk*) at each decision
 804 point. The *vrk* system evolves along each pathway enabling or constraining decisions at each
 805 point. Adaptation services increasingly provide options for adaptation, represented as
 806 'bundles' of ecosystem services. At each decision point, the bundle available will be different
 807 from those at previous points. Path dependencies arise where a decision limits future
 808 adaptation options, or management for adaptation services enables future options. The
 809 boundary to what is considered maladaptive space (where available ecosystem services no
 810 longer meet societal needs and there are limited or no options to transform to a desirable
 811 state) also changes over time.

