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Ecosystem services or services to ecosystems? Valuing cultivation and reciprocal relationships between humans and ecosystems

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ABSTRACT

The concept of Ecosystem Services (ES), widely understood as the "benefits that humans receive from the natural functioning of healthy ecosystems" (Jeffers et al., 2015), depicts a one-way flow of services from ecosystems to people. We argue that this conceptualisation is overly simplistic and largely inaccurate, neglecting the reality that humans often contribute to the maintenance and enhancement of ecosystems, as often evidenced (but not exclusively) in many traditional and Indigenous societies. Management interventions arising from Ecosystem Services research are thus potentially damaging to both ecosystems and indigenous rights. We present the concept of 'Services to Ecosystems' (S2E) to address this, closing the loop of the reciprocal relationship between humans and ecosystems. Case studies from the biocultural ecosystems of Amazonia and the Pacific Northwest of North America (Cascadia) are used to illustrate the concept and provide examples of Services to Ecosystems in past and current societies. Finally, an alternative framework is presented, advancing the existing framework for Ecosystem Services by incorporating this reconceptualization and the loop of reciprocity. The framework aims to facilitate the inclusion of Services to Ecosystems in management strategies based upon Ecosystem Services, and highlights the need for ethnographic research in Ecosystem Service-based interventions.

1. Introduction

While the concept of ecosystem services (ES) has been successful in raising awareness of the value of natural systems and their importance for humanity (Chan et al., 2012a), critical gaps remain (Plieninger et al., 2014). These relate to its insufficient treatment of the group of services classed as 'cultural ecosystem services' (CES; Daniel et al., 2012); and a more fundamental oversight, namely the lack of recognition of the roles of humans in actively cultivating, improving and positively contributing to ES. Such reciprocal relationships between humans and ecosystems are often (but not exclusively) evidenced in indigenous and traditional rural societies through subsistence practices, oral history, ritual and other actions.

This paper argues that an improved understanding and consideration of CES is required, and that the false concept of ES as a one-way flow of benefits from ecosystems to humans needs to be reconsidered. We challenge the current mainstream understanding of ES, through the perspective of human cultivation of ecosystems in cultural landscapes over time. We show that humans often play an important role in cultivating and enhancing ES, or providing what we term 'Services to Ecosystems' (S2E); by which we mean,

> *Actions humans have taken in the past and currently that modify ecosystems to enhance the quality or quantity of the services they provide, whilst maintaining the general health of the cognised ecosystem over time.*

Ecosystem health refers broadly to the resilience of the ecosystem and the maintenance of its structure and function (see Costanza, 2012); and the cognised ecosystem stresses the importance of considering the local understandings of what constitutes an 'ecosystem' in effectively managing ecosystems by outsiders.

To illustrate the concept of S2E and how it can constructively improve the notion of ES, we present a literature review, identifying gaps where the ecosystem service approach, and management decisions that arise from its use, are currently insufficient. Specifically, we highlight critical gaps in the large body of ES literature (2.1) and analyse dominant and subaltern conceptualisation of ES and CES (2.2). We discuss the importance of CES in ES-based management (2.3) and review progress in CES thinking and practice

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to date, evaluating mentions of reciprocity—or its conspicuous absence (2.4). We address ES from the perspective of Indigenous peoples, outlining the focus of the article (2.5). Finally, the most critical gap in the ES framework is introduced: the neglect of the role of humans in providing services to ecosystems (S2E) (2.6).

We document and construct a pathway to filling a critical gap—the incorporation of contributions made by humans to ecosystems, completing the circle of a reciprocal relationship. We explore the suggestion that CES, and ES in general, can be improved via S2E. Existing literature and primary ethnographic research construct two case studies from two rainforest environments: Amazonia (Section 2) and the Pacific Northwest of North America (Cascadia; Section 3). These document a diversity of practices to illustrate the role of reciprocal relationships between humans and their environment in shaping ecosystems and the services they provide—a dimension often missed in contemporary management systems, We suggest that neglecting this reciprocal dimension undermines the utility of the current ES framework and management practices based upon it. It also risks devaluing the role of human cultures, especially Indigenous and traditional cultures, in establishing and maintaining the social-ecological systems they inhabit. ES thus must incorporate impacts from humans on ecosystems, completing the circle of a reciprocal relationship.

An alternative framework is proposed to facilitate this reconceptualization, incorporating the S2E loop, to support the implementation of a more holistic management of cultural landscapes and social-ecological systems (Section 4). This enhanced framework builds on the Millennium Ecosystem Assessment (MEA, 2005) framework by facilitating consideration of the role of human societies over time in cultivating ecosystems and the services they provide. We further suggest that integration of the reciprocal ES-S2E concept into environmental management will yield useful insights as to appropriate interventions to support or restore sustainable social-ecological systems. We synthesise these ideas with a discussion on the implications for future management and application of the ES framework (Section 4).

1.1. The ecosystem services legacy: mind the Gap(s)

The concept of 'ecosystem services' (ES) (Costanza et al., 1997; Daily, 1997) has been heralded as a critical tool for integrating environmental values, previously dismissed as externalities, into decision-making (Chan et al., 2012a). It has arguably fulfilled its initial goal—to address a perceived "near total lack of appreciation of societal dependence upon natural ecosystems" (Daily, 1997:xv). In particular the framework presented in the Millennium Ecosystem Assessment (MEA, 2005) has received widespread attention in the fields of biodiversity conservation, natural resource management, development policies, environmental accounting and business, and the ES concept has been increasingly used as a framework for action (Jax et al., 2013).

However, important gaps remain and the ES concept currently does not do justice to the reality of human-ecosystem interactions (Plieninger et al., 2014). When environmental management based on the concept lacks critical connections and feedbacks, unintended and potentially negative consequences can result (Patterson and Coelho, 2008; Norgaard, 2010). To reduce these risks, the role of humans as existing within and as an integral part of ecosystems, contributing to their structure and composition over historical time-periods, and often increasing their services and functioning (e.g. Balée, 2013; Shepard & Ramirez, 2011; Thornton, 2015) needs to be recognised and taken into account. In short, humans are not only (and not the only) consumers of environmental resources and services, but also contribute to their development, maintenance, and flows. Unfortunately, the 'financialisation of nature' language typically fails to capture this dynamic (Sullivan, 2013; Smith, 2007).

Rather than add to this substantial economic-centred debate (e.g. Kline et al., 2009; Norgaard, 2010), this paper seeks to broaden the fundamental conceptualization, reciprocal dimensions, and methodological issues concerning how humans interact with so-called ES. We develop a concept of 'Services to Ecosystems' (S2E) to achieve this, and incorporate the concept into ES-based interventions.

1.2. Ecosystem services: mainstream and sublaltern positions

The ES concept has moved beyond its initial normative origins as a metaphor for human dependence on nature (Jax et al., 2013) and become heavily integrated within science, policy and management, developing into a mainstream conservation paradigm (Plieninger et al., 2014). However, aspects of ES that cannot be easily quantified have come to be viewed as 'intangible' and 'subjective.' Harder to value economically, 'cultural ecosystem services' (CES) have been comparatively neglected in ecosystem service assessments (Sagie et al., 2013; Daniel et al., 2012) and conceptualisations of CES beyond the generic definition of "ecosystems' contribution to the non-material benefits that arise from human-ecological relations" (Chan et al., 2011: 206) remain conspicuously underdeveloped or absent. CES are thus marginalised as a residual category within the rapidly growing field of ES research and practice (Chan et al., 2012a,b). Instead, the focus has become fixed on that which nature provides for people in concrete, measurable, quantifiable ways (Raymond et al., 2013). This may be a legacy to the original founding metaphor, which highlights a unidirectional dependence of humans on ecosystems (Patterson and Coelho, 2008, 2009; Flint et al., 2013), and to the dominant role of materialist-oriented economists and ecologists in ecosystem services research (Orenstein, 2013). Yet it is increasingly acknowledged that this focus doesn't adequately address the complexity of human-nature interactions (Plieninger et al., 2014), and reduces critical components of complexity that may be needed for effective ecosystem management (Norgaard, 2010).

Management that focuses disproportionately on certain aspects of ecosystem services risks allowing the ignored ES, and thus the ecosystem as a whole, to be undermined (Raymond et al., 2013). This has been repeatedly demonstrated in agroecosystems throughout the 'Green Revolution' (Lansing 1991, 2006). Whereas traditional management supported a range of ES, Green Revolution regimes concentrated solely on boosting provisioning services, in particular the intensification of cash crop production through monoculture specialization and inputs of chemical fertilizers, pesticides, and machines. This frequently led to the erosion of the capacity of agricultural ecosystems to deliver a diverse, resilient flows of integrated ES, thus increasing the vulnerability of the system (Gordon et al., 2010; Nieto-Romero et al., 2013). A more holistic conceptualisation of CES and ES more generally, and a more critical assessment of the use of the ES concept in management and assessment, is needed (Plieninger et al., 2014).

In response, a subaltern position has begun to emerge. This position considers CES not only as relatively neglected, but also as: (1) not exclusively "intangible" (Satterfield et al., 2013; Gibson et al., 2011), (2) often the most highly valued of ES by inhabitants of places (see Martín-López et al., 2012); and (3) principal motivators in fostering responsible environmental behaviour (Orenstein, 2013; Gobster et al., 2007). Whilst these points are increasingly touched upon in the literature, there remains an additional point yet to be acknowledged: (4) that CES, and ES in general, can be improved via processes of what we term "Services to Ecosystems" (Patterson, 2013; Thornton, 2015): enhancing the values and services provided by habitats for those dependent on them, through cultivation and reciprocal exchange relations, whilst maintaining overall ecosystem health.

1.3. Why CES are so important

CES have been shown to be of foundational importance to ecosystem conservation. Social perception studies, far from giving them secondary status, frequently indicate a preference for CES greater than or at least comparable to regulating or provisioning services (Sagie et al., 2013; Martín-López et al., 2012). It has been shown that cultural and provisioning services are the most directly experienced and intuitively appreciated by people, with most direct links to human wellbeing (Daniel et al., 2012; Plieninger et al., 2013), suggesting that it could be the most effective vehicle to communicate the importance of protecting ecosystems (Orenstein, 2013; Gobster et al., 2007). The rationale for conserving what may otherwise seem an ES-poor environment can be enhanced by factoring in CES (Sagie et al., 2013); often the most persuasive arguments for the conservation of landscapes involve their spiritual and religious significance (Daniel et al., 2012), their relationship to social or cultural identity, or their recreation and tourism uses (Stynes, 2005). Increased attention to CES can increase the cultural sensitivity of ES assessments (Chan et al., 2012a), and interventions that may follow, by improving understanding of their relevance for local stakeholders (Martín-Lopez et al., 2012).

In contrast, without explicitly and adequately including CES in ES assessments, policy plans or activities based on the ES framework risk being ineffectual, even counterproductive (Chan et al., 2012a). The sociocultural values embedded within CES can be key determinants of the success or failure of conservation strategies (Mascia et al., 2003), and neglecting CES can thus undermine ES-based interventions and their environmental and social objectives. Indeed, management decisions, currently based largely on assumptions, often overlook possible synergies between different ES (Daniel et al., 2012) and potentially neglecting what actually matters most to the people affected (Chan et al., 2012a).

1.4. CES development in theory and in practice

Whilst some recent literature has focused on improving the inclusion of culture in ES approaches (see e.g. Satterfield et al., 2013; Pröpper and Haupts, 2014; Church et al., 2011; Gould et al., 2015), developments of the CES concept invariably bias “leisure-time” concepts of the use of nature, such as tourism, recreation, beauty and inspiration (Pröpper and Haupts, 2014), or the mental and physical health benefits of interacting with nature (Russell et al., 2013). These viewpoints are seated in Western, idealized visions of nature as a wilderness; a place to escape and recuperate from urbanised living; and a focus on passive cultural interactions with the environment (Satterfield et al., 2013; Cole and Yung, 2010). Whilst relevant in certain developed nations, this only serves to reinforce the subordination of indigenous and rural interactions with ecosystems, potentially perpetuating inequality and unequal power dynamics in land valuation and management. There remains a paucity of work addressing the crucial aspect of how to account for reciprocal relationships between humans and nature in ES management.

The inclusion of Indigenous and other minority perceptions of culture in efforts to conceptualise CES are rare. Few models exist that accommodate reciprocal, cultivating or restorative interactions between humans and ecosystems (Patterson and Coelho, 2008; Patterson, 2014). Research tends to be restricted to the one-way discourse of what the ecosystem provides (Satterfield et al., 2013; Gould et al., 2015). The UK’s National Ecosystem Assessment (Church et al., 2011) sets out to improve CES methodologies, yet the focus is on quantification and assessment of CES using economic valuation, a technique widely criticized as inadequate for accounting for the complex, dialogical nature of CES (Satterfield et al., 2013). Ideas of co-production between humans and nature are mentioned, but only in introductory sentences and not developed further (Church et al., 2011: 634; 639). The Millennium Ecosystem Assessment (MEA, 2005) categories of CES include: Cultural diversity; Spiritual and religious values; Knowledge systems; Educational values; Inspiration; Aesthetic values; Social relations; Sense of place; Cultural heritage values; and Recreation and ecotourism—and similarly emphasise values drawn from, rather than cultivated in, nature. The complexities of human-environment relationships remain insufficiently addressed (Hernández-Morcillo et al., 2013). It is the more integrated and dialogical model of CES, and ES generally, incorporating inputs from human societies, that we seek to develop in this paper, using case studies of two bioculturally diverse rainforest environments to illustrate the reciprocal relations between ES and S2E.

1.5. Ecosystem Services and Indigenous Peoples

For Indigenous and traditional rural communities, with a likelihood of high dependence on natural systems for their livelihoods (Nakashima et al., 2012; Gadgil et al., 1993), the risks of neglecting cultural values are particularly significant. Due to longstanding associations with landscapes and features of the ecosystem, many have an intimate knowledge of, profound dependence on, and adaptive integrity with, local natural environments (Gadgil et al., 1993; Nakashima et al., 2012), and longstanding and reciprocal relationships with ecosystems and landscapes are often integral to their cultural identity (Holmes and Jampijinpa, 2013). Since indigenous or minority ontological, epistemological, and teleological perspectives on human-environmental relations may vary significantly from the dominant views of land and resource managers, CES are increasingly important to consider in accounting for this. Yet there exists an almost complete lack of attempts to explicitly consider indigenous definitions of CES (Satterfield et al., 2013).

We suggest the concept of ES can be improved by incorporating a worldview that is commonly held by Indigenous groups and traditional rural societies—that human communities are a part of the ecosystem, cannot be meaningfully separated from it, and have a role in contributing positively to it (Nelson, 2008). The concept of Services to Ecosystems relates closely to this. Meanwhile, it is important to recognise that many Indigenous peoples have been or are currently subjected to discrimination, dissemination, exploitation and worse—and that not all Indigenous societies behave in adaptive ways (Smith and Wishnie, 2000; Berkes, 2012). Acknowledging this reality and avoiding essentialising the ‘Indigenous worldview’ is critical in responding to this.

1.6. Human services to ecosystems (S2E): expanding the ES framework

Human communities often actively alter ecosystems to enhance, modify or degrade their services, whether deliberately or unconsciously (Termorshuizen and Opdam, 2009; Raymond et al., 2013). Often evolving over long time periods, these human interactions with or modifications of ecosystems can be an integral feature of the ecosystem and thus the services it provides (Balée, 2006). Examples of such impacts are numerous, and include the enhancement of soil quality and plant diversity in early Amazonian communities (Lehman et al., 2003; Tollefson, 2013; Balée, 2013); cultivation of mangrove forests for storm protection in coastal regions (WWF 2011); conservation and restoration of wetlands for their water filtration and energy generation properties (as seen in New York City (Stolton and Dudley, 2007) and Rwanda (Hove et al., 2010); and the preparation of spawning beds for returning fish, boosting fish populations (Thornton, 2015; Thornton et al., 2015). Such activities maintain or enhance the health of the ecosystem (see Costanza, 2012), and can constitute an enhancement of ES—that is, an overall increase in the quality or quantity of the services provided by the ecosystem to the human (and non-human) communities most dependent on it. Examples of such impacts are numerous in both Amazonia and Cascadia, as expanded on in the case studies that follow.

A powerful and emerging argument states that ecosystems cannot be justifiably considered without acknowledging the role humans have played over time in shaping them (UNESCO, 2008; Guevara and Laborde, 2008); and by neglecting to do so, the sustainability of ecosystems may be undermined (Rozzi, 2012). Similarly, the field of historical ecology (Balée, 1998, 2006) takes as its premise the co-evolutionary (in fact inseparable) role of humans and nature in creating landscapes and contributing to ecosystem functioning. Given their foundational role in shaping nearly every inhabited environment on the planet from the earliest periods of significant settlement, ecosystem management that neglects the roles of humans essentially risks the very services it attempts to protect (UNESCO, 2008; Guevara and Laborde, 2008; Rozzi, 2012). Correlatively, failure to include affected human communities in environmental management and conservation decision-making can harm these communities and the cultural diversity they represent (UNESCO, 2008). Consider the cases of wide-scale eviction of Indigenous peoples from their homelands in order to 'protect' the ecosystems and the services they provide (cf. Callicott, 2008; Dowie, 2009)—a tragic reality that has occurred in many regions of the world, Amazonia and Cascadia included. Ignoring the historical co-evolution of these societies and the ecosystems that support them threatens to undermine their integrity and resilience as social-ecological systems, with severe consequences. Indeed, they have led some Indigenous leaders to single out 'conservation' as their biggest new enemy (Dowie, 2009)—an indication that past and current concepts of conservation and management of ecosystems are falling short. This is not to suggest that indigenous "management" or S2E was or is always conservative or productive of ES, but rather that often it is, and this fact has been frequently overlooked.

The views and roles of Indigenous and local societies are necessary to include, as their omission in environmental management generally, and the ES framework in particular, threatens those communities who are often the most closely linked with, or most directly dependent upon, these ecosystems. These same communities are amongst those most able to articulate the deep cultural significance of restorative practice – a regretful irony. The reciprocal relationships that often exist between Indigenous and traditional rural communities and their ecosystems, evolved over generations of close interactions, may be fundamental to ecosystem services – and thus need to be included and managed within environmental decision-making.

We argue that a revitalised definition of CES, and its position within the ES framework, is required. The framework must recognize and valorize that the integrity of ecosystems and the services they provide is a function of human-environmental interactions and exchanges. This includes both material and so-called "intangible" interactions, and specifically what we term "services to ecosystems" (S2E). The modified framework (Fig. 1, Section 4) does this. In a rapidly changing world, resilience of ecosystems is largely an unknown, and cultural diversity and ecosystem practices are often being undermined by land-use and governance changes–be it in the name of development or conservation. We suggest that full consideration of the scope and diversity of CES is critical for the persistence of stable biomes, biocultural diversity, and human wellbeing.

2. Services to ecosystems in Amazonia

2.1. The Amazon as false wilderness

The Amazon rainforest is an iconic example of contemporary under-appreciation of the role of humans in ecosystems. The largest tropical ecosystem in the world and home to over a third of the world's biodiversity, mainstream ideas in both popular and scientific spheres are that the areas of rainforest still standing are remnants of a pristine 'wilderness', devoid of the destructive impact of human activity (Balée, 2013; Pinedo-Vasquez et al., 2012; McMichael et al., 2014; 2012a,b; Meggers, 2004). The reality, that the Amazon is one of the world's biocultural hotspots (Loh and Harmon, 2005), a landscape shaped by numerous and varied historical interactions between human societies and the ecosystem (Balée, 2013), remains outside common understanding. Indeed, global assessments of bioregions and diversity, even those that pertain to consider cultural diversity (e.g. Gorenflo et al., 2012) class Amazonia as a 'wilderness area,' a category defined by low human densities and a perceived low human impact (Mittermeier et al., 2003; Gorenflo et al., 2012). Such concepts of wilderness and the absence of human activity are in part a result of the massive depopulation that occurred after European arrival (Balée, 2013). They are also a legacy to the US Wilderness Act of 1964, which mainstreamed a concept of wilderness as "areas devoid of permanent inhabitants," (Callicott and Nelson, 1998) and was responsible for the now heavily criticised U.S. National Parks movement, which drove the removal of many thousands of local peoples from lands they had inhabited or used for many centuries (Hargrove, 2008; Callicott, 2008). Fictional writings and explorers' memoirs further propagated the concept of the Amazon as a vast wilderness; yet these depictions are increasingly shown to be, as in Sub-Saharan Africa (Fairhead and Leach, 1996), misreadings of the Landscape, neglecting the historical role of human groups in shaping ecosystems considered 'wild'.

Far from untouched, evidence of a long and detailed history is still emerging of the significant and sustained impacts historical Amazonian societies have had in shaping the Amazon rainforest that exists today. Beginning up to 20,000 years ago (Guevara and Laborde, 2008) and continuing today (Rival, 2006; Balée, 2013), these interactions have transformed the Amazonian Landscape, and enhanced the ecosystem and the services it provides (Pinedo-Vasquez et al., 2012; Rival, 2006; Lehman et al., 2003). As described in this section, these interactions range from the modification and domestication of wild plant species (Clement, 2006a; Balée, 1999) and cultivation of entire resource-rich forest regions (Balée 1989, 1993; Rival 2006; Section 2.2), the enhancement of the quality and productivity of the soil (Lehman et al., 2003; Tollefson, 2013; Section 2.3), engineering the landscape topography to better meet local societies' needs (Pinedo-Vasquez et al., 2012; Tollefson, 2013; Section 2.4), to impacts on game population and distribution, and modifications at the landscape scale (Balée, 1989, 1999; Posey, 1984b, 1985; Section 2.5). These actions are sometimes deliberate adjustments to the rainforest's services, and sometimes motivated by historical cultural beliefs and rituals, evolved through many generations of interactions with the ecosystem (Balée, 2013; Shanley and Galvão, 1999 Sections 2.6 and 2.7).

Table 1 outlines some of the examples of the human modifications of and services to ecosystems in the literature, many of which are expanded upon throughout this section.

2.2. Plant domestication, diversification, and anthropogenic forests

Human influence on the plant base of Amazonia involves the modification and cultivation of individual plant species, largely to

Table 1
Some services to ecosystems in Amazonia.

Service or activity	Resource affected	Reference
Domestication of plant species	Manioc, papaya, cashew, peanut, cacao, pineapple, arrow cane, tobacco, annatto (a dye tree), guava, rope plant, cocoyam, chili peppers, Peach palm (*Bactris gasipaes*), Biribá (*Rollinia mucosa*)	Balée, 2013, 1999; Arroyo-Kalin, 2010; Clement, 2006a,b; Rival, 2006
Trait modification through selection	Peach palm	Clement, 2006b
Cultivation	Brazil nut (*Bertholletia excelsa*), soursop, acai, bacuri (*Platonia insignis*), piquiá (*Caryocar villosum*), tucumã (*Astrocaryum tucuma*)	Balée 1999, 2013; Posey, 1999; Clement, 2006a,b; Brondízio, 2006
Transplantation, translocation of cuttings	'Valued' or useful species such as fruit plants, palms, crops; chili peppers, other horticultural plants	Erickson, 2010; Hugh-Jones, 2001
Planting, sowing seeds	Brazil nut trees; babaçu palm; cacao; Burití palm (*Mauritia flexuosa*)	Anderson & Posey 1989; Shepard & Ramirez, 2011; Rival, 2006; Erickson, 2006
Incidental seed dispersal through use and distribution	Brazil nut; cacao; acai Macaúba palm; tucumã (*Astrocaryum aculeatum*); bacaba (*Oenocarpus* sp.)	Clement, 2006b; Neves & Petersen 2006; Rival, 2006; Balée 2013; Shepard & Ramirez, 2011
'Protecting' useful species	Nitrogen fixers: *Trema micrantha*,*Inga* spp.	Balée, 1989; Hecht & Posey, 1989
Weeding to promote useful species	Brazil nut trees; various fruit trees	Erickson 2006; Schelhas, 1996; Comberti, 2015, pers. obs.
Earthworks: raised planting beds, water channels, fish weirs	Soil composition; Common crops: manioc, sweet potatoes, peanuts, beans, squash, and maize; chocolate; Native fish species: e.g. pirarucu (Arapaina gigas), aruana (*Osteoglossum bicirrhosum*), piranha (*Serrasalmus* sp.), tamoatá (an armored catfish, *Hoplosternum littorale*); mussuã turtle (*Kinosternon scorpioides*); large game species: e.g. deer, tapir, peccaries	Erickson, 1994, 2006; Pinedo-Vasquez et al., 2012; Schaan, 2010
Rituals, cultural prescriptions, beliefs or taboos to guide or regulate resource use	Large game species (e.g. deer, tapir, spider monkeys, peccaries)	Shepard Jr. 2004; Harner, 1973; Arhem, 1996; Shepard et al., 2012; Shanley & Galvão, 1999.
Burning	Babaçu palm; Soil fertility (inc. *terra preta*); Reduction of Bracken and other shrubs	Hecht, 2009; Barbosa & Fearnside, 2005; De Toledo & Bush 2007, 2008; Hankins, 2013; Clement, 2006b; Ratter et al. 2006; Balée, 1999
Enhancing fertility of soils (*Terra preta*; *terra mulata*)	Soil nutrients, composition	Pinedo-Vasquez et al., 2012; Balée, 1999; Erickson & Balée, 2006; Clement, 2006b; Woods & McCann, 1999; Mann, 2000; Anderson et al., 1991; Whitmore, 1992
Planting of game-attracting species	Large game species; e.g. deer, tapir, spider monkeys, wild peccaries.	Balée, 1985, 1999; Erickson & Balée, 2006

enhance their properties useful to people (Clement, 2006b), or the services these plants provide. There are over 100 examples of plant domestication in the neotropics—more than any other world region (Balée, 1999: 122), supported by numerous ethnobiological studies documenting historical practices of plant domestication amongst Indigenous Amazonians (e.g. Clement, 2006b; Balée, 1999; Rival, 2006). One such plant is the peach palm (*Bactris gasipaes* var. *chichagui*), transformed from a 1 g oily fruit to a fruit of up to 100 g and 50% more water, making it a far better fermentation substrate and thus substantially more useful to the people using it (Clement, 2006b: 188). Domestication transformed the services available to humans from the Amazon, and may be "the most important relationship between humans and their landscape." (Clement, 2006b: 166).

Collectively, human influence on Amazonia's plant base goes beyond the modification of individual species. The overall biodiversity of the region, as highlighted by a growing number of ecologists, ethnobiologists and anthropologists, has been altered, indeed enhanced, by human populations (Balée, 1999 2013; Erickson, 2010 2006; Arroyo-Kalin, 2010; Clement, 2006b; Rival, 2006; Mann, 2005; Denevan, 2001). Domestication played an important role in this (Balée, 1999), along with a variety of other actions. Selection of desirable phenotypes within promoted, managed or cultivated plant populations may have led to the creation of new species, increasing the overall diversity in certain forest regions (Balée 1999; Posey, 1999)—and altering the services it provides.

Evidence of such impacts today remains in old fallows—long-abandoned lands deep within the rainforest once cultivated by indigenous communities (Balée, 1999). Many species of plants are found either exclusively, or with far higher frequency, in fallows, and include many of the most important food provisioning species of the rainforest; a possible footprint of genetic selection and the actions of historical societies in enhancing the ecological diversity of Amazonia and its ecosystem services (Anderson, 1990; Denevan and Padoch, 1988; Balée, 1999). Such fallows, and forests with a high density of resources such as various species of palm, bamboo, and Brazil nut, are described as "indigenous orchards" (Balée, 1999:37), and are visible products of the cultural activities of ancient populations in providing S2E in Amazonia.

Far from being 'wild' resources, many of Amazonia's most important ES can be traced to historical human activity. The Brazil nut, for example, has been used for subsistence of Amazonian Indigenous peoples for thousands of years (Sheperd and Ramirez, 2011), and is today a keystone resource across eastern and central Amazonia, across Peru, Brazil and Bolivia; where it occurs, the species is irreplaceable in its importance and services provided to a large number of indigenous and *campesino* communities (Ribeiro et al., 2014; Cronkleton and Pacheco, 2012; Comberti, 2015, pers. obs.). There is growing evidence that its distribution, and perhaps productivity, is heavily dependent on past human activity: its distribution, genetic traits and analysis of linguistics relating to the species all suggest cultivation and human influence on its current status (Shepard and Ramirez, 2011; Gribel et al., 2007; Kanashiro et al., 1997). Observations of communities today corroborate, often seen deliberately planting Brazil nut trees (Anderson and Posey, 1989, of the Kayapó communities of Gorotire, Brazil; Comberti, 2015, pers. obs. of the Tacana II communities of Bolivia), and many are actively managing the resource, intentionally or unwittingly (Posey, 1985; Balée, 2013). Further, their distribution closely correlates with findings of *terra preta*, (Arroyo-Kalin, 2010; Kern et al., 2004) which is itself a footprint of human historical influence (see Section 2.2).

Beyond influence over distribution, communities have also been observed to undertake deliberate activities aimed to enhance the production of the Brazil nut trees. These include cutting vines hanging from their branches (Comberti, 2015, pers. obs.; Kainer et al., 2007), which can increase production over time (Kainer et al., 2007). Weeding around the base of the brazil nut trees has also been observed, along with making small incisions in the bark to let the sap of the tree run, with the specific intention of increasing production (Comberti, 2015, pers. obs.), although currently no scientific studies have been carried out to demonstrate the outcomes of these latter activities.

The evidence is sufficient to conclude that the Brazil nut tree and its presence in groves can be considered an indicator species to mark historical human influence on the forest (Balée, 2013, 1989; Shepard and Ramirez, 2011). One of the most economically and culturally important services in certain regions of the Amazon is actively enhanced by human communities, with conscious intent, and has been for centuries.

Weeding around bases of wild plants whose growth they wish to encourage has also been observed amongst the Huaorani of the Ecuadorian Amazon (Rival, 2006). This, and other 'marginal modifications' such as leaving behind seeds in abandoned camps, have "enriched their habitat for humans" (Rival, 2006:17) through S2E.

The use of fire in traditional practices is another S2E, and has been shown to significantly alter plant composition in many regions (e.g. Hecht, 2009; Barbosa and Fearnside, 2005; De Toledo and Bush, 2007, 2008). Fire has enhanced the diversity of plant species and increased the dominance of 'useful' species. The babaçu palm (*Orbignaya phalerata*), one of the most useful and culturally important palms (Balée, 2013, 1989) impacts the forest by recycling soil nutrients and improving soil structure (Anderson et al., 1991). Its cryptogeal germination means they remain underground, protected from fires, and thus often dominate after burning events to become the most ecologically important species in post-burn plots (Balée, 1989). Forests rich in babaçu are thus reliable indicators of human disturbance over time (Balée, 2013; Clement, 2006b).

Servicing of forests to enhance their provisioning potential thus appears to be an ancient practice, with significant impacts on the diversity, structure and services provided by forest ecosystems (Shepard and Ramirez, 2011). An increase in provisioning ES does not necessarily constitute a S2E, or may be temporary at best (as the green revolution's failures show; cf. Lansing, 1991, 2006). However the significant modifications of the diversity, structure, and density of 'useful plants' as documented above suggests that many Amazonian forest patches, and the ecosystems more broadly, are anthropogenic in origin. Moreover, the ES provided are shaped by reciprocal relationships between human populations and ecosystems over long timescales, without the apparent adverse effects of many modern interventions.

These findings have led to many referring to these modified forest regions as "anthropogenic forests" (Balée, 1999:6; Rival, 2006:6) or forests "of archaic, cultural origin" (Balée, 1989: 2). An early estimate posits that such forests account for 12% or more of the Brazilian Amazon region (Balée, 1989: 15).

2.3. Improvements to soil quality

Human impacts on the forest go beyond the plant base. Across large areas of the Amazon, one of the largest ecosystems in the world, the very soils that support the vast rainforest are a footprint of human inputs. Soils, a globally threatened and continually undervalued resource (Monbiot, 2015), provide fundamental supporting ES. Evidence showing that humans have enriched its fertility, structure and nutrient base, thus the services it provides, illustrates the important role humans can play in providing S2E. A key point in the development of understanding of human influences on the Amazon ecosystem was the discovery of *terra preta* (literally 'black earth' in Portuguese). These soils, amongst the most fertile in Amazonia (Balée, 1999; Pinedo-Vasquez et al., 2012), have been shown to be anthropogenic in origin and are largely viewed as evidence of long-term occupation of past societies *terra preta* appears to have been made by adding charcoal, fish and animal bones, and manure to otherwise relatively infertile Amazon soils over extended time periods, and burning this mixture at very low temperatures to create a charcoal that is stable over long periods of time (Balée, 1989; Clement, 2006a; Pinedo-Vasquez et al., 2012). The resulting enriched and darkened soil covers large areas of the Amazon (Pinedo-Vasquez et al., 2012), with one recent model-based estimate suggesting that *terra preta* covers 3-4% of the Amazon basin (McMichael et al., 2014) and others ranging up to 10% (Tollefson 2013; Mann 2002).

Yet human impact on soils reaches beyond the range of *terra preta* proper. Another modified soil, *terra mulata*, is slightly lighter in colour and deliberately altered for agriculture by mixing in wood ash (Woods and McCann, 1999:9), and it can cover areas ten times greater than *terra preta* itself (Mann, 2000). In addition, soils in fallows, such as those of the Ka'apor in Brazil, have been shown to be of significantly higher fertility than those of the wider forest, being richer in nitrogen, carbon, phosphorus and other elements (Balée, 1999). Certain tree species found at higher densities in the fallows have been shown to contribute to soil quality, and may be a key reason behind this (Anderson et al., 1991; Whitmore, 1992; Balée, 1999). Thus, a significant proportion of the Amazon's core supporting ES harnessed by contemporary humans have been cultivated by past human groups.

2.4. Earthworks to enhance ecosystem services

The discovery of massive earthworks across the Amazon has been another turning point in understanding the human impact on the Amazonian ecosystem (Balée, 2013; Denevan, 2001). Man-made alterations of the topography of vast regions of Amazonia, some dating to 400 BC, started to be uncovered in the 1960s, including thousands of kilometres of raised fields standing above the seasonally flooded grasslands of the Beni region of Bolivia (Balée, 2013). Known as the Llanos de Moxos (Lombardo et al., 2013; Tollefson, 2013; Pinedo-Vasquez et al., 2012), these appear to be evidence of traditional peoples' creation of a complex, engineered Landscape, which permanently transformed the ecosystem and the services it provides (Balée, 2013; Denevan, 2001). Their constriction involved moving vast quantities of earth to create raised agricultural fields, causeways, reservoirs, forest islands, ring ditches, fish weirs, ponds, and other structures—permanently modifying not just the topography of the region but also the hydrology, soil structure and fertility, faunal and floral communities, biodiversity, and local climate (Balée, 2013; Erickson, 1994, 2006). The agricultural potential of the region was transformed, largely through the enhancement of nutrient production, capture, and recycling in canals alongside thousands of hectares of raised beds (Balée, 2013: 266). The earthworks were also used to improve drainage, to enable adaptation to seasonal flooding, and to channel fish populations into weirs and trap them as floods receded (Erickson, 2006, 2010; Balée, 2013; Mann, 2000), and enabled the management of other economically important faunal and floral resources (Balée, 2013).

Recent experiments to revitalise these practices and build new raised beds in the Beni landscape have demonstrated the benefits of using such techniques to achieve soil quality improvements (Pinedo-Vasquez et al., 2012) and far greater yields and more frequent harvests of crops such as manioc and sweet potato

(Erickson, 1994; Oxfam, 2009). Similar evidence from Marajó Island in Brazil, supports the case that "Amerindian societies have been actively transforming their surroundings for millennia" (Schaan, 2010: 182), with clear benefits to ecosystem services

2.5. Faunal and landscape domestication

In addition to managing aquatic fauna as mentioned above, some human communities of the Amazon regulate or enhance the terrestrial faunal populations. In some cases, this results in increases in populations of game species around communities. Many game species are attracted to the vegetation found exclusively in settlements and swiddens (Balée, 1999), and Posey (1984a,b, 1985) has shown that some communities deliberately plant or protect game-attracting tree species. This draws the faunal food base closer to the villages, effectively enhancing a crucial provisioning service of the Amazonian ecosystem. This evidence has even led Balée (1999) to class these game as 'semi-domesticated'.

Such is the scale of possible human impacts on the forest profile, services and structure, some have described the indigenous impact on the Amazon landscape as 'transformational' (Rival, 2006: 7; Clement, 2006a: 34). Others have proposed that it is a case of 'landscape domestication' – a term defined by Harris (1989) as "a conscious process by which human manipulation results in changes in a landscape's ecology and the demographics of its plant and animal populations, thereby creating a habitat that is more productive and congenial for humans" (Clement, 2006a). Landscape manipulation in Amazonia can range from simple promotion of useful species; to management, where landscapes are "intensively manipulated to increase the abundance and diversity of food and other useful plant species;" to "the complete transformation of the biotic landscape to favour the growth of a few selected food plants and other useful species" (Clement, 2006a: 34). We argue that, as outlined above, several regions of Amazonia show evidence of landscape domestication, and through changes to the plant diversity and structure, soil, topography, aquatic and terrestrial fauna, the ecosystem services that the habitat provides have been enhanced, and in some cases, transformed. The Amazon thus serves as a mega-scale example of the evidence of the role of humans in providing S2E.

2.6. Conservation with intent?

Scholars have often debated the intentionality behind landscape practices (cf. Krech and Elizabeth Vibert, 1999; Smith and Wishnie, 2000). Management strategies of several Brazilian forest-dwelling communities have been shown to possess a complexity comparable to that of agroforestry or integrated forest management (Posey, 1984a; Pinedo-Vasquez et al., 2012); and the high level of knowledge necessary for complex plant and landscape management techniques (Clement, 2006a) has also been widely documented (Balée, 2013). Evidence of conscious management includes weeding around desirable wild species, and transplanting seeds and cuttings to concentrate crops into forest patches are documented (Posey, 1999; Rival, 2006) However, here we are more concerned less with intentional species conservation, and more with the conceptualisation of S2E as a reciprocal engagement with and cultivation of ecosystems for the purpose of sustainability and human wellbeing in dynamic systems (see Thornton et al., 2015 for further discussion of this point). Traditional Ecological Knowledge (TEK; Berkes, 2012) related to servicing ecosystems need not always be consciously held in order for it to be transmitted and actualized, and the integrity of ecosystems may rely upon the persistence of cultural integrity and the transmission of such TEK—and should thus be considered in management activities.

2.7. Cultural beliefs and practices guiding ecosystem management

Traditional ecological knowledge (TEK), maintained through oral history and social networks, is amongst the most important knowledge in influencing practical ecological activities (Shanley and Galváo, 1999). Adoption and promotion of knowledge that can influence consumption and demand is an important means of incorporating ES concepts into management and behaviour (Patterson, 2014; Patterson and Coelho, 2009). Throughout Amazonia, strongly held beliefs relating to reciprocity and respect for the forest ecosystem influence and regulate the use of its resources—and are thus a key element of S2E.

One such belief that is widespread across Amazonian communities is of a forest spirit, the owner of the forest. This guardian of the fauna and flora is known by a variety of names across the Amazon, including *el Duende* (Bolvia: Comberti, 2015, pers. obs.), *Chullachaqui* (Peru: Beyer, 2010), and *Churupira* (Brazil: Shanley and Galvão, 1999) and also referred to simply as *el dueño*, or *madre del monte* (Comberti, 2015; pers. obs.). Believed to exist in order to protect the forest and its animals (Beyer, 2010; Comberti, 2015 pers. obs.), he sleeps in the trunks of the tauri/bitumbo tree (Shanley and Galvão, 1999; Comberti,2015, pers. obs.), can appear in the forest in various forms and shapes, and can abduct people or lead them under false guises deep into the forest and leave them lost. He is also believed to cause illness in those that upset him, even death. Significantly, he is angered if hunters are 'greedy' and take more animals from the forest than they need, thus disrespecting his 'property' (Salvatierra, 2015a, pers. comm. with CC; Beyer, 2010), and will appear to punish them. This belief, through fear of being reprimanded, serves to promote responsible hunting and use of forest services, and actions that allow the revitalisation of forest ES.

As one member of a Tacana II community in Northern Bolivia explained,

> "He appears if the people are taking too many animals from the forest. . . . To protect the forest. You have to respect the forest, not take too much. You have to not upset *el Dueño*." (Salvatierra, R. 2015, Pers. comm. to CC.)

Similar stories are widespread and commonly discussed amongst Amazonian communities, and fear of being reprimanded appears to regulate extractive behaviour and drive respect and responsibility (Comberti, 2015 pers. obs.; Salvatierra, 2015b, pers. comm. with CC; Beyer, 2010).

Another key aspect of reciprocity common in Indigenous practice is a belief in the interconnectedness of the natural world, and in treating all aspects of the ecosystem as equals and with respect. As Arhem (1996) describes in the case of the Makuna, NW Amazonia, a cosmological understanding of human-nature interactions centres around duality and transformation between human and animal or plant states, drives reciprocity. These beliefs and the myths that sustain them are regulators of land use, and "extremely efficient ones since they are at once ecologically informed, emotionally charged and morally binding." (Arhem, 1996: 200).

In summary, examples of complex forest management practices to enhance diversity and distribution of service-providing plant species, to enhance soil quality and productivity, and topographical engineering to maximise ES, documented over many decades and across vast regions of the Amazon rainforest, provide robust evidence of the significant role of humans in modifying the Amazon to enhance the services it provides. Yet alongside recent publications that increasingly highlight human modifications of ecosystems, are those perpetuating the traditionally-held view of a relatively "undisturbed Amazon," which argue that anthropogenic forests account for only a small fraction of the Amazon, or that disturbances and impacts on overall diversity caused by human populations were small (McMichael et al., 2014, 2012a,b; Bush et al., 2007; Leigh et al., 2004). However, evidence provided here suggests that the role of humans in cultivating the great Amazon ecosystem as it exists today cannot be separated from the ecosystem itself. Dominant understandings of humans as separate from nature – or alternatively, as destroyers or stressors of ecosystems, a largely unchallenged model which drives most conservation management interventions – need to be altered to consider the potential of humans as servicers of the ecosystem, integral to the health of the wellbeing of the Amazon rainforest, and crucial for effective management. As Foster (2000) states, "Failure to appreciate the [past] human element in these lands certainly leads to erroneous ecological interpretations, misdirected research emphases, and misguided approaches to management" (Foster, 2000: 27).

3. Services to ecosystems in Cascadia

The Amazon has an analogue in the Northern hemisphere both in terms of rich biocultural diversity and human-ecosystem reciprocity: the Pacific Northwest Coast temperate rainforest. In this section, we document examples of floral and faunal management in the coastal areas of the Pacific Northwest bioregion of North America, also known as Cascadia. Cascadia extends from southern Alaska to northern California, between the Pacific Ocean and the Continental Divide (Cascadia Institute, 2010). Akin to the Amazonia case study above, the relationships between cultural and biological ecosystems, including evidence of management and cultivation by Indigenous people, have been largely neglected for this bioregion. In this section we review the existing literature from the region, and highlight examples of management of ecosystems or resources, including two case studies from the authors' own fieldwork. Throughout this discussion, we will explore Indigenous people's links to ecosystem management as an expression of CES and human-environmental reciprocity.

As in Amazonia, until recently there has been relatively little acknowledgement of Indigenous cultivation of Cascadia rainforest ecosystems. There are several reasons for this oversight, including the methods by which people manage their resources, the signatures that these techniques leave on the Landscape, and how the 'lens' of the European worldview affects how this is perceived. For an example, an extensive work documenting plant cultivation in North America (Doolittle, 2000) includes few examples from Cascadia, because signs of plant management here were not characterized by the usual obvious signs, such as (1) major phenotypical modifications of the plant to become fully domesticated (e.g. corn); or (2) major terrestrial habitat modifications to support agricultural crops (e.g. terraces for potatoes).

Indigenous peoples in the Pacific Northwest cultivated their resources in a more subtle way, and management techniques thus went largely unnoticed by newcomers (Deur and Turner, 2005). This is due, in part, to the fact that colonial settlers expected 'cultivation' and 'agriculture' to be expressed on the landscape similarly to how it was expressed in their home environments. For example, plant habitats that were not clearly marked as owned (e.g. with fences) or overtly managed through continuous tending, were thought to be "natural" or "underutilized", and thus not taken full advantage of for cultivation (Lepofsky, 2009). Similarly, cultivation of animals, consisting of modifications to the environment and engagement of species so as to increase their abundance, accessibility, and predictability, could be hard to identify (Caldwell et al., 2012; Deur n.d.; Groesbeck, 2013; Groesbeck et al., 2014; Lepofsky and Caldwell, 2013; Thornton et al., 2010, 2015). Yet recent work has highlighted human-driven modifications to the physical characteristics of many culturally important plant species in the Cascadia region. These modifications often enhance the species' desirable traits, an outcome of a range of possible cultivation practices (Deur, 2002). The Pacific crabapple (*Malus fusca*), discussed below, is one example of such a plant species.

Species exhibiting signs of these modified physical traits are often considered to be *cultural keystone species* (Garibaldi, 2009; Garibaldi and Turner, 2004; Peroni et al., 2007; Turner, 1988). This term, analogous to the ecological term "keystone species," (Paine, 1969) is used to describe "culturally salient species that shape in a major way the cultural identity of a people, as reflected in the fundamental roles these species have in diet, materials, medicine, and/or spiritual practices" (Garibaldi and Turner, 2004: (4). Cultural keystone species typically form part of an animistic or 'kincentric worldview' among local Indigenous peoples (Salmón, 2000; Turner, 2005) wherein people view other-than-human constituents of their nature, including plants and animals, as kin, and thus often practice techniques to ensure their continued presence and health, in a sustainable and respectful manner. Similar to Amazonian Indigenous peoples, First Nations groups in Cascadia with this kincentric view regard resource management not as simply management of resources but also of the cultivation of respectful relations within an extended network of relatives (Thornton and Kitka, 2010).

Among hunting and gathering peoples in the Pacific Northwest and other regions, services to ecosystems are achieved through two major cultivation processes. The first is *habitat cultivation* in which conditions for the productivity of important ecosystem services are enhanced, maintained, or restored. The second is the *cultivation of reciprocal relations* with animate beings within the ecosystem through the principle of respect. Respectful engagement of these non-human persons by humans underlies what Langdon (2006) has termed for Tlingits and Haidas "relational sustainability" and Fienup-Riordan (1994:46) an for Yupiit "collaborative reciprocity" (see also Brightman, 1993 and Hallowell, 1960). Such moral-ecological paradigms of cultivation, for example the planting of attractive substrate for herring to spawn upon, can be highly developed, sanctioned in myth and ritual, and realized through a range of practical and highly localized techniques for interaction developed through mythic charters, experiment, and trial and error (see Turner and Berkes, 2006; Thornton et al., 2015). In cultivating and regulating relationships with a local species and habitats the emphasis remains firmly on sustaining their availability, which is considered vulnerable to atrophy, competition, or degradation if not actively maintained.

The impetus, in short, is toward "keeping it living" (from a Kwakwaka'wakw term used to describe such interventions—see Deur and Turner, 2005). Further, such cultivation extends beyond plants to a range of other cultural keystone species and their habitats within marine and terrestrial ecosystems, all of which show evidence of being serviced by humans to maintain or increase their productivity.

3.1. Ecosystem servicing in Cascadia

The last half century of research in Cascadia has uncovered many examples of cultivated landscapes and resources in both terrestrial (cf. Deur and Turner, 2005) and marine environments (cf. Lepofsky and Caldwell, 2013; Thornton and Deur, 2015). Management techniques, as shown, are practiced on both individual species (e.g. herring, eelgrass) and entire ecosystems, often composed of a complex of culturally important species (e.g. estuarine root gardens, garry oak meadows). Landscape management to increase the productivity of harvested resources, or servicing ecosystems to increase the provisioning services they

Table 2
Some servicing ecosystems techniques from Cascadia.

Servicing or cultivation technique	Resource	Reference
Pruning	Pacific Crabapple; hazelnut; orchards; Various berries (including salmonberry, blueberry, red huckleberry, soapberry, and others)	Turner and Peacock, 2005; Davis et al., 1995; McDonald, 2005
Tilling and digging	Root gardens; clam gardens; camas; garry oak meadows	Turner and Peacock, 2005; Lloyd, 2011
Transplanting	Herring; salmon; wapato; clams; Pacific crabapple; Northern riceroot; root gardens; orchards; camas; hazelnuts; eelgrass; highbush; cranberry; soapberry	Deur and Turner, 2005; McDonald, 2005; Moss, 2011; Cullis-Suzuki, 2007; Turner and Peacock, 2005; Thornton, 1999; Thornton et al., 2010a,b, 2015
Replanting (often at time of harvesting)	Salmon; herring; camas; riceroot; silverweed; clover; wild carrot; crabapple	Lloyd, 2011; Turner and Peacock, 2005; Wyllie de Echeverria, 2013; Thornton, 2008; Thornton et al., 2010a, 2015.
Terracing	Clam gardens; root gardens; hazelnuts; crabapples; riceroot	Downs, 2006; Williams, 2006; Deur et al., 2015
Burning	Camas; garry oak meadows; wetlands; various berries; hunting areas for elk, deer, and other game	Deur and Turner, 2005; Turner and Peacock, 2005; Barsh et al., 2011
Weeding	Camas; garry oak meadows; crabapple orchards; riceroot beds; berry patches	Turner and Peacock,2005; Compton, 1993; McDonald, 2003; Thornton, 1999
Territorial boundary and habitat maintenance	Salmon spawning streams; halibut banks; herring spawning areas; eulachon fishing sites; clam and other invertebrate beds; terrestrial game territories; Crabapple; Seaweed; various Berries; fireweed; silverweed	Drucker, 1951; Schalk, 1977; Richardson, 1982; Thornton, 2008; Turner and Peacock, 2005; Turner et al., 2005; Thornton, 1999
Fertilizing, feeding	Camas spp.; various Berries	Turner and Peacock, 2005; Thornton, 1999; de Laguna, 1972
Harvesting at specific growth stages	Seals; Halibut; Camas spp.; seaweed	Turner and Peacock, 2005

provide, is evident in Cascadia in ways similar to Amazonia's cultivated forests.

Table 2 below lists key ecosystem servicing techniques referenced in the ethnographic literature on Cascadia. Several of these techniques are analysed further in the case studies that follow. Additional information and scientific names for resources can be found in the references listed.

As shown, numerous techniques, many involving direct cultivation, were used to create a rich and varied landscape and maintain or augment the provisioning services of the ecosystem to secure plentiful harvests—and perhaps increase diversity within the ecosystem. All of these were conscious respectful techniques of cultivation, though not all were directed at "management" per se, as that term has little resonance and no linguistic equivalents in Indigenous ontologies (Nadasdy, 2005; Thornton et al., 2015). Epiphenomenal results of engagement, such as disturbance legacies (e.g. from plant harvest activities) leading to increased resilience, diversity, and functioning of ecosystems (Seidl et al., 2014), or human mobility (Hunn, 1982) leading to reduced or disbursed harvest pressure, are not considered here.

To illustrate the management methods described above, case studies involving a fish species, Pacific Herring (*Clupea* pallasii), and plant species, Pacific crabapple (*M. fusca*) are presented, both managed by humans using a variety of the above mentioned techniques.

3.2. Services to spawning fish: the case of the Pacific Herring

In the coastal marine environment, services to ecosystems can be illustrated by techniques associated with the cultivation of Pacific herring (*C. pallasii*) to gather and spawn (Thornton, 2015). Herring are a key pelagic schooling species and a foundation forage fish for salmon, seal, seabirds and other species in the North Pacific marine food web. In the early spring each year, adult herring migrate to breed between the subtidal and intertidal zones of protected shorelines, depositing thousands of eggs on kelp, eelgrass and other available substrate. For millennia herring have been a cultural keystone species for indigenous peoples throughout the Pacific Northwest Coast, from California to Alaska. Their meat, mash and eggs are consumed, and their flesh traditionally rendered for oil. Herring subsistence values were extended by their preservation as oil, smoked fish, and dried (nowadays frozen) eggs. They were also valued for their availability in the spring and fall when fresh salmon and other critical food sources were scarce. The presence of these forage fish drew other species of cultural interest too, especially salmon and seals, upon which people also relied. Thus, the spring arrival of herring for spawning was celebrated and certain prescriptions and prohibitions were enacted to facilitate reproduction, effectively servicing the ecosystem to improve its provisioning services and other benefits.

These interventions require detailed understanding of the ecology of herring reproduction, including spawning behaviour, habitat preferences, and ecosystem functions. Practical cultivation of herring probably began with attempts to enhance spawning habitat, to make areas of shoreline safe and attractive to spawning herring. Emmons and de Laguna (1991) observed that Alaskan Tlingits and Haidas "cut hemlock boughs which they placed on the shore at low water, and weighted down with boulders" so as to maximize surface area in the desired depth for spawning. Similarly, patches of broad-leafed macrocystis kelp and sea grass or hair kelp, both substrates that could be consumed with the spawn, unlike the hemlock boughs, were also tended for spawning herring.

Having prepared the spawning beds, herring might be further *cultivated by a proper "invitation"* to enter their spawning grounds, a sign of respect to the fish "tribe" whose return from their "house under the sea" had to be actively cultivated (Drucker, 1955: 155). As Tlingit elder Clara Peratrovich of Klawock, AK (Thornton et al., 2010a; p. 68) explains, there was a respectful way of inviting the herring into the bays to spawn on boughs: "Instead of just picking it [the hemlock branch] up and throwing it [in the sea], you got to pick it up and call in the [herring]; it's just like wishing the herring to come in . . . You're motioning it into a spawning area. And so that's *showing respect*." At the first sign of significant male herring milt, Tlingits in Sitka would lay their branches with the invocation, "This [substrate] is for your girlfriends [to spawn upon] " (John Duncan, 2015, pers. comm.).

It was considered disrespectful to disturb spawning grounds before active spawning began, and risky to move branches excessively during the spawn, as this would perturb herring, potentially to the point of withdrawing. At the same time, the context of "inviting" herring to the spawning area was also an invitation *to observe their behaviour closely, as guests.* Intimate observations of spawning behaviour, in turn, lead to improved understanding of how to best maintain optimal "host" conditions under which herring could spawn successfully.

Reducing noise and perturbations in spawning areas was only one means of enhancing spawn production. Human activity in relation to herring also was regulated according to a conceptualized zone of reproductive viability, above or below which herring eggs were unlikely to survive to hatch. Tlingit elder Harvey Kitka observes: "According to the old Indians... six feet above the low water line and almost three feet below, [between] those are the only ones [i.e., herring hatchlings] that swam away. Anything deeper than that or anything shallower than that died."

Harvesting too many eggs in the zone of reproductive viability could also bring supernatural sanction, as reported in the case of a "greedy" woman who took eggs continuously, even after dark, from a sacred spawning site and consequently turned into an owl. This has interesting parallels with the Amazonian legend of the *Duende/Curupira* (see Section 2.6). Many Tlingits still only *target herring eggs in the non-viable zone* lying more than 3 feet below the mean low water line for their own harvest, as a means of conserving the viable stock in the "survival zone." (Setting above 6 feet is not practical given the presence of birds and other predators; see Thornton et al., 2010a; Thornton, 2015.)

Another important strategy for servicing herring ecosystems is the active *transplantation of fertilised eggs* to new areas considered ideal for reproduction. This was common in Southeast Alaska (Thornton et al., 2010a) and has also been reported in other areas (Wu, 2013, pers. comm.; Lepofsky and Caldwell, 2013). Transplanting, a technique also noted in Amazonia, was often proximal, effectively replanting (Table 1), for example moving eggs on kelp or moving branches from without to within the zone of viability for successful hatching, or to extend herring production to new or revitalizing areas of shoreline beyond their existing range. Alternatively, herring eggs might be moved to new areas altogether to colonise new shorelines for spawning production. Live herring also were reportedly transplanted, though less frequently, using various techniques (see Thornton, 2015). Successful transplanting, like other habitat protection and enhancements, made herring spawning more abundant, accessible, and predictable, effectively enhancing ecosystem services and reducing ecological and economic risk.

Many of these ecosystem servicing techniques are still practiced today, especially in Sitka Sound, though typically not on a large scale. There is a potential to apply them more widely, as in the past, to enhance herring spawning areas, and thus improve the productivity of marine habitats, providing value and ES to human and non-human species alike (Thornton and Kitka, 2015).

3.3. Management of fruiting services: pacific crabapple

The pacific crabapple (*Malus fusca*) is an important plant species showing signs of cultivation in Cascadia forests. Crabapple distribution ranges from southern Alaska to California, and trees occupy moist to wet habitats primarily west of the Pacific Cordillera mountain range. Crabapples are used widely throughout their range of distribution, including for direct consumption of the fruit, ceremonial food at feasts (Turner, 1995), stored as a staple winter food, and for trade (Burton, 2012; Turner and Bell, 1973). The hard wood was used to make tools and fishing and cooking equipment (Turner, 2007), and the bark for medicines (Turner and Hebda, 1990; Burton, 2012). The recognition of different 'folk' varieties of this species amongst the Tsimshian, the Hanaksiala, and the Haisla (Burton, 2012; Turner and Thompson, 2006; Compton, 1993), where western plant taxonomies only recognize a single species, is further illustration of the intimate knowledge of and attention paid to this plant among Cascadian peoples.

Evidence suggests that the species has been impacted and even cultivated by Indigenous peoples in the region for many centuries, especially around village sites, to ensure a consistent supply of the highly valued fruit (Burton 2012; McDonald, 2005; Moss, 2005; Turner and Peacock, 2005; Turner and Thompson, 2006). Accounts exist of Indigenous people interacting with the trees through management (including pruning, weeding and fertilization) and translocation (Downs, 2006; Turner, 2004), and marking trees to indicate ownership, possibly aiding their management across generations (Turner, 2005; Turner & Peacock, 2005). Crabapple trees are often found close to abandoned settlements, possible evidence of the role of humans in their distribution (McDonald, 2005), and Burton (2012) notes that when certain Nisga'a groups moved to a new village site, they would bring crabapple saplings to transplant in the new location. Crabapple fruits were also moved as a commodity through trade networks, and as dowry payments (Burton, 2012; Turner 1995; increasing the likelihood of a human influence on their distribution. These exchange networks, in addition to impacting the ecologically and culturally important resource base, and thus important ecosystem services of the region, may have also have facilitated the transfer of knowledge, skills, and technology throughout this area.

Crabapples clearly constitute an important ecosystem Service, and may also contribute to ecosystem stability. Growing in edge environments, particularly along riverbanks, or at the interface between estuarine and riverine systems, the trees serve to stabilize the river banks against erosion, and are suggested for use in riparian restoration projects (King County Department of Public Works, 1993). In providing stability and cover, crabapples provide important co-benefits to other riparian species, including fish, and niche species in estuarine edge environments, thus contributing to ecosystem diversity and health. Crucially, with local reports of increasing periods of rainy and stormy weather (Turner and Clifton, 2009) and rising sea levels (A. Clifton pers. comm., 2011a), observations also noted by some scientific measurements and predictions (Abeysirigunawardena and Walker 2008; IPCC, 2013), this function may be of increasing importance into the future.

There is awareness amongst the many Indigenous peoples that the interventions they perform, largely pruning the trees and picking fruits whilst removing shoots, increases their productivity and health. The following observations by Gitga'at elders demonstrate this, and suggest an awareness of the need to service ecosystems in order to maintain the ecosystem services provided by crabapple trees:

> "You're just . . . clipping them off, but, like I say . . . I think the *moolks* [crabapple] fields up there grew so well because the people were picking them all the time and it's just like any . . . plant, you're taking [the] shoots off, and so then it grows well". H. Clifton, 2011b.

Similarly, a Haisla elder noted, (Davis et al., 1995: 29):

"Old people would cut the branches from the top – this would ensure there were lots next year – just cut the ones that had lots of fruit"

Paradigms of respect and reciprocity were evident in the control and caretaking of crabapple patches. Conceptualisations of "ownership" on the Northwest Coast embody an ethos of conscious, responsible and respectful care and relations by which human communities cultivate ecosystems and their individual components. Territorial markers were used to denote caretakers and cultivation of key ecosystem services, and stewardship responsibilities and cultivation techniques were transferred through kin-based learning networks and ceremonies (Salmón, 2000; Deur and Turner, 2005; Thornton and Deur, 2015). Additionally, recognition of the species' importance in the ecosystem and of responsible harvesting are shown in the lyrics of a traditional song. Sung whilst travelling in canoes to collect crabapples and accompanied by rhythmic beating of the sides of the boats, they sang, (lyrics translated by N. Turner, pers. comm. 2015): *"Bears, we're coming to collect the crabapples, please get back; but don't worry, we won*'t take them all—we'll leave some for you."

The techniques and approaches described above all serve to enhance the productivity and longevity of key ecosystem services. Within a kincentric worldview First Nations people acknowledge sustaining productive relationships beyond simply managing or owning resources. Rather than maximizing harvest in the short term, First Nations stewards engage in cultivating reciprocal relations of sustainment, extending the longevity and reliability of resources like herring and crabapple through generations.

4. Discussion

As our review of the existing literature and presentation of two rainforest case studies in the Americas shows, the present concept of ecosystem services (ES) is too narrow in its development of the ES paradigm to date. The original framework for ES, limited to a uni-directional conceptualisation of nature's supply of services to humans, is over-simplistic, and neglects to consider the multiple and complex ways in which humans may contribute to, cultivate, or enhance ES through the maintenance of the general health of the cognised ecosystem over time. These actions we term 'Services to Ecosystems' (S2E), and as we have shown in this article, they are often fundamental to shaping ecosystems existing today and the services they provide. In addition, the group of services known as CES especially are insufficiently conceptualised, and cannot be treated as a separate, residual category of "intangible" benefits that ecosystems provide. Rather, they must be seen as reciprocity between humans and the environment, the relationship itself critical to co-evolution and system sustainability. A revised approach is needed to acknowledge that ecosystems not only provide services to humans but humans also service ecosystems to ensure sustainability, increasing or stabilising supply, and reducing demand, or competition (cf. Smith, 2011a,b).

We propose a revised framework (Fig. 1), which explicitly situates the role of human services to ecosystems (S2E) and their role in relation to the wider system linking ecosystems and human communities. The S2E are sorted into categories according to their impact on the ecosystem and its services: protecting; enhancing; restoring; and supporting.

This revision of the ES framework is necessary to extend the concept beyond describing ES as a flow of benefits from ecosystems to people. It is intended to establish consonance between ES theory and indigenous perspectives which, failing to find alignment with prior conceptualizations, have not received the attention or representation they deserve. It supports the reconceptualization of ES to include these perspectives, by acknowledging the concept of S2E and encouraging its consideration in all interventions and management plans based on the ES concept.

The concept of maintenance or enhancement of the overall health of the ecosystem is integral to the definition of S2E, setting true S2E apart from actions that could be seen to enhance certain ES whilst minimising others, and/or that cause degradation of the ecosystem over time. These could include unsustainable agriculture, to maximise provisioning ES whilst degrading other services and the health of the ecosystem overall. As Costanza (2012) outlines, ecosystem health is a concept that refers to the resilience of the ecosystem and the maintenance of its structure and function

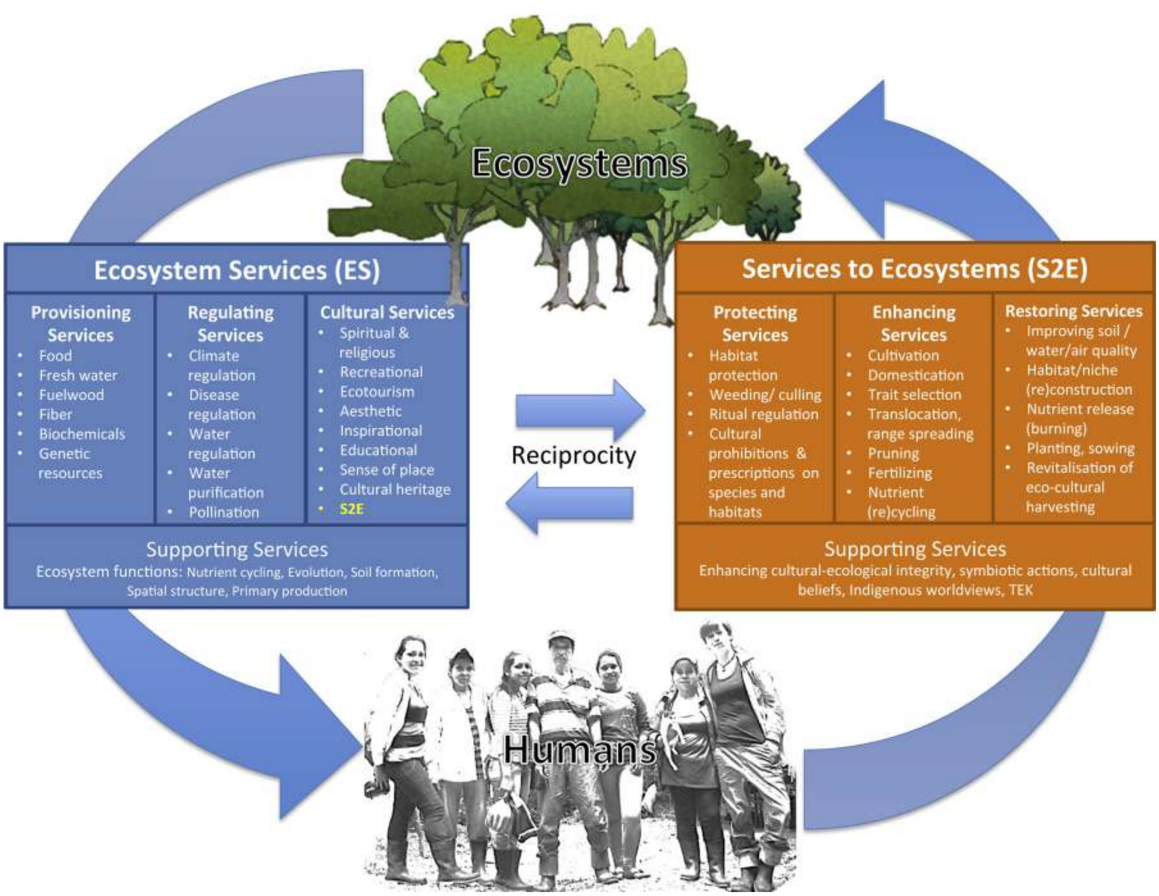

Fig. 1. A revised framework showing the ES-S2E loop of reciprocity.

over time. In addition, we argue that consideration of the 'cognised ecosystem', or what is understood as the 'ecosystem' by those involved in carrying out S2E, is important to understand, document, and plan management applications that consider S2E – which we propose should be considered in all interventions based on the ES framework. Methodologies should not be restricted to ecological processes and concepts of recreational and health benefits of ecosystems – as has often been the case (Pröpper and Haupts, 2014). To fully understand the processes and outcomes of S2E, ethnographic and social science methodologies are important.

To illustrate of how the revised framework incorporating S2E can be realised in practice, we revisit two examples, one from Amazonia and one from Cascadia. The first visits the case of the Brazil nut tree groves in the Amazon regions of Bolivia, Peru and Brazil (Ribeiro et al., 2014). Management and conservation of these groves under the original ES framework would consider the main service provided by the Brazil nut tree, namely its provisioning of a valuable trade item, the Brazil nut, as a service that the forest provides naturally, outside of human interventions. Management plans to guard the resource, following traditional conservation models facilitated by the ES concept, regulate human access to Brazil nut groves (e.g. Cronkleton et al., 2012). A management plan that considers the revised framework would require ethnographic groundwork to investigate which S2E may have been delivered by historical human communities, and which may continue today. This would reveal that the distribution, number and perhaps productivity of Brazil nut trees has been influenced by past human use, and that these impacts remain today (Shepard and Ramirez 2011; see Section 2.2). Further, it would find that the Brazil nut tree provides multiple other cultural ecosystem services amongst the communities that use them, including as medicine, oil for cooking and applying to skin, and as a material in traditional wear; and that the presence of the tree and the activity of harvesting its fruit forms an important aspect of the culture and identity of the communities. They would also find that these communities possess extensive knowledge regarding the trees, their locations, and factors affecting their health and productivity (Comberti, 2015, *pers. obs.*). Thus, management plans addressing the Brazil nut tree arising from the revised ES framework would involve working closely with the communities that currently, and traditionally, have used the resource, rather that marking off areas as conservation zones that restrict human activity – as has frequently occurred, to the misfortune of historical communities (Dowie, 2009).

In Cascadia, the revised model of ES-S2E might include promotion of herring cultivation and habitation enhancement practices in areas of historical ecological significance that have become depleted by previous overfishing or habitat changes. Currently, herring are recognised as having been overfished and their spawning areas and productivity reduced as result of commercial fishing (Thornton and Hebert, 2014). Meanwhile, Indigenous peoples of Cascadia continue to harvest herring eggs by creating habitat and otherwise making nearshore waters attractive for spawning herring. The placement of substrate, such as hemlock boughs, in spawning waters yields many more eggs than are actually harvested by humans, thus potentially enhancing herring productivity and provisioning services for a range of species that depend on them (e.g. marine mammals, seabirds, salmon, halibut, cod). However, these techniques presently are not supported by fisheries managers, who manage commercially viable fisheries by a simple, single-species biomass forecast model. Self-regulated subsistence herring egg harvesters tend to target remaining reliable areas for spawning closest to their villages (often in conflict with commercial fishers for sac roe; see Thornton and Kitka, 2015), rather than more distant areas with depressed herring populations. This is a clear example of where S2E could stimulate herring ES by boosting production in areas historically receptive to spawning, thus building the strength and diversity of local spawning schools and enhancing the resilience of the regional meta-population (Thornton, 2015).

Such cultivation and other S2E should not be viewed as a panacea but rather as a means of applying tried and tested principles of sustainability, based on reciprocal relationships, respect for other-than-human constituents of the ecosystem, and sustained ecosystem health. These concepts, which form the basis of many indigenous cosmologies and ecologies, would undoubtedly broaden the orientation and "toolkit" of conservation and management professionals as well.

5. Conclusion

Numerous examples from the rainforests of the Americas reveal the extent of engagement patterns between humans and ecosystems that exist outside the current conceptualisation of the framework for ecosystem services. We have concentrated on certain key processes and techniques by which humans provide services to ecosystems. S2E involves apprehending and responding to the needs of the lands, waters, and their keystone species inhabitants, so that they reciprocate with provisioning and other services and benefits to those who depend on them. In missing the reciprocal relationships and techniques of sustainment that characterize human-environmental relations in diverse landscapes, the extractive ES paradigm has oversimplified the very social-ecological systems it seeks to enhance, value and protect. Current conservation initiatives seeking to use the ES framework to protect ES and the benefits they provide generally do not adequately acknowledge the inputs of Indigenous peoples in maintaining the qualities of these ecosystems through a wide variety of S2E. This risks harming both the ES and the human communities that rely upon and have historically helped to shape them.

Meanwhile, political and economic institutional structures are emerging around global-scale environmental governance (increasingly third-party and market-oriented instruments) and financing (e.g., payments for ecosystem services); and these may undermine more adaptive, holistic and integrative local renderings of ES and prevent them from being supported, either in concept or practice, unless they can be translated into narrow "ecosystems-at-our-service" terms. Our historical ecological analysis of Amazonia and Cascadia suggests this framing would be a blow for both biological and cultural diversity, and human wellbeing.

In contrast, if Indigenous or local peoples' servicing of ecosystems is recognised and supported as part of a social-ecological systems paradigm, the basis of biocultural diversity, adaptive management, and sustainable livelihoods in relation to ecosystem services would be better clarified and maintained, as the Brazil nut and Pacific herring examples illustrate. This would seem to be a matter worthy of consideration, beginning with a radical, reciprocal rethinking of the ES/CES framework within a dynamic, multi-scale ecological stewardship paradigm (cf. Chapin et al., 2009). Rather than focussing on a unitary regime of simple utilization, economic valuation, and trade-offs, this paradigm actively supports the cultivation of diverse cultural and ecosystem values, practices, and services at the landscape scale. For CES, such a paradigm shift is more than a technical process; it necessarily involves political recognition and valorization of minority values and strategies.

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