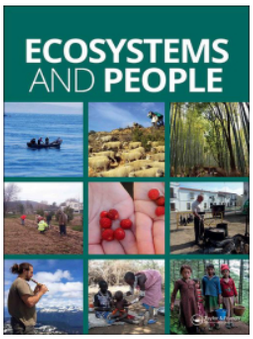

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Using Indigenous mental models to conceptualise and report on ecosystems services and benefits

Silva Larson[a,b], Diane Jarvis[a] and Nywaigi Traditional Owners[c]

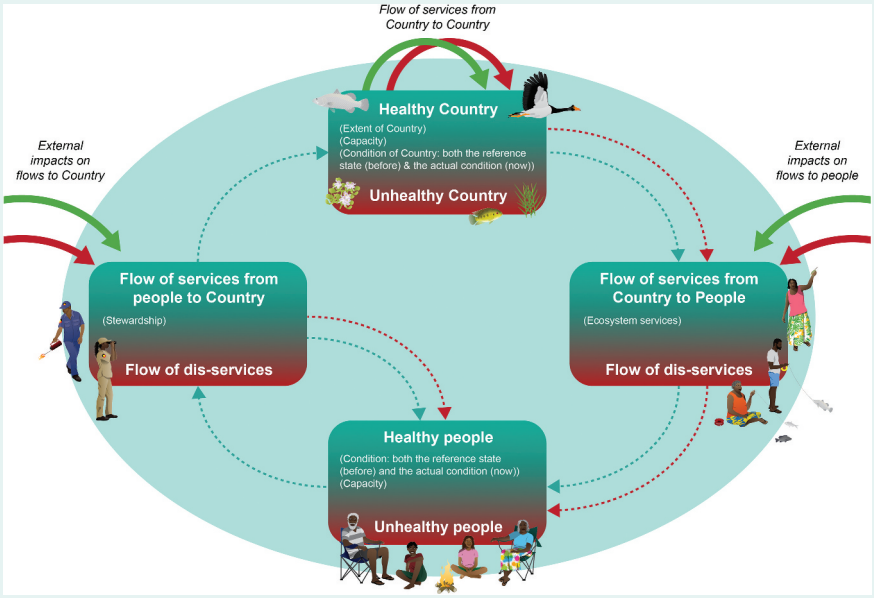
[a]College of Business, Law and Governance, James Cook University, Cairns, Qld, Australia; [b]School of Science, Technology and Engineering, University of the Sunshine Coast, Sippy Downs, Qld, Australia; [c]Nywaigi Traditional Owners, Mungalla Station, Ingham, Qld, Australia

ABSTRACT

We explore relations between Indigenous and the Western conceptualisation of flows of services from nature to people, and specifically, flow of ecosystem services as per SEEA-EA accounting framework developed and promoted by the United Nations. This case study was a partnership with the Nywaigi Traditional Owners from North Queensland Australia and was conducted as a series of workshops with the Nywaigi representatives. We present Nywaigi conceptualisation of the ecosystem services (and disservices) linked to Mungalla Station on their Country. Starting from the Western point of view, we introduce 'crosswalk' from SEEA-EA ecosystem services to Nywaigi conceptualisation; and starting from Nywaigi perspective, 'mental map' that links Nywaigi wellbeing to SEEA-EA framework. Our findings indicate that some of the concepts are very similar between First Nation and SEEA-EA, and confirm importance to Nywaigi Traditional Owners of circular and interconnected conceptualisation of the nature-people system and of longer conceptualisation of time. Suggestions on further modifications to conceptualisations of nature-people-nature system are presented, and the temporal scale of expected changes is discussed. Specifically, we discuss concepts of flows of services from nature to nature; category of disservices – explicit recognition that ecosystem flows can be beneficial but also detrimental for human wellbeing, both physical and mental/spiritual; and important role of outside influences (capitals other than natural capital) in determining the actual use of what ecosystem services might be supplying. Our findings present empirical evidence of alternative conceptualisations that emphasise continually unfolding processes and relations.

KEY POLICY HIGHLIGHTS

- We explore relations between Indigenous and the Western conceptualisation of flows of services from nature to people.
- Researchers and Nywaigi Traditional Owners from North Queensland, Australia, partnered to explore flows of ecosystem services as per SEEA-EA accounting framework.
- Importance of describing the system as circular and interconnected naturepeoplenature system, with long temporal scale, was confirmed.
- Concepts additional to SEEA-EA framework, flows of services from nature to nature; disservices; and outside influence, were also discussed.
- We also found that some of the concepts are very similar and crosswalk can be developed between Indigenous and Western approaches.



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CONTACT Silva Larson silva.larson@gmail.com

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Circular conceptualisation of flows of services from Country to people, and from people to Country, that also includes dis-services, flow of services and dis-services from Country to Country, and external influences. Figure attribution to Ella Schirru @science.Graphics.by.ella. Symbols courtesy of the NESP resilient landscapes hub (nesplandscapes.Edu.au) and from integration and application network (ian.Umces.edu/media-library).

1. Introduction

In this paper we build on the previous work that explores relations between Indigenous people (First Nations; Traditional Owners) and the Western conceptualisation of flows of services from nature to people. Several structured approaches to evaluation and valuation of ecosystem services have been developed and applied (e.g. Millennium Ecosystem Assessment MEA 2005), Common International Classification of Ecosystem Services – CICES (Potschin-Young et al. 2018) and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services – IPBES (Díaz et al. 2015; UN 2021), helping decision-makers recognise the diverse forms of benefits provided by ecosystems to humans. Recent developments are increasingly recognising that flows are not only one way (from nature to people), but that reciprocal flows from people to nature, are equally important (Díaz et al. 2015, 2018; Cooper et al. 2016; Pascual et al. 2017; Raymond et al. 2017; Delevaux et al. 2018; Morishige et al. 2018; Stoeckl et al. 2021). There is also an acknowledgment that many ecosystem services are co-produced, with the resulting benefits being a result of combined natural and other (human, built) capitals (Jones et al. 2016; Costanza et al. 2017; Raymond et al. 2017).

The System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA-EA), designed by the United Nations Department of Economic and Social Affairs (UN et al. 2021b) (and officially published following endorsement by UN in 2024), is one such Western system increasingly being used as a policy instrument (Farrell et al. 2021; Edens et al. 2022; Lange et al. 2022; Chairat and Gheewala 2024; King et al. 2024). According to the UN, in 2023 there were 90 countries on all continents implementing the SEEA framework, with the additional 48 countries that do not currently implement the SEEA committed to initiate implementation in the future (UNCEEA 2024). Recognising that decision makers in these countries risk implementing non-optimal policies, due to the lack of First Nations knowledge and perspectives captured within the SEEA framework, we focus here on SEEA-EA, rather than other frameworks developed to be more inclusive of Indigenous values (for example Nature's Contributions to People (Díaz et al. 2015)).

The broad ambition of the SEEA-EA is to describe in a comprehensive manner the relationship between the environment and the economy. The SEEA-EA is defined as a '*spatially-based, integrated statistical framework for organizing biophysical information about ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition, valuing ecosystem services and assets and linking this information to measures of economic and human activity . . . . with a focus on making visible the contributions of nature to the economy and people*' (UN et al. 2021b, p1). It comprises a set of three main types of environmental accounts, namely, the extent, condition and ecosystem services (ES) flow accounts. ES flow accounts record the contributions of ecosystems to society – monitoring their supply and use in economic and other human activity, by households, enterprises and government (UN et al. 2021b). The use of an accounting approach takes advantage of the inherent structure of accounts wherein both stocks and flows are part of a single recording system. Conceptualisation and organisation of the ES in the SEEA-EA builds on the previous work (MEA 2005; Díaz et al. 2015; Potschin-Young et al. 2018) and is similarly structured into three broad categories of services: provisioning; regulating and maintenance; and cultural.

With wider use of the SEEA-EA accounts, there is also emerging literature on use of the accounts to record the contributions of nature to Indigenous peoples (Beamer et al. 2021; Normyle et al. 2021, 2022, 2024; Finau et al. 2023; Woodward et al. 2023). Importantly, SEEA-EA as a system does not specifically preclude inclusion of the Indigenous values: it does not, however, provide guidance to their inclusion either (Larson et al. 2025). Emerging studies however do provide guidance on inclusion of Indigenous values into Western systems. For example, Stoeckl et al. (2021) discuss the critical importance of longer timelines, interconnections between and within the human and natural systems, reciprocal values (looking after Country), and the need for direct physical connections with the Country that strengthen spiritual connections.

Building on the previous work on inclusion of the Indigenous perspectives into Western approaches to measuring and valuing ES, we present a case study co-designed between one of the Australian First Nations, Nywaigi Traditional Owners, and Western scientists, exploring how the Nywaigi concept of the ES of importance to Nywaigi Traditional Owners fits – and does not fit – with the ES concepts and the SEEA-EA flow accounts. This project sought to follow best practice guidelines for designing and populating ecosystem accounts in partnership with the Nywaigi (Nursey-Bray et al. 2023; Woodward

et al. 2023). We also sought to avoid the noted issue whereby much literature focuses on accounting 'for' Indigenous people, rather than accounting 'by' Indigenous peoples (Buhr 2011). Experimental methodology used to populate SEEA-EA flow accounts and the resulting accounts, as well as details of the co-design approach and guiding principles when working with the Indigenous peoples, are described in Jarvis et al. (2025).

In this paper we present Nywaigi Traditional Owners' conceptualisation of the ecosystem services (and disservices) linked to Mungalla Station on their Country. We introduce the 'crosswalk' from Western concept of SEEA-EA ES to Nywaigi conceptualisation; and the Nywaigi 'mental map' that links Nywaigi well-being to SEEA-EA framework. Nywaigi suggestions on further modifications to conceptualisations of nature-people-nature system are presented, and the temporal scale of expected changes is discussed.

2. Methods

2.1. Nywaigi traditional owners and the Mungalla Homestead

Nywaigi people have occupied their Country in North Queensland for over 45,000 years (Figure 1). The location of their lands in tropical coastal areas

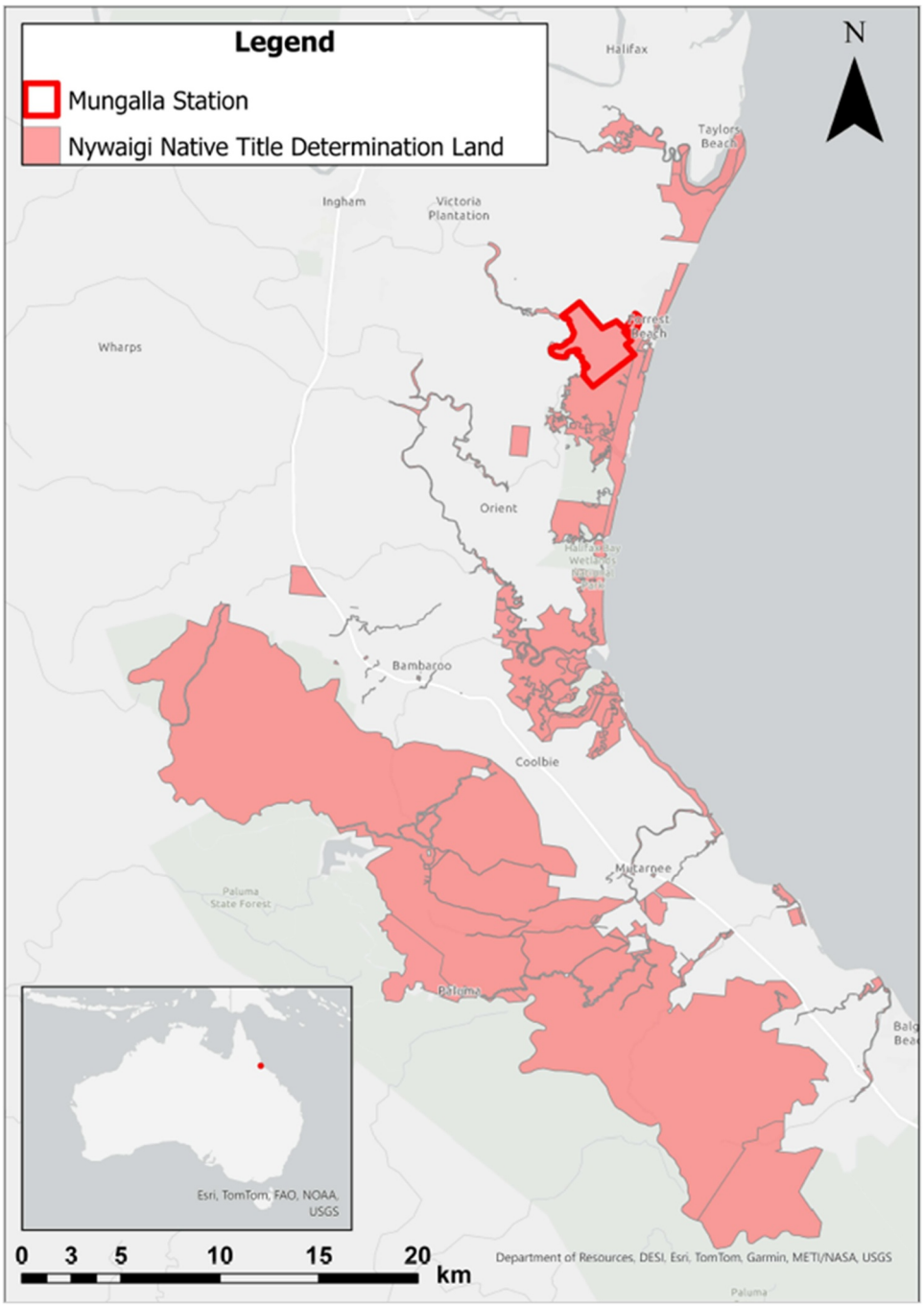

Figure 1. Map of project area, showing Nywaigi traditional lands in northern Queensland as recognised by their native title determination, and the location of Mungalla Station.

meant plentiful supplies of wildlife, fruits, berries and seafood. However, with the colonisation in 19th century, Nywaigi lands became the property of European settlers and from the 1860s onwards, Nywaigi had been forcibly removed from their traditional ancestral lands as the sugar cane and cattle industries encroached (MAT 2018).

In April 2018, the Australian Federal Court formally recognised the Nywaigi People's native title rights and interests over almost 40,000 hectares of land and waters, including both exclusive (over about 8600 hectares) and non-exclusive (over about 30,000 hectares) native title rights (Figure 1). The non-exclusive native title rights include rights to be present on the land, to hunt, fish and gather, to hold meetings and conduct ceremonies, and to maintain places of importance and areas of significance. Exclusive rights include Mungalla Station, a cattle property near Ingham, founded in 1882 on the lands of the Nywaigi people (Figure 1). Some hundred years later, in 1999, the property was purchased by the Indigenous Land Corporation, and the ownership of the 880 hectares that make up the property today was returned to the Nywaigi people (MAT 2018).

Nywaigi country has a wet tropical climate in the north that gradually becomes drier towards the south. It encompasses two bioregions, the Wet Tropics and the Brigalow Belt North, which contain upland and lowland rainforests, coastal dry sclerophyll forest, coastal savanna woodlands and mangroves (Larson et al. 2006). Nywaigi traditional county has experienced significant ecological and hydrological changes since European arrival, with transformation of rainforest and coastal savanna to an agriculture and grazing dominated landscape. The tropical climate is ideal for growing sugar cane, banana and other tropical fruit. Sugar cane fields have replaced most of the lowland rainforests and cattle grazing also occurs in the dryer areas. Former clearing and ongoing agricultural activities in the area have resulted in in-stream water quality decline, in particular elevated sedimentation and nutrient and pesticide levels (Larson et al. 2006).

Today, the three Nywaigi corporations (being the Mungalla Aboriginal Corporation for Business, the Nywaigi Aboriginal Land Corporation, and Warga Badda Nywaigi Aboriginal Corporation RNTBC) have a mandate to utilise the Mungalla Station to improve the economic and social position of Nywaigi people. About 110 Nywaigi are registered with the corporations, living within the key centres of current Nywaigi demographic distribution including individuals and families living in and around Townsville, Ingham, Cardwell, Tully, Innisfail and Cairns, and on Palm Island.

Mungalla Station still operates as a cattle business and runs a successful cultural and nature tourism business (NALC - Nywaigi Aboriginal Land Corporation 2008). Daily guided tours are provided to cruise ship and school groups and individual visitors, and include biodiversity and cultural components. Camping grounds are also available. Mungalla Aboriginal Tours have won the Queensland Tourism Award Indigenous Tourism category for three years running and has been inducted into the Hall of Fame for Queensland Tourism (Mungalla Aboriginal Tours 2025). Recently, one of Nywaigi employees received High Commendation Young Achiever Award at North Queensland Tourism and Events annual awards.

Mungalla Station is located on the coastal plains of the Herbert River valley and consists of grazing lands, sand ridge forests, and freshwater wetlands. Mungalla includes approximately 230 hectares of seasonally inundated wetlands which are adjacent to the World Heritage Great Barrier Reef and the IUCN listed Halifax Bay Wetlands National Park. Mungalla Station is included in the large 1.2 million hectares Girringun Indigenous Protected Area (GIPA). Nywaigi have described Mungalla as 'the leverage to all our aspirations on Nywaigi Country' (NALC - Nywaigi Aboriginal Land Corporation 2008, 14), providing the opportunity for marrying 'murray' and 'white fella' business approaches, whilst contributing to the health of the wetlands (NALC - Nywaigi Aboriginal Land Corporation 2008).

The Nywaigi Traditional Owners have determined that they would like to return the wetlands to a more natural state and through a series of projects funded through the Australian Government and in partnership with Greening Australia, they have begun the process of rehabilitation. This project was linked to the restoration of the wetland located at Mungalla Station on Nywaigi County.

2.2. Exploring Nywaigi concepts of ecosystem services flows and resulting benefits

Project co-design process and timelines are described in detail elsewhere. In summary, at the start of this project from October to December 2023, researchers introduced the proposed project and codesign process to representatives of the Nywaigi corporations. Two researchers and the research organisations engaged in this project have a working relationship with Nywaigi people spanning decades, which has assisted in establishing project relations. The process of forming Project Reference Group (PRG) was initiated in parallel and was completed by February 2024; PRG has then met monthly from February 2024 to November 2025 to discuss the progress of the project and data collections, findings and analyses completed, and grant approvals to share them with the scientific community, funding agency and wider.

The key concepts and components of ecosystem services (ES), SEEA-EA, and flow accounts were described

to Nywaigi representatives. Whilst Nywaigi understood the logic underpinning these approaches, concern was expressed at the linearity of the approach, focusing on the flows from Country to people. Similar to many other Indigenous groups, the Nywaigi worldview can be encapsulated in the phrase noted by Woodward and McTaggart (2019), 'you care for Country and Country cares for you'. It was felt by the PRG that the ES approaches and the SEEA-EA framework only capture the second half of this relationship, failing to fully recognise the cultural connections between Nywaigi people and Country underpinned by their role as traditional custodians of their traditional lands.

Concern Nywaigi expressed at the linearity of the SEEA-EA approach, focusing only on the flows from Country to people, is similar to concerns reported in previous work with the Indigenous groups (Jarvis et al. 2022; Normyle et al. 2022, 2024; Larson et al. 2023). Thus, researchers proposed a conceptual model that seeks to capture the interconnected and non-separable worldview held by many Indigenous peoples, based on the circular model reported in Stoeckl et al. (2021) and aligned with SEEA-EA (Larson et al. 2025). Conceptualisation of 'Healthy Country' is well aligned with the SEEA-EA notion of stock accounts, whilst flow accounts would then depict key flows (supply and use) between people and Country. Some flows may reflect ecosystem services supply and use (flow of services from Country to people), others may reflect stewardship (flow of services from people to Country). Both types of flows, ecosystem services and the stewardship have an impact on the condition, health and wellbeing of people (Stoeckl et al. 2021; Larson et al. 2025). Such a circular conceptualisation of connections between people and the nature was deemed by Nywaigi as appropriate.

Project steps were co-designed and data collection and validation was completed in series of nine in-person and online workshops that took place between February 2024 and August 2025, including an on-Country celebration where project-related survey was completed. In total, 14 Nywaigi people (7 females, 7 males) participated in workshops and 38 Nywaigi people (20 females, 18 males) participated in the survey (noting that some anonymous survey participants may also have been workshop participants). Of those, 29% lived on, or close to, their traditional Country, and 79% reported visiting Country at least every year. All Mungalla employees contributed to this research.

In discussions with the Nywaigi PRG, it was agreed to first capture perspectives on flows of services and perceived benefits to Nywaigi Traditional Owners from Country, through a development of a 'mental map of Nywaigi wellbeing'. Discussions related to the mental map were informed by previous wellbeing work conducted with Nywaigi in 2005, when 58 Nywaigi participated in 12 focus groups discussing their conceptualisation of contributors to personal and community wellbeing, and linkages between wellbeing and Country (Greiner et al. 2005; Larson et al. 2006). Relevance of this work was reconfirmed, and it was agreed that domain 'Country and Culture' is the one most pertinent to this project and should be the one further explored. Mental map of flow of services and benefits between Nywaigi and Country was designed in a one-day workshop held on country and attended by four women and four men, representing Nywaigi Elders, mature people and young people. Through a follow-up meeting and series of on-line and in-person interactions, Nywaigi 'translated' the benefits recorded in the mental map of links between Nywaigi and their Country into a set of 17 statements, describing flows of ecosystem services and benefit between Nywaigi Traditional Owners and their Country. In addition, over three workshops with a total of eight women and nine men representing Nywaigi elders, mature people and youth, project identified 14 ecosystem service and 4 disservice flows relating to culturally important species of plants, birds, fish and aquatic species, and land animals; providing provisioning and cultural services to Nywaigi.

An on-Country and online workshop was then organised to discuss how to arrange this data into SEEA-EA compliant way (reported in Jarvis et al. 2025); but also in a way meaningful to Nywaigi, as reported in this paper. 'Crosswalk' approach applied by UN et al. (2021b) in order to support discussions among experts from different parts of the world, bringing together different classifications and typologies of ecosystem services, was presented to Nywaigi as a possible approach to bringing together SEEA-EA and Nywaigi visions, making a connection that would allow for experiences to be better shared and results compared (UN et al. 2021a). As discussed in SEEA Ecosystem Accounting Chapter 6, a definitive global classification of ecosystem services has not yet been developed and hence the SEEA-EA has established a reference list of ecosystem services. The reference list was developed in consultation with leading experts in ecosystem services measurement and classification work.

Discussion on Nywaigi conceptualisation of linkages between the Country and wellbeing included likely timeframes for the occurrence of the 35 ecosystem services, disservices and benefits previously noted by Nywaigi. All findings, summaries, visuals and text were reported to the Nywaigi community, and in person and online workshops were conducted to check, modify and finalise them; before they went for approval by the PRG to share them with the scientific community, funding agency and wider.

3. Nywaigi conceptualisation and organisation of ecosystem services and benefits

3.1. Linking SEEA-EA ecosystem services concepts to Nywaigi concepts

A 'crosswalk' table, providing linkages between services and disservices identified during our study and the SEEA-EA classification of the ES (UN et al. 2021b), was co-developed with the Nywaigi Traditional Owners and is presented in Table 1. On the left-hand side, table starts with the prescribed SEEA-EA ES categories, and SEEA-EA code and description is provided for each ES category identified as relevant in this study. Ecosystem services flows identified by Nywaigi are provided on the right-hand side of Table 1, for relevant prescribed SEEA-EA ES categories.

It can be observed in Table 1 that some of the prescribed SEEA-EA ES categories are omitted (as they are of no cultural relevance to Nywaigi); others correspond to one Nywaigi equivalent service; while others contain more than one service to Nywaigi. For example, regulating service 2.2 - Rainfall pattern regulation service is not included as it was not reported by Nywaigi participants. Soil quality regulation service – 2.5 is included in the table, as it provides the services of providing quality soil that is required to meet the Nywaigi reported benefit of having 'Healthy soils for natural medicine, plants and wildlife'. On the other hand, Biomass provision service – 1.7, Wild animals plants and other biomass contains six services, all of them identified by Nywaigi as relevant and belonging to this category. In total 71 animal and plant species were identified as being culturally important to Nywaigi, including 39 species identified as providing provisioning services to Nywaigi. Of these, 22 species provided services in the form of food, whilst eight provided materials for natural medicine and 10 provided materials for other purposes such as for weaving or use as tools. It should be noted that these categories are non-exclusive, for example the Wallaby provided food and also materials for other uses (fur and sinews).

What can also be observed in the table is that cultural services are the most numerous, corresponding to 14 out of the total of 30 species and service flows identified in this study. Benefits from country to Nywaigi people, recorded in the 'mental map of Nywaigi wellbeing' were not included within this crosswalk as they encapsulate different types of concepts to ES. Out of the total 71 species of plants and animals that were identified as providing cultural services to Nywaigi, 69 were considered to provide visual amenity services, comprising 21 wild birds, 19 wild fish and aquatic animals, four wild land animals and 25 wild plants. Fifteen species were culturally important for other cultural services, being Recreation related (recreational fishing from one wild fish and other aquatic animals, and three wild birds and two wild land animals enabling visitors to see rare/endangered species), and Other cultural services which include species which act as seasonal indicators (one wild bird, five wild plants).

In addition, some ES flows identified by Nywaigi as important to them, did not fit in any of the SEEA-EA ES categories prescribed, yet similar types of services have been previously reported by other First Nation groups (Carnell et al. 2023; Nursey-Bray et al. 2023; Normyle et al. 2024). We have thus added another category of services to our table, Stewardship services, a set of practices that involve sustainable management of the Country, and relate specifically to upholding caring responsibilities for future generations (Table 1).

We have also added a new category of Ecosystem disservices to include species providing disservices to Nywaigi by negatively impacting their wellbeing. This category includes invasive and pest species of animals and plants Nywaigi would prefer not to have on their Country (Table 1). It is important to note that disservices to Nywaigi caused by the pests and weeds go beyond conceptualisation of 'threats' in Pressures/threats accounts of SEEA-EA. For example, category 'invasive pest – fish' refers to the presence of tilapia in the waters at Mungalla. Tilapia compete with native fish for food and habitat, and also disturb sediment and plant life, impacting on water quality. Thus, tilapia does present a threat to biodiversity and to provisioning and cultural ecosystem services, by the impacts it has on native fish and aquatic plants. Accordingly, the impact of tilapia should be reflected in the biodiversity and condition accounts. However, beyond this threat to the ecosystem, presence of tilapia is also directly providing a spiritual disservice to the Nywaigi Traditional Owners: 'it breaks people's hearts to see their Country unhealthy' (Nywaigi Elder, male, FGD). The awareness by Nywaigi Traditional Owners that Mungalla is not maintained in the condition required by their roles as traditional custodians creates feelings that Nywaigi are not appropriately fulfilling their cultural responsibility for Caring for Country, to ancestors and to future Nywaigi. Thus, the disservices capture the feelings of sadness and frustration that Country is unhealthy, and are captured as cultural disservices within the accounts and within the crosswalk table.

3.2. Linking Nywaigi Traditional Owners' concepts to SEEA-EA ecosystem services concepts

As a way that closely reflects their conceptualisation, Nywaigi study participants have also explored

Table 1. Crosswalk from Nywaigi conceptualisation of ecosystem services, disservices and stewardship services to SEEA-EA ecosystem services classifications (* Final ecosystem service, ** Intermediate ecosystem service, *** Final ecosystem disservice, **** Final stewardship service).

SEEA EA categories	SEEA EA code and description	Flows of services identified by Nywaigi
Provisioning services		
Biomass provisioning services	1.6: Wild fish and other natural aquatic biomass provisioning services are the ecosystem contributions to the growth of fish and other aquatic biomass that are captured in uncultivated production contexts by economic units for various uses, primarily food production. This is a final ecosystem service.	Food – Wild fish and other aquatic animals*
	1.7: Wild animals, plants and other biomass provisioning services are the ecosystem contributions to the growth of wild animals, plants and other biomass that are captured and harvested in uncultivated production contexts by economic units for various uses. The scope includes non-wood forest products (NWFP) and services related to hunting, trapping and bio-prospecting activities; but excludes wild fish and other natural aquatic biomass (included in previous class). This is a final ecosystem service	Food – Wild land animals* Food – Wild birds* Food – Wild plants* Materials – Wild land animals* Materials – Wild plants* Natural medicine – Wild plants*
Regulating and maintenance services		
Global climate regulation services	2.1: Global climate regulation services are the ecosystem contributions to the regulation of the chemical composition of the atmosphere and oceans that affect global climate through the accumulation and retention of carbon and other GHG (e.g. methane) in ecosystems and the ability of ecosystems to remove (sequester) carbon from the atmosphere. This is a final ecosystem service.	Carbon management – Carbon sequestration, Carbon storage, Carbon sink*
Soil quality regulation services	2.5: Soil quality regulation services are the ecosystem contributions to the decomposition of organic and inorganic materials and to the fertility and characteristics of soils, e.g. for input to biomass production. This is most commonly recorded as an intermediate service.	Soil quality regulation**
Nursery population and habitat maintenance services	2.20: Nursery population and habitat maintenance services are the ecosystem contributions necessary for sustaining populations of species that economic units ultimately use or enjoy either through the maintenance of habitats (e.g. for nurseries or migration) or the protection of natural gene pools. This service is an intermediate service and may input to a number of different final ecosystem services including biomass provision and recreation-related services.	Nursery population – Small/bait fish providing food for larger fish** Habitat maintenance – Space for wildlife**
Cultural services		
Recreation-related services	3.1: Recreation-related services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment. This includes services to both locals and non-locals (i.e. visitors, including tourists). Recreation-related services may also be supplied to those undertaking recreational fishing and hunting. This is a final ecosystem service.	Recreational fishing by non-Nywaigi recreational fishers – Wild fish and other aquatic animals* Recreation related visual amenity – Visitors seeing rare/endangered species – Wild land animals* Recreation related visual amenity – Visitors seeing rare/endangered species – Wild birds*
Visual amenity services	3.2: Visual amenity services are the ecosystem contributions to local living conditions, in particular through the biophysical characteristics and qualities of ecosystems that provide sensory benefits, especially visual. This service combines with other ecosystem services, including recreation-related services and noise attenuation services to underpin amenity values. This is a final ecosystem service.	Visual amenity – A welcome sight/good to see culturally important species – Wild fish and other aquatic animals, Wild birds, Wild land animals, Wild plants*
Education, scientific and research services	3.3: Education, scientific and research services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that enable people to use the environment through intellectual interactions with the environment. This is a final ecosystem service.	Education – Knowledge sharing and skills from Elders to Nywaigi youth on Country* Education – Right people (Nywaigi) to be trained on Country* Education – Advising non-Nywaigi people on traditional protocols and how to behave on Country*
Spiritual, artistic and symbolic services	3.4: Spiritual artistic and symbolic services are the ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems, that are recognised by people for their cultural, historical, aesthetic, sacred or religious significance. These services may underpin people's cultural identity and may inspire people to express themselves through various artistic media. This is a final ecosystem service.	Spiritual, and symbolic – Pride belonging and practicing culture on Country* Spiritual, and symbolic – Nywaigi understanding Nywaigi cultural system and protocols* Spiritual, and symbolic – Young Nywaigi people on Country, and engaged, avoiding social ills* Spiritual and symbolic aspects (feelings) of healthy people eating healthy food from Country (avoiding social ills)* Spiritual and symbolic aspects (feelings) of making traditional items (spears, baskets, shields, stone tools) from materials on Country*
Other cultural services	3.5	Seasonal indicators/other cultural services uses – Wild birds, Wild plants*

(*Continued*)

Table 1. (Continued).

SEEA EA categories	SEEA EA code and description	Flows of services identified by Nywaigi
Flows of non-use services		
Ecosystem and species appreciation services	4.1: Ecosystem and species appreciation concerns the wellbeing that people derive from the existence and preservation of the environment for current and future generations, irrespective of any direct or indirect use.	Ecosystem and species appreciation services – Feeling connection to Country & Nywaigi people*
Additional category from Nywaigi and other research with First Nations groups		
Stewardship services	Stewardship services are the set of practices that involve sustainably managing the natural resources and harvests of lands, territories, waters, and coastal seas. Stewardship services relate specifically to upholding these caring responsibilities for future generations. This is a final ecosystem service.	Maintaining healthy Country by monitoring and caring for Country****
Additional category from Nywaigi		**Ecosystem disservices identified by Nywaigi**
Ecosystem disservices provided by unwanted species	Ecosystem disservices are the ecosystem contributions that are negatively impacting on wellbeing of local people. This includes impacts of weeds, ferals and pests within the ecosystem. This is a final ecosystem (dis)service.	Spiritual disservices – feelings of sadness and frustration that Country is unhealthy – Wild birds considered to be pests*** Spiritual disservices – feelings of sadness and frustration that Country is unhealthy – Wild invasive and pest fish and other aquatic animals*** Spiritual disservices – feelings of sadness and frustration that Country is unhealthy – Wild feral land animals*** Spiritual disservices – feelings of sadness and frustration that Country is unhealthy – Wild invasive plants***

organisation of concepts recorded (services flows and benefits) using circular representation of links between nature and people.

ES of importance to Nywaigi people are perceived as flows from Country to People (Figure 2 panel A, Nywaigi Ecosystem Services). These include biomass provisioning services (such as wild fish, birds, wild animals and plants for food, natural medicine and the materials); Regulating and maintenance services (such as soil quality regulation, habitat provision, nursery populations and carbon management); and a range of Cultural services (recreation-related services, visual amenity, education scientific and research, spiritual artistic and symbolic, ecosystem and species appreciation, and other services).

This flow of ES creates a range of benefits to Nywaigi Traditional Owners (Figure 2 Panel A, Healthy People). These benefits include benefits from soil quality regulation services that result in healthy soils for natural medicines, plants and wildlife; but also Spiritual, artistic and symbolic services such as building a keeping place (museum) that holds Nywaigi traditional knowledge; and improving amenities and facilities on Country for Elders. These benefits are linked to wetland restoration activities through both financial benefits (improve income flow from tourism activities, i.e. visitors to the wetlands) and through human and social benefits (improved capacity of Nywaigi Traditional Owners to undertake such projects). On the left hand side of the figure, there are Nywaigi stewardship services – flow of benefits from People to Country. Maintaining healthy Country by monitoring and caring for Country will result in a direct wellbeing benefit to Nywaigi (dotted back-flow in Figure 2, Panel A), as well as (ecological) benefit to the Country.

Flows of benefits from People to Country are expected to lead to a creation of a 'positive spiral' (Figure 2 Panel B), where the extent and condition of the Country will improve due to Nywaigi caring, and will as a result create more and better services to Nywaigi in the future. This is the key to Nywaigi conceptualisation, that future timelines and benefits are of equal and greater importance to the people than the present, with the main consideration of how the current flow of services can continue growing into post-wetland restoration time. Thus, the benefits of importance to Nywaigi do not occur at the same time: some happen closer to now (Figure 2 Panel A), the other additional benefits are created only later in time (Figure 2 Panel B, Healthy People).

Figure 2 (Panels A and B) also incorporates two new concepts created by Nywaigi, that are additional to previous circular conceptualisations (Stoeckl et al. 2018, 2021; Larson et al. 2025). The first additional concept is what Nywaigi refer to as 'Ecosystem services flows from Country to Country' (Figure 2, Panels A and B, yellow text), and examples of such benefits include healthy soils and space and food for animals (wildlife). Conceptually, these flows very much resemble concepts of supporting and regulating services.

The other additional concept, introduced in the previous section, relates to the idea of disservices (Figure 2, Panels A and B, red circles). For each flow of services, there is also a flow of 'disservices', as long as Country and/or People are unhealthy. Flow of ecosystem disservices from Country to People is essentially linked to disservices that flow in the opposite direction, from People to Country, stemming from Nywaigis' inability to look after Country in the ways they would prefer to (not fulfilling traditional custodianship role appropriately and thus letting down their ancestors and future generations) – due to capacity, financial and access constrains. Thus, both internal (health of the Nywaigi

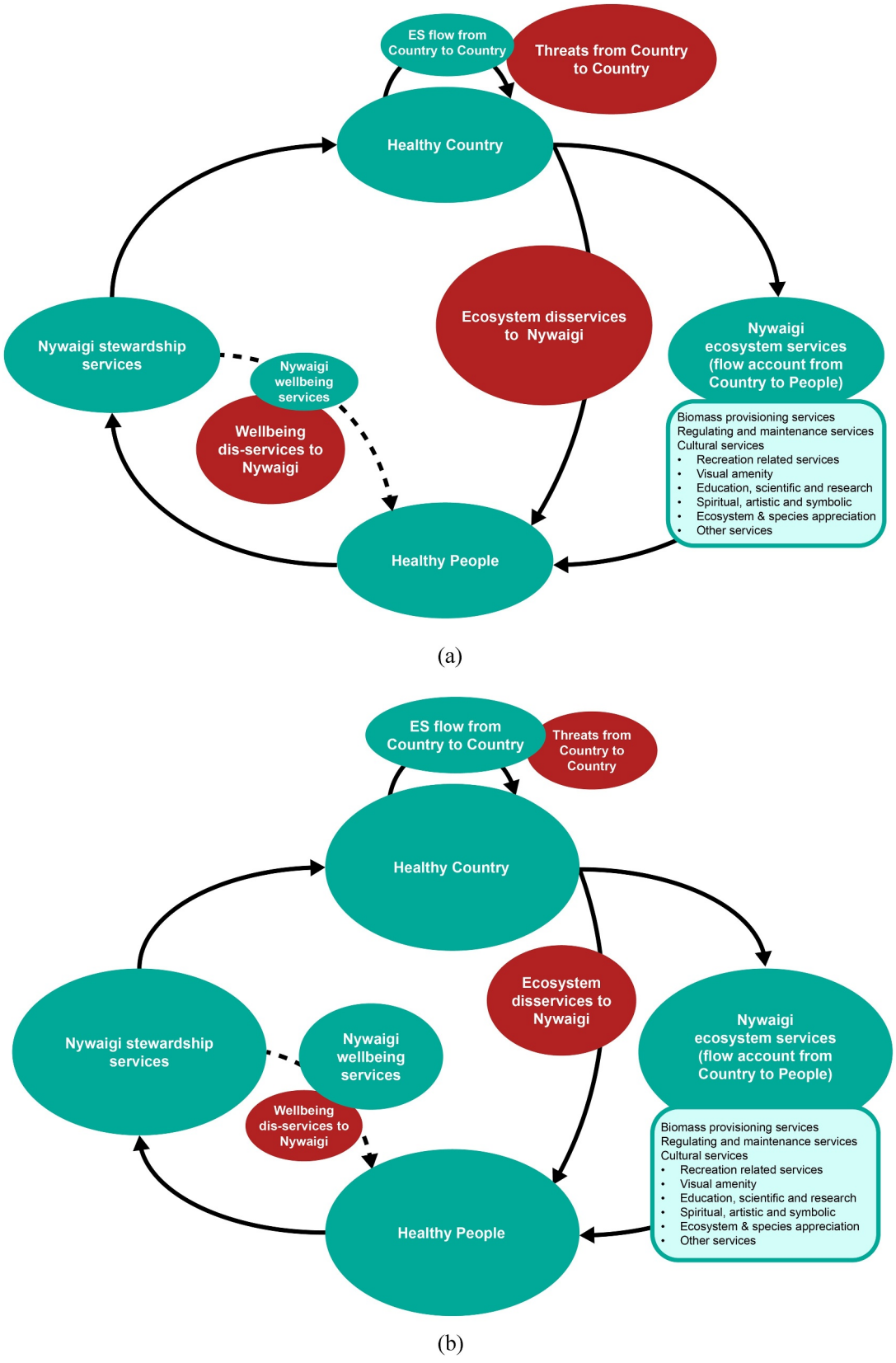

Figure 2. Full details of the text from 17 wellbeing statements and the culturally important species, incorporated into the Nywaigi Traditional Owners' benefits positive spiral, (a) Now to near future; and (b) Near future into the future. Circles for 'good things' shown in green, the threats and disservices from invasive species and weeds shown in red. Note that green circles get bigger and red circles smaller in B compared to a showing anticipated benefits of wetland restoration.

Traditional Owners) and external constraints (financial, access) impact on Nywaigi capacity to look after the Country. Should the capacity not improve, it could indeed result in a 'negative spiral', where the flows of disservices will increase, reducing both the health of the Country and health of its people.

3.3. Revisiting opening conceptual models

In the final workshop, original conceptualisation based on Stoeckl et al. (2018, 2021) and Larson et al. (2025) was revisited, and was amended as to include additional learnings stemming from this project (Figure 3). As in previous conceptualisations, Healthy Country provides flows of ecosystems services that result in benefits to people, Healthy People. On the left-hand side of Figure 3 are stewardship services – flow of benefits from People to Country. Maintaining healthy Country by monitoring and caring for Country will result in a direct wellbeing benefit to Nywaigi Traditional Owners, as well as (ecological) benefit to the Country.

The two new concepts created by Nywaigi are also incorporated, additional to previous circular conceptualisations: the concept of 'Flow of services from Country to Country' (top of Figure 3) and the concept of disservices (red colouring and red arrows in Figure 3). Healthy soils for natural medicine, plants and wildlife (soils quality regulation services) and Space and food for animals (maintenance of habitat including provision of sufficient space for wildlife) are described by Nywaigi as services that flow from Country to Country and thus are not perceived as services to people (very similar to Western concept of intermediate ecosystem service). Rather, Nywaigi people and households are able to use the natural medicines, plants and wildlife that result from an ecosystem that is healthy. For each flow of services, there is also a flow of 'disservices', as long as Country and/or People are unhealthy. A third new concept is that of arrows coming from outside this system, and influencing flow of services, both from Country to people and from people to Country. These can be negative influences (red arrows) such as for example restricted access to parts of the Country, or pollution; but can also be positive influences (green arrows), such as funding for Caring for Country activities.

We note that the temporal dimensions of Nywaigi conceptualisation are considerably longer than those commonly considered by Western scientists: the present is seen as a component of the past (preserving and honouring culture) and the future (with aspirations for future). Thus, for Nywaigi Traditional Owners, current time is a bridge from past to the better future. Flow of benefits from nature to people, and from people to nature, is seen as a continuous spiral evolving through time. Nywaigi aspire for this spiral to be an upwards one, a vision of the improving connection between people and the Country over time, with management and restoration activities improving the condition and extent of the Country (Figure 4). In turn, the health of the Country, 'looked after properly', will increase continuously, and so will flow of ecosystem services, improving the health of

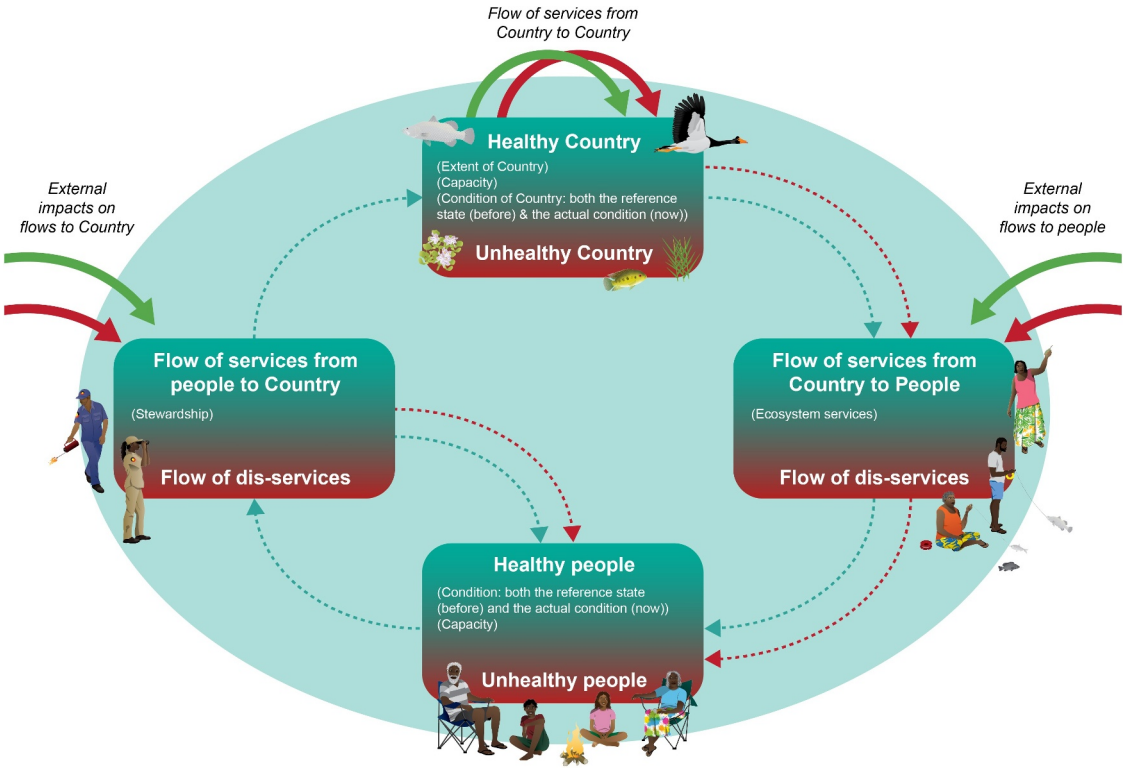

Figure 3. Circular conceptualisation of flows of services from Country to people, and from people to Country, that also includes disservices, flow of services and disservices from Country to Country, and external influences. Figure attribution to Ella Schirru @science.Graphics.by.ella. Symbols courtesy of the NESP resilient landscapes hub (nesplandscapes.Edu.au) and from integration and application network (ian.umces.edu/media-library).

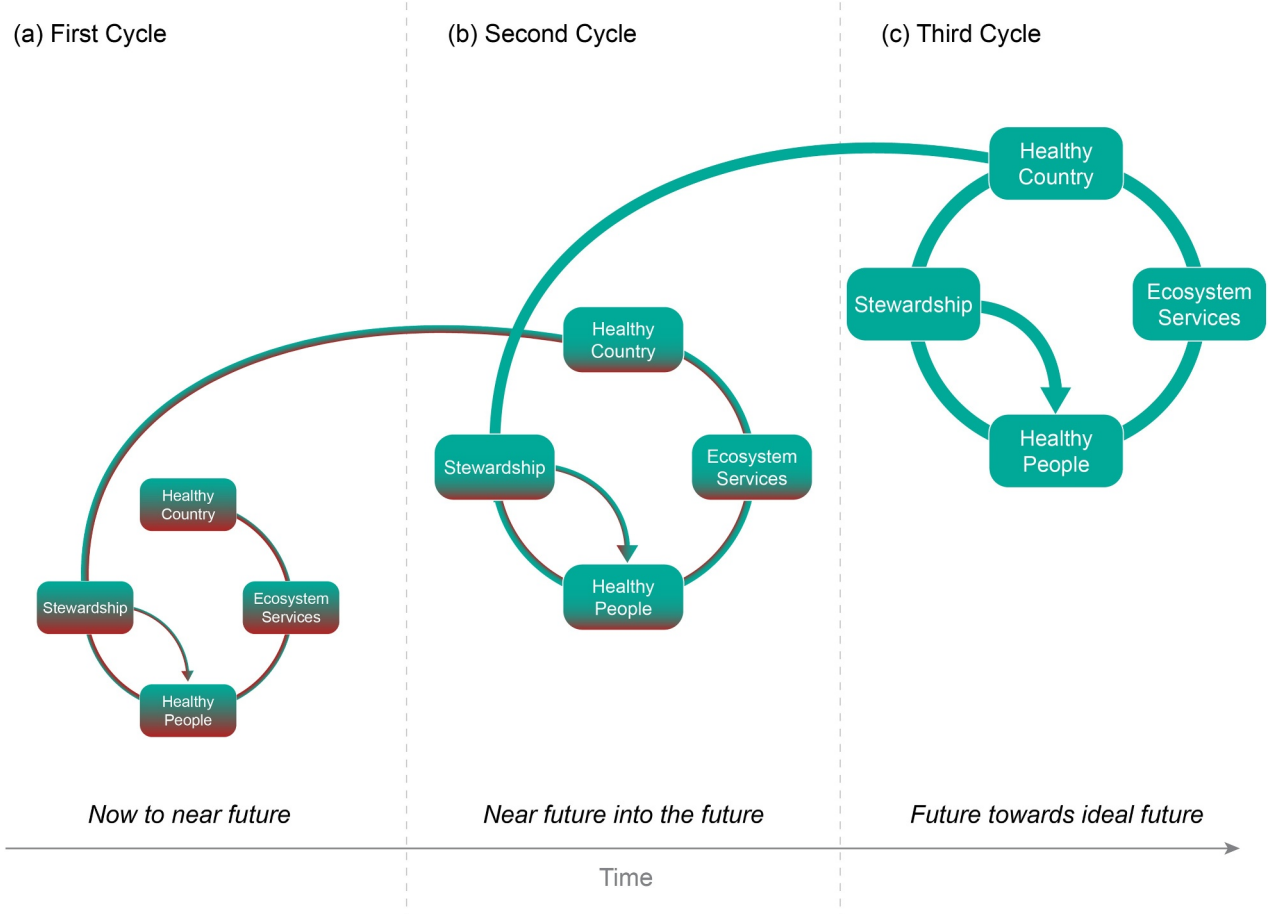

Figure 4. Conceptual spiral of connection between people and the Country over time, upwards spiral when the Country is 'looked after' continuously increasing the health of the Country, flow of ecosystem services and health of people, who then can look after Country better leading to future increases; this would also require succession planning and training of the Nywaigi for the future. It could also be a downward spiral of deterioration of people and Country, if Country is not looked after; or if capacity of people is not built and they are not able to get the benefits from the wetland restoration. The red shading represents ecosystem disservices and the social ills that are happening now, and are decreasing and then disappearing into the future. Figure attribution to Ella Schirru @science.Graphics.by.ella.

the people; who then can look after Country better, leading to future increases in ecosystem services flows and resulting benefits. But this spiral can also be reversed into a downwards spiral when country is degraded (what happened post colonisation), leading to deterioration of the condition of both people and Country.

4. Discussion

In this paper we present Nywaigi Traditional Owners conceptualisation of the ecosystem services (and disservices) linked to Mungalla Station on their Country: both, as a 'cross-walk' from ES to Nywaigi conceptualisation; and as a 'mental map' of how Nywaigi see their country and their wellbeing, related to concepts of ES. We discuss here our learnings, on circularity and interconnectedness, on services from Country to Country, disservices, outside influences and timelines.

Objective of this research project was to co-design the research with the Nywaigi people to their perceptions of the important ES and resulting benefits they receive from the existing (degraded) ecosystem at Mungalla Station were captured. As noted in this paper, early concerns were expressed by Nywaigi at the linearity of the approach, focusing on the flows from Country to people. This raised uncertainty around how well SEEA-EA would be able to capture the Nywaigi cultural perspectives, hence an early focus of the work was to develop the crosswalk between Nywaigi conceptualisations of services between Country and people and services as set out within SEEA-EA, realising that if these conceptualisations could not be aligned then preparation of SEEA-EA aligned flow accounts would be near impossible. This requirement to bring forward and prioritise the crosswalk analysis, in combination with time and funding constraints, compounded by extreme weather events, resulted in a number of challenges. These were mainly overcome by flexibility on behalf

of Nywaigi and the researchers, in planning and in actually conducting research activities (workshops, on Country events, PRG meetings, etc.). That is, rather than fully co-designing the project prior to commencing research, an iterative approach to co-design and data collection had to be adopted, circling back to earlier phases of the work and refining information when required. We would recommend that future projects should allocate sufficient time and resources for early co-design, and ensure flexibility in workstreams, to ensure First Nations values are appropriately reflected in the accounts.

The circular interconnected conceptualisation of links between Nature and the People was proposed in earlier work with the Indigenous people (Díaz et al. 2015; Jacobs 2000; Lyver et al. 2017; Pascual et al. 2017; Kadykalo et al. 2019; Matuk et al. 2020). Relational logic, typical for Indigenous people's conceptualisation emphasises complex interactions, fluid boundaries and multiscale perspectives, with time, space and entities interconnected, cyclical and intergenerational (Pérez-Hämmerle et al. 2025). Gallhofer et al. (2000), working with the Australian Aboriginals, New Zealand Maori and Canadian First Nations people, discuss their similarities in conceptualising environment as a deep respect for the earth, an appreciation of the interrelatedness and interdependence between people and the environment, and the subjective character of the environment. Teixidor Toneu et al. (2025) argue that practising reciprocity can result in positive reciprocal contributions between people and nature, leading to more equitable, inclusive and effective conservation and sustainability policy and practices. Stoeckl et al. (2021) presented a cyclical and integrated human-nature model developed with the Ewamian Aboriginal Corporation, where nature provides benefits to people via ecosystem services and where people also provide benefits to nature; and where Nature, Society, Ecosystem Services and Stewardship are interconnected. Larson et al. (2025) then provide a conceptual linking of this circular model to SEEA-EA conceptualisation of stocks and flows. This circular conceptual framework also recognises the well-being benefits that flow back to people directly as a consequence of stewardship activities, be that for First Nations caring for Country (Larson et al. 2023), or for volunteering in nature activities (Black and Living 2004; Choi and Kim 2011; Molsher and Townsend 2016). Whilst not described within SEEA-EA (or developed as part of this project), Healthy People account tables could also be developed to capture the extent of different features/aspects of human wellbeing connected to Country and culture (Larson et al. 2025).

Work presented in this paper builds on previous circular conceptualisations, but two important new concepts are added, that of 'Ecosystem services flows from Country to Country' and that of disservices. Nywaigi conceptualise ecosystem services as two types: services that create benefits to Country and services that create benefits to people. Services that create benefits to Country (Country to Country ecosystem services, Figure 2) are conceptually similar to Western classifications of regulating and maintenance services. Similar finding was noted by Stoeckl et al. (2021), where several maintenance and regulating services (air filtration, water purification, carbon sequestration, Table 1 in Stoeckl et al. 2021) were classified as 'important', but as services that do not 'fit' into Indigenous conceptualisation of benefits. Our findings indicate that this might be due to conceptual separation of benefits (benefits to Country and benefits to people) similar to one in our findings. In addition, those services 'from Country to Country' are conceptually similar to what is in SEEA-EA classification referred to as 'intermediate services'.

For both types of ecosystem services, and indeed, all flows recorded in the revisited conceptual model in Figure 2, Nywaigi have introduced a concept of disservices (red arrows in Figure 2). Part of this concept is similar to the Western conceptualisation of 'threats' (such as in Pressures/threats accounts of SEEA-EA). This part is related to ecosystem disservices from Country to Country and includes presence of pests and weeds in the ecosystems, that create disbenefits to the ecosystem itself. The other part of the concept of disservices goes beyond this threat to the ecosystem and relates to disservices flowing from Country to people: presence of tilapia makes people sad and frustrated. The awareness by Nywaigi Traditional Owners that wetlands are not maintained in the condition required by their roles as traditional custodians creates feelings that Nywaigi are not appropriately fulfilling their cultural responsibility for Caring for Country, to ancestors and to future Nywaigi. Presence of pests and weeds is thus directly providing a spiritual disservice to the Nywaigi Traditional Owners.

The idea of ecosystem disservice (EDS) as such is not new (Anderson et al. 2025), particularly in invasion science (Shackleton et al. 2019). Literature reports on cultural disservices due to the presence of invasive species that include loss of sense of place, loss of aesthetic values and reduced cultural value (de Wit et al. 2001; Shackleton et al. 2007; Le Maitre et al. 2011). However, concept of ecosystem disservices is not addressed in SEEA-EA framework beyond Pressures/treats accounts. Nywaigi conceptualisation of disservices is closely aligned with the Cultural and aesthetic ecosystem disservices (EDS) classification by Vaz et al. (2017), which include negative perception of nature on people's fulfilment of cultural traditions, anxiety, fears, as well as unpleasantness due to beliefs.

Further, similar to Nywaigi, Vaz et al. (2017) link disservices to social-ecological management. They thus suggest first identifying and evaluating both potential ES and EDS, then promoting management actions that protect and maximise ES and avoid and minimise EDS while restoring ES, and finally, compensating for loss of wellbeing due to remaining EDSs. It can be noted in Figure 2 that red arrows can also flow from People to Country, in cases where there is insufficient capacity to care for country as desired by Nywaigi. Conceptual spiral of connection between people and the Country over time, presented in Figure 3, also includes red shading representing EDS and the social ills that are happening now, but are wished to decrease and then disappear into the future. Benefits to people are thus maximised when ES are increased, and EDS is reduced. Conversely, dis-benefits increase when EDS is maximised and ES is reduced (Vaz et al. 2017). We concur with Zimmermann Teixeira et al. (2019) that for more consistent ES valuations, recording of both ES and EDS is required. We also argue that the costs of management and mitigation for reducing or removing EDS should be included in valuation exercises such as SEEA-EA. We encourage further research into circular interdependent conceptualisations of the nature-people systems, including research on incorporation of cultural ecological disservices into valuation systems.

Flow of services, be it ES from Country to people or Stewardship services from People to Country, are impacted by the outside influences, such as (lack of) legal right to access the country, built capital (roads, boat ramps) or capacity of people (technical, financial) to conduct stewardship activities (arrows at the left and the right hand side of Figure 2). This conceptualisation of important impacts of influences outside of the nature-people system is aligned with the recent Western literature highlighting that many ES are co-produced, being the product of natural capital and other inputs/capitals (Jones et al. 2016; Costanza et al. 2017; Raymond et al. 2017). Sustaining and enhancing human wellbeing thus requires a balanced portfolio of individual people, society, the built economy, and ecosystems, with goods and services created from different combinations of these capitals (Costanza et al. 2021). Costanza et al. (2014) note that, as ES do not flow directly from natural capital to human wellbeing, rather, the flow occurs in interaction with the other forms of capital; the key challenge in ES valuation is assessment of the relative contribution of the natural capital versus other forms of capital. Importantly, different cultures will have different 'forms of capital' available to them (Larson et al. 2025) – for example, boat and fishing gear to catch the fish, before the provisioning ecosystem service can be realised. Hence co-designing ES flow accounts with the Traditional Owners of the area being accounted for, is likely to result in interactions, interdependencies and co-production of flows that are context-specific. SEEA-EA, as an international statistical standard with specific guidelines on how to compile a coherent set of interrelated accounts, is set to record sections of the national economic activity related to the interactions between humans and nature, with a focus on making visible the contributions of nature to the economy and people (UN et al. 2021b). As such, it is primarily interested in accounting for changes in natural capital (extent and condition) and resulting changes in flows of services from the natural capital (Carnell et al. 2023), and as such does not account for the co-contribution of co-creation of values with other forms of capital.

Linking from the co-creation discussion above, some ESs are recognised to flow 'more directly', while other require greater co-creation. Importantly, this co-creation does not always happen in the same time period. Several ecosystem service flows recorded by Nywaigi Traditional Owners require improvements to the current condition, before they can be co-created (as presented in Figure 1 panel B and Figure 3). Also, some of the ES flows identified by Nywaigi are 'more distant' from nature so would not be recognised as ES but rather benefits in SEEA-EA – they require more of other capitals and less of natural capital: however, part of the benefit is still contingent on natural capital and flow of ES. For example, when discussing building a keeping place (a museum), Nywaigi envisage money for this activity to come from income realised from tourism (recreational ecosystem service), with the increased numbers of tourists visiting Mungalla Homestead after wetland restoration. So income is not the final benefit, it is what that income is used for that is important. But also then there is a feedback into increasing the tourism income as now there is a wetland and a museum, co-creating greater future benefit. Relative contribution of natural capital to overall wellbeing thus might even decrease over time, as other forms of capitals available to Nywaigi improve and increase.

Another concept discussed by Nywaigi Traditional Owners is that of timelines. Temporal dimensions of Indigenous conceptualisations, considerably longer than those commonly considered by Western scientists, has been reported in literature (Awasis 2020; Reid et al. 2020; Stoeckl et al. 2021; Larson et al. 2023). The present is seen as a component of the past (preserving and honouring culture) and the future (with aspirations for future) (Stoeckl et al. 2021). Our findings support this conceptualisation, with temporal dimension – of current being a bridge from past to the better future – being a strong feature of Nywaigi concept. As reported in Figure 4, flow of benefits from nature to people, and from people to nature, is seen as

a continuous spiral evolving through time. Nywaigi aspire for this spiral to be an upwards one, a vision of the improving connection between people and the Country over time, with management and restoration activities improving the condition and extent of the Country (Figure 4).

We propose that findings of our study have a stronger meaning applicable beyond Nywaigi Traditional Owners and other First Nations, one that can also inform discussions on 'relational turn' paradigm: away from focusing on interactions between nature and societies, towards emphasizing continually unfolding processes and their relations (West et al. 2020; Gould et al. 2023). Our empirical study presents an example of practice that could support more pluralistic policymaking (West et al. 2020; Pérez-Hämmerle et al. 2025). We agree that existing ES approaches, including SEEA-EA, risk encouraging utilitarian and inflexible views on complex system of linkages between nature and people (Boswell 2023). For our work we focused on eliciting those services and benefits that mattered most to Nywaigi to ensure we were accounting for the 'right' flows, and used crosswalks from their conceptualisations to the SEEA-EA concepts; this provided proof of concept that SEEA-EA flow accounts can be developed to reflect First Nations worldviews. Such an approach could be usefully transferred to other contexts (locations and First Nations groups): whilst specific outcomes (what gets measured) might vary, the use of a consistent process would allow for temporal, spatial and contextual comparisons. Thus, our explorations indicate that crosswalks between Indigenous and the Western conceptualisation of flows of services from nature to people and from people to nature are possible, building up on similarities rather than pointing at differences. Such calls in relation to SEEA-EA framework are still in their infancy (Vardon et al. 2023). As the current SEEA-EA revision cycle (2022–-2025) concludes, and the upcoming 2026–2028 cycle is concentrating on better integration and harmonisation of SEEA Central Framework with the SEEA-EA (SEEA – System of Environmental Economic Accounting 2025), we highlight the importance of integration of Indigenous value systems and knowledge, issues currently still absent from the development plans for Environmental Economic Accounting.

5. Conclusions

In this paper we build on the previous work that explores relations between Indigenous people and the Western conceptualisation of flows of services from nature to people, and specifically, SEEA-EA accounting framework. We did this in partnership with the Nywaigi Traditional Owners from North Queensland Australia. Our crosswalk from the Indigenous to the SEEA-EA conceptualisation indicates that some of the concepts are very similar between the two. Key findings are confirmation of importance to Nywaigi Traditional Owners of circular and interconnected conceptualisation of the nature-people-nature system; concept of not only flows of services from nature to people and of people to nature, but also important flows of services from nature to nature; category of disservices – explicit recognition that ecosystem flows can be beneficial but also detrimental for human wellbeing, both physical and mental/spiritual; important role of outside influences (capitals other than natural capital) in determining the actual use of what ecosystem services might be supplying; and need for recognition of importance of longer timelines when considering impacts or evaluating benefits and co-benefits in nature-people system. We propose that conceptualisations reported in this paper are applicable beyond Nywaigi Traditional Owners and other Australian First Nations, and are of relevance to international audiences.

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Author contributions

CRediT: **Silva Larson:** Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft **Diane Jarvis:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review and editing **Nywaigi Traditional Owners:** Conceptualisation, Investigation, Methodology, Validation, Writing – review and editing

Ethics

This project was conducted under approval of the James Cook University Human Research Ethics Committee, approval number H9252.

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