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Accounting for ecosystem services – Lessons from Australia for its application and use in Oceania to achieve sustainable development

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ABSTRACT

This paper aims to illustrate the conceptual and practical issues that need to be considered if ecosystem service accounting is to be used to achieve sustainable development in Oceania. Recent international activity has focused on setting international standards for accounting for ecosystem services via the System of Environmental-Economic Accounting (SEEA). This includes defining the assets from which ecosystem services are generated. We examine how ecosystem services are incorporated into accounting and the benefits of doing this. This is done using Australia examples from the Great Barrier Reef region and elsewhere. Key lessons relate to: (1) the practical issues facing the producers of ecosystem accounts, including data availability and quality; (2) the need to account for both ecosystem services and ecosystem assets to assess sustainability, and; (3) explaining how ecosystem accounting can assist with sustainable development via policy as well as the management of specific ecosystem assets.

1. Introduction

The importance of the environment to economic prosperity was recognized at the Rio Earth Summit in 1992 (UN, 1992) and renewed through the adoption of the Sustainable Development Goals (SDGs) in 2015 (UN, 2015). Unfortunately, these initiatives have not stopped environmental degradation, with human use of the environment reaching dangerous levels (e.g. Rockström et al., 2009), and better ways need to be found to achieve sustainable development. The European Commission, Organisation for Economic Development, United Nations and World Bank (UN et al., 2014b) promote recognising and assessing ecosystem services combined with environmental-economic accounting as a way of integrating data to provide policy relevant information for achieving sustainable development. A range of other activity has followed on from this including: technical recommendations for ecosystem accounting (UN, 2017) as well as documents from the European Union (e.g. Maes et al., 2018), the United States of America (e.g. Boyd et al., 2018) and elsewhere (e.g. Castaneda et al., 2017).

In this paper, we aim to outline how accounting for ecosystem services and ecosystem assets has progressed, to derive some lessons as to how such accounting can better assist sustainable development in Oceania. The lessons are based on several studies, but we focus mainly on accounting for the Great Barrier Reef (ABS, 2017) which looked at both terrestrial and marine ecosystems and the experience is likely to apply to both the producers and users (or potential users) of information on ecosystem services in Oceania. Producers and users of ecosystem service information can be from either the public or private sector, but almost all of the work we have reviewed is from the public sector – government agencies, research agencies and international organizations (e.g. the United Nations and World Bank). Hence, the lessons we describe are mostly for the public sector.

Several papers review the ecosystem service literature (e.g. Cork et al., 2012b; Bagstad et al., 2013; Egoh et al., 2012; Martinez-Harms and Balvanera, 2012) but none has focused on ecosystem accounting and how ecosystem accounting can be used in decision-making processes. This paper begins to address this gap, building on previous accounting work at the global level (e.g. Bass et al., 2017; Ruijs and Vardon, 2018) as well as experience in Australia (e.g. ABS, 2017; Keith et al., 2017) and Oceania (e.g. Bertrand et al., 2018, Naidu and Vardon, 2018). However, before moving to an examination of this experience and the lessons, we start with a brief introduction to the System of Environmental-Economic Accounting which has guided the production of accounts in the region and around the world.

Following the introduction to the System of Environmental-Economic Accounting, the paper goes on to present in Section 2 the case study of the ecosystem accounts for the Great Barrier Reef (ABS, 2017). Include in Section 2 are example accounts for ecosystem condition and ecosystem services. This then leads to Section 3 on the main lessons that have emerged from the experience in Australia and elsewhere. Section 4 is the "Conclusions and where to now?"

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1.1. System of Environmental-Economic Accounting (SEEA)

The System of Environmental-Economic Accounting Central Framework (SEEA Central Framework) was adopted as an international statistical standard in 2012 (UN et al., 2014a). The SEEA Central Framework integrates environmental information with the economic information found in the System of National Accounts (SNA), which among other things produces the indicator GDP or gross domestic product (EC et al., 2009). The SEEA is a systematic framework for the organisation of information, allowing data from different sources to be compiled and presented in a consistent way. A key innovation of SEEA is 'combined presentation', which presents information about the environment and ecosystems in both monetary and physical (or non-monetary terms), for example, the flows of water in litres as well as the value of this water in monetary terms (e.g. dollars). The benefits of this innovation are discussed further below.

The SEEA Central Framework was not able to include a range of issues related to ecosystems, with valuation of ecosystem services and assets a key area (Obst et al., 2016).

This led to the development of the SEEA Experimental Ecosystem Accounting (UN et al., 2014b) as an experimental system that is being tested via case studies and is undergoing revision, with a view to finalisation and adoption by 2021 (UN, 2019). The SEEA Experimental Ecosystem Accounting provides a common set of terms, concepts, classifications and an integrated accounting structure for measuring ecosystem assets, their extent and condition, and ecosystem services, in both physical and monetary terms at national or sub-national levels. To further advance the development of international standards for ecosystem accounting, a document containing technical recommendations for the production of ecosystem accounts was produced (UN, 2017).

According to the SEEA Experimental Ecosystem Accounting (UN et al., 2014b, p.1):

'Ecosystem accounting goes beyond other approaches to ecosystem analysis and assessment through the explicit linking of ecosystems to economic and other human activity. The links are seen both in terms of the services provided by ecosystems and also in the impacts that economic and other human activity may have on ecosystems and their future capacity. While ecosystem accounting does consider ecosystems and the economy to be different systems, they are analysed jointly reflecting the fundamental connections between them. The use of an accounting framework enables the stock of ecosystems – ecosystem assets – and flows from ecosystems – ecosystem services – to be defined in relation to each other and also in relation to a range of other environmental, economic and social information'.

One important aspect of ecosystem accounting is that the physical flows of ecosystem services can be recorded as being used both within the formal economy (and hence captured in GDP) as well outside it. For example, oxygen flows from the atmosphere to both industrial processes and human respiration. Such flows raise some complex issues of valuation (e.g. UN et al., 2014b, Obst et al., 2016, Saner and Bordt, 2016, Droste et al., 2018), but because of combined presentation we do not need to wait for these issues to be resolved in order to produce accounts that can be used, for example to measure the extent and condition of ecosystem assets or to identify people's dependencies on, and actual and potential risks to, ecosystems.

Australia has been a leading implementer of the SEEA Central Framework (Obst and Vardon, 2017) while five nations in Oceania have also produced or are developing accounts from the SEEA Central Framework (Table 1). To date, no Pacific Island nation has prepared ecosystem service accounts, although the countries that have produced or are producing water accounts (Federated States of Micronesia, Fiji, Palau, and Samoa) could probably produce accounts for the ecosystem service of water provisioning without much additional effort.

In Australia, a range of research relating to ecosystem accounting is available (e.g. ABS, 2017; Aisbett and Kragt, 2010; Adjani and Comisari, 2014; Binning et al., 2001; Crossman et al., 2013; Eigenraam et al., 2013, 2016; Gillespie et al., 2008; Keith et al., 2017; Cork et al., 2012b; Russel-Smith et al., 2013; Stoeckle et al., 2011; Straton and Zander, 2009; Stoneham et al., 2012; Tovey, 2008; Van Dijk et al., 2014; Varcoe et al., 2013). This activity has added significantly to the theory and practice of environmental and ecosystem accounting in Australia.

Different initiatives have focused on different aspects of the accounts, in terms of concepts, themes or metrics. For example, ecosystem services flows were the focus of DEWHA (2009), Maynard et al. (2012) and Cork et al. (2012a,b), while the condition of ecosystem assets was the focus of the Wentworth Group (Wentworth Group 2008, 2013; Sbrocchi, 2015) and Eigenraam et al. (2013, 2016). The study by Eigenraam et al. (2016) looked at both the ecosystem assets and services of Port Phillip Bay in the Australian State of Victoria, but while the ecosystem services were identified, they were not quantified. The Australian Bureau of Statistics (ABS) has compiled accounts from the SEEA Central Framework for land, water, waste and energy covering both stocks and flows in physical and monetary measures (Obst and Vardon, 2017) and many of these are published annually (e.g. ABS, 2018).

The ABS has also produced ecosystem accounts for the Great Barrier Reef (Power et al., 2014 ABS, 2015, 2017). We examine the accounts for the Great Barrier Reef in more detail below as these accounts are probably the most relevant in terms of geography and lessons learnt.

2. Case study: Accounting for the Great Barrier Reef

The stated aims of Experimental Environmental-Economic Accounts for the Great Barrier Reef (ABS, 2015) were twofold:

1. To connect some of the very large body of scientific work being undertaken in the region to other environmental and macro-economic information compiled by the ABS.
2. Provide feedback to the United Nations on the development of SEEA Experimental Ecosystem Accounting (UN et al., 2014b), which had recently been published.

The Great Barrier Reef is a globally significant area located in the Coral Sea off the coast of Australia. It extends for more than 2300 kilometres along the north-eastern coast near the Australian state of Queensland (Fig. 1). It is the world's largest coral reef ecosystem and is listed on the register of World Heritage[1]. The terrestrial (Great Barrier Reef Catchment Area) and marine (the Reef) ecosystems provide a number of benefits to humans through the generation and use of ecosystem services, mainly primary production and tourism (ABS, 2017).

The Great Barrier Reef World Heritage Area totals 348,000 km^2, extending from the most north-eastern point of Queensland to the north of Bundaberg. Ninety-nine per cent of the area (344,400 km^2) is comprised of the Great Barrier Reef Marine Park as set out in the *Great Barrier Reef Marine Park Act 1975*. The accounts for the Great Barrier Reef (ABS, 2017) were prepared using data that were collected primarily to inform the management of the Marine Park. The extent of overlap between the Marine Park and World Heritage area mean that the data available should give a good representation of both areas. The 3600 km^2 of the World Heritage Area located outside the Great Barrier Reef Marine Park falls under the jurisdiction of the Queensland State Government and includes islands, ports and other internal waters.

The Great Barrier Reef marine ecosystem is also closely linked with the 28 terrestrial river catchments that drain into the sea in the area. These catchments cover over 38 million hectares. The 28 river catchments are grouped into six Natural Resource Management Regions (NRMs): Burdekin; Burnett Mary, Cape York (eastern-draining areas

[1] UNESCO list of World Heritage site, Great Barrier Reef https://whc.unesco.org/en/list/154

Table 1
Status of SEEA implementation in Pacific Island countries.

Country	Accounts produced	Accounts planned or possible over short to medium-term	Reference
Federated States of Micronesia	Energy PSUT, MSUT	Water Further iteration of energy account	www.sbs.gov.ws
Fiji	Energy PSUT Water PSUT Solid waste PSUT	Land cover (in-progress) Further update and iteration of accounts produced	www.statsfiji.gov.fj
Palau	Energy PSUT, MSUT Water PSUT, MSUT	Waste Further update and iteration of accounts produced	http://palaugov.pw/system-of-environmental-economic-accounting-seea/
Samoa	Water PSUT, MSUT	Energy Further iteration of water account	www.sbs.gov.ws
Vanuatu	Currently collating data for compiling land cover accounts	Water	http://www.unescap.org/resources/implementation-system-environmental-economic-accounting-pacific-achievements-and-lessons

Source: After Naidu and Vardon (2018).

only); Fitzroy; Mackay Whitsunday; and Wet Tropics. This area has a human population of over one million people (ABS, 2017).

Threats to the condition or health of the reef include climate change, declining water quality (from catchment run off) and the loss of coastal habitats (from coastal development and fishing impacts). Some of these threats are the result of regional or global actions, beyond the boundaries of the Great Barrier Reef Marine Park.

The Great Barrier Reef region is a well-studied area and the Great Barrier Reef Marine Park Authority (GBRMPA) produces an Outlook Report every five years containing a large amount of information (e.g. GBRMPA, 2009). In addition, the links between activities on the land and the condition of the reef are well documented (e.g. Stoeckl et al., 2011) while other reports have examined the economic contribution of the reef to the Australian economy (e.g. Access Economics, 2009; Deloitte Access Economics, 2017).

Using these and other information sources, the Australian Bureau of Statistics developed an experimental set of ecosystem accounts to test the SEEA Experimental Ecosystem Accounting and provide integrated environment and economic information to assist with the management of the region (ABS, 2017). A suite of 51 accounts was presented in the report and these covered a range of ecosystem services and ecosystem condition as well as data from the national accounts (ABS, 2017). Summaries of ecosystem condition for the marine areas in terms of marine assets, climate variables and pollutant loads are shown in Table 2 for the years 2007–08 to 2014–15. Full results and methodologies and reasons for choosing particular measures are found in ABS (2017). Physical measures of ecosystem services are shown in Table 3 for the same time periods, while the estimated values of the ecosystem services to the industries that used them in the productions of goods and services are shown in Table 4 in Australian dollars (AUD$) in

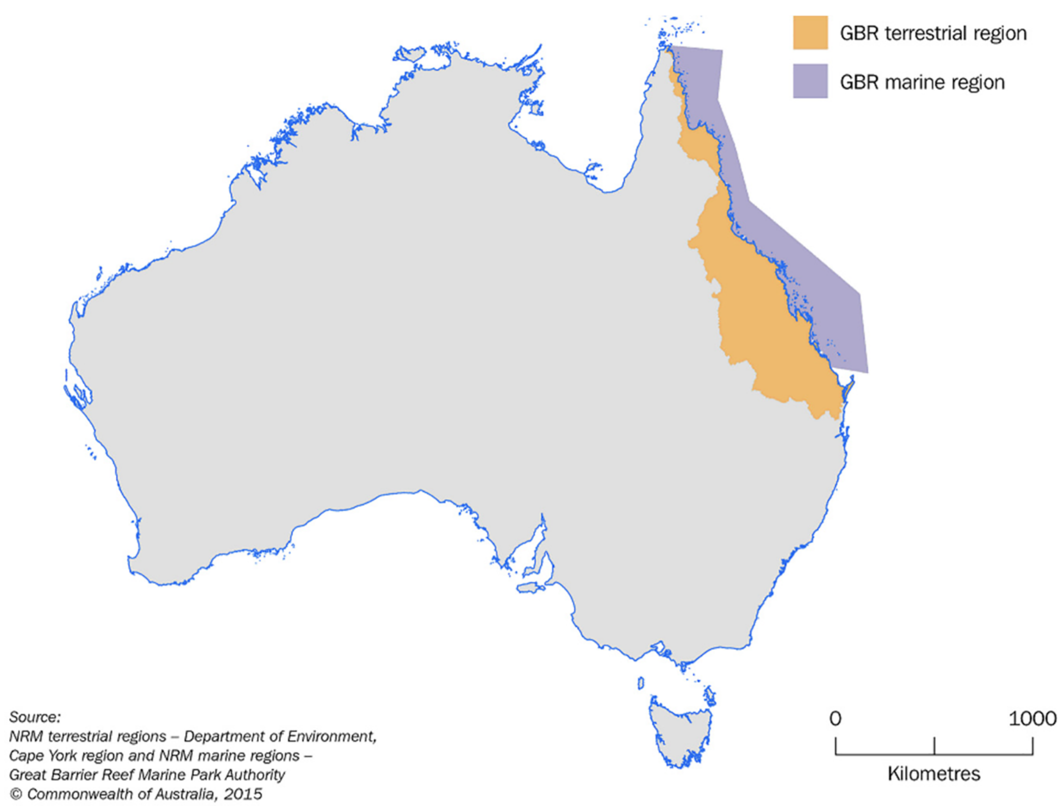

Fig. 1. Map of the Great Barrier Reef (GBR), terrestrial and marine regions covered in the ABS ecosystem accounts Source: ABS (2017) http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4680.0.55.001Explanatory%20Notes12015?OpenDocument.

Table 2
Ecosystem Condition Summary, Great Barrier Reef Region, 2007–08 to 2014–15.

	Units	2007–08	2008–09	2009–10	2010–11	2011–2012	2012–13	2013–14	2014–15
Marine condition									
Coral (a)	Score	47	48	47	43	38	39	40	44
Seagrass (a)	Score	35	33	28	21	19	28	34	33
Water Quality (a)	Score	47	44	44	31	37	37	34	43
Climate									
Mean annual sea surface temperature (b)	°C	24.7	25.0	25.7	24.5	24.9	25.1	24.9	25.2
Mean annual sea surface temperature anomaly (b)	°C	−0.27	0.30	0.53	−0.38	−0.16	0.12	−0.11	0.24
Mean annual rainfall	mm	1070.0	1090.0	946.0	1633.0	1100.0	903.0	869.0	760.0
Pollutant Loads in selected monitored areas (c)									
Total suspended solids	kilotonnes	18788.0	12639.0	6889.8	19647.0	5532.0	9559.0	1243.3	2074.6
Total nitrogen	kilotonnes	57.6	36.9	29.3	101.0	27.5	33.7	10.1	8.9
Total phosphorus	kilotonnes	16.2	9.2	9.2	32.0	7.7	9.3	1.5	2.5

(a) Marine condition scores were sourced from the Reef Water Quality Protection Plan, Great Barrier Reef Report Card series (2015 issue).
(b) Mean annual sea surface temperature and mean annual sea surface temperature anomaly are in calendar years starting from 2008 to 2015. These measures were sourced from the Bureau of Meteorology, eReefs Marine Water Quality Dashboard, Commonwealth of Australia.
(c) Pollutant loads were sourced from the Department of Science, Information Technology and Innovation, Queensland Government.
Source: ABS (2017).

current prices.

For ecosystem condition, Table 2 shows much variation in many of the condition indicators, including those for coral, seagrass and water quality. While all these indicators show slight improvement between 2007–08 and 2014–15, there is much variation in the years in between. One area of clear improvement is the pollution loads of suspended solids, nitrogen and phosphorus, all of which have declined between 2007–08 and 2014–15.

For ecosystem services, Table 3 again shows much year-to-year variation in the physical measures of many services, e.g. for various food services and agricultural materials. Carbon sequestration was little changed, with an average of 2836 megatonnes stored per year. Supply of cultural services increased across the period, measured by increases of 2.6 million visitors (Table 3) and AUD$ 1869 million in value (Table 4) between 2006–07 and 2015–16.

The monetary and physical measures in Tables 3 and 4 can be shown in a combined presentation by, for example, taking 2007–08 as the base year (i.e. all values for 2007–08 are set to 100). This is done for the years 2007–08 to 2015–16 for cultural services in Fig. 2, while comparisons between different ecosystems services are shown for the year 2014–15 in Fig. 3. In reading Figs. 2 and 3, numbers below 100 represent a decrease in the level of service from the level in 2007–08, while numbers above 100 are an increase.

Fig. 2 shows that while the physical and monetary measures can move in the same direct, as happens from 2012–13 to 2015–16 for cultural services, they can also move in opposite directions as happened in 2010–11 and 2011–12. The differences are due to a range of factors including the type of tourists (international or national), the length of stay and which part of the region was visited (for further discussion see ABS, 2017).

Fig. 3 again shows changes in physical and monetary terms can be different and in opposite directions. For example, the provisioning service of "Food- Other food", where the physical measure was 72 (hence 28% below the 2007–08 level), whereas the monetary measure was 107 (a 7% increase). Changes can be in the same direction but to different levels. For example, the provision service of fish was down to 78 in the physical measure and 89 in the monetary measure, whereas provisioning from Aquaculture was 148 in physical terms and 174 in monetary terms. This later reflecting both a growth in the industry and well as changes in price.

2.1. Accounting for biodiversity

There is positive link between biodiversity and ecosystem services (Harrison et al., 2014; Mace et al., 2012). Biodiversity conservation is major challenge for governments as is recognized at local, national and international levels and demonstrated internationally by biodiversity conservation targets in the Convention on Biological Diversity (e.g.

Table 3
Ecosystem services in physical measures, Great Barrier Reef Region, 2007–08 to 2015–16.

Ecosystem Services	Units	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16
Provisioning Services										
Food – Meat cattle	Tonnes	496,936	476,429	424,720	451,056	469,908	457,618	570,682	586,460	na
Food – Sugar	Tonnes	29,404,592	29,299,735	28,262,411	23,054,570	23,430,218	25,738,628	28,483,702	29,591,928	na
Food – Other food (a)	Tonnes	3,092,298	2,323,465	2,634,682	2,015,614	2,427,179	2,124,068	2,297,696	2,231,453	na
Agricultural materials	Tonnes	218,638	459,167	166,123	201,491	278,478	277,154	314,808	379,084	na
Fishing	Tonnes	10,967	12,061	11,525	10,645	9052	9837	8889	8593	8259
Aquaculture	Tonnes	4501	4271	5899	5493	5056	5064	5398	6662	6471
Timber	m^3	na	na	na	914,989	977,852	726,366	735,115	886,748	na
Regulating Services										
Carbon stored (b)	Megatonnes	2849	2844	2842	2839	2833	2832	2831	2828	2827
Cultural Services										
Visitors	Million	15.2	15.2	15.0	16.4	14.5	17.8	17.3	16.9	17.8

na – not available.
(a) Excludes Dairy and eggs.
(b) Amount of carbon stored at the end of the financial year.
Source: ABS (2017).

Table 4
Estimated value of ecosystem service inputs(a) to selected industries, Great Barrier Reef Region, 2006–07 to 2015–16.

	2006–07 AUD$ million	2007–08 AUD$ million	2008–09 AUD$ million	2009–10 AUD$ million	2010–11 AUD$ million	2011–12 AUD$ million	2012–13 AUD$ million	2013–14 AUD$ million	2014–15 AUD$ million	2015–16 AUD$ million
Agriculture	na	205.4	433.8	410.4	636.9	980.7	1,049.1	972.7	1,226.5	na
Forestry	na	na	na	na	9.4	16.5	11.2	15.3	28.5	na
Fishing	29.9	34.6	41.6	41.7	34.9	44.3	38.7	46.5	45.5	na
Aquaculture	14.6	13.0	16.3	13.2	11.3	10.9	17.0	24.6	21.1	na
Tourism	310.6	332.6	290.9	320.7	299.0	404.2	535.0	470.0	523.3	594.8

na – not available.
Source: ABS (2017). Note: all values in current prices.
(a) Resource rent method.

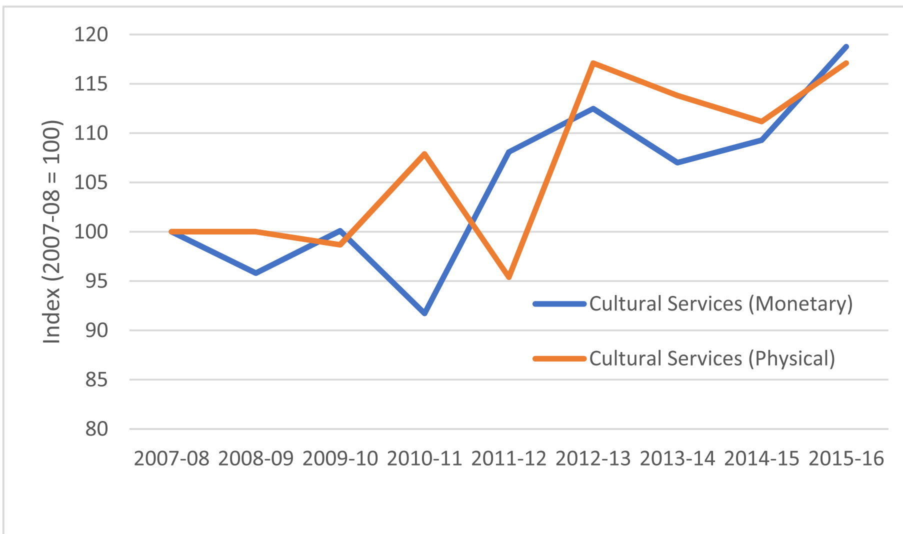

Fig. 2. Comparison of the physical and monetary measures of cultural services from the Great Barrier Reef. Source: After ABS (2017) Tables 1.3 and 1.4. Note the index takes 2007–08 as the base year (=100).

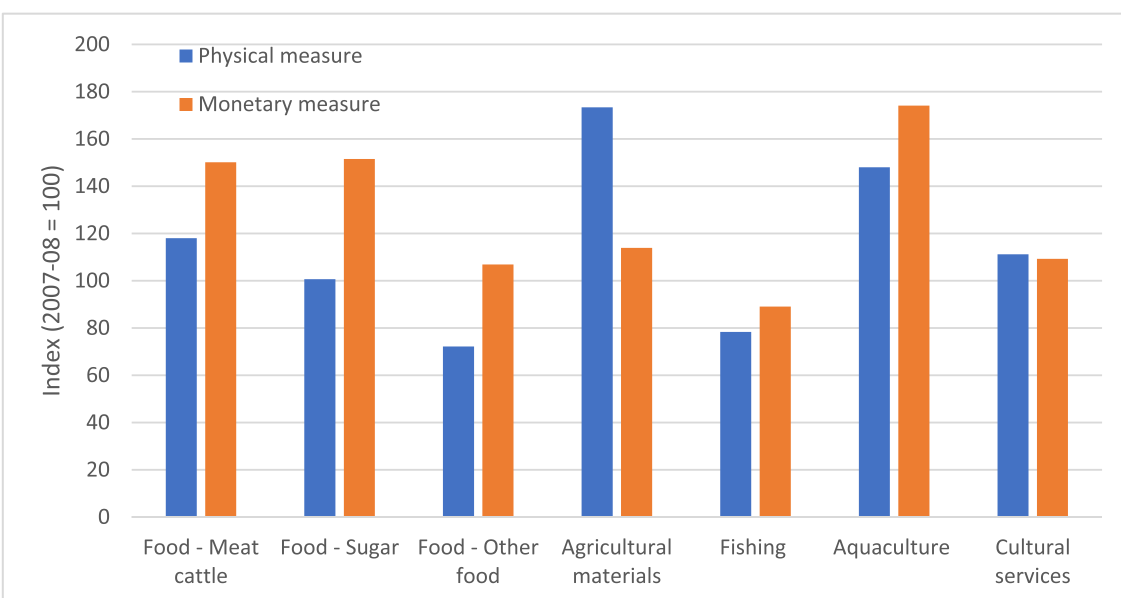

Fig. 3. Comparison of the physical and monetary measures of selected ecosystem service of the Great Barrier Reef, 2014–15. Source: After ABS (2017) Tables 1.3 and 1.4. Note the index takes 2007–08 as the base year (=100).

Aichi Biodiversity Target 2; see https://www.cbd.int/sp/targets/) and the SDGs (e.g. Goal 15; United Nations 2015). The Aichi Target 2 states:

‘By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.’

Aichi Target 2 provides a clear entry point for biodiversity and accounting experts to work together. One potential obstacle is that the valuation of biodiversity has proved difficult. The valuation work within the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has focused on the different conceptions of value with respect to the environment (an important discussion) but is only now progressing to consider the value of biodiversity specifically for the integration of environmental and economic values into national accounting, which requires monetary valuation (UN et al., 2014b, Obst et al., 2016). While there is an urgent need for agreed concepts and approaches to the monetary valuation of biodiversity if the accounting element of Aichi Target 2 is to be met in full, much of Target 2 can be met without resolving these issues, first because some ecosystem services have conventional exchange values and second because SEEA provides for non-monetary quantification under the principle of combined presentation. This would allow, for example, development planning that protected biodiversity assets and the ecosystem services they generate by reference to accounts based on physical ecosystem extent and condition alone.

The same point can be made in relation to the SDGs. SDG 15 aims to:

‘Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.’

This broad ranging aim has several aspects that make it amenable to monitoring using accounting approaches. At its simplest, accounting for the number of species, their distribution, abundance and age structure would provide a metric for measuring the component on biodiversity loss. One of the features of the ecosystem accounts for the Great Barrier Reef (ABS, 2017) was the species accounts. Table 5 provides an example of a marine fish species account but other tables were prepared for marine mammals and terrestrial mammals. Table 5 shows the species grouped by conservation status and the threats to species.

The Great Barrier Reef is rich in terms of its biological diversity with approximately: 411 species of hard corals; 150 species of soft corals and sea pens; 39 species of mangroves; 15 species of seagrasses; 1625 fish species (including 1400 coral reef species); 136 species of sharks and rays; 6 species of marine turtles; 30 species of marine mammals; 3000 species of molluscs; 500 species of worms; 1300 species of crustaceans; 630 species of echinoderms; 14 breeding species of sea snakes, and; 20 nesting species of sea birds (ABS, 2017). The Great Barrier Reef provides habitat for a range of endangered or iconic species, including the endangered dugong, two endangered marine turtles and for some whales.

The full potential of ecosystem accounting emerges when addressing the sustainability aspects of SDG 15. This involves not just reporting on biodiversity loss but the connecting of data on such loss to data on the extent and condition of ecosystems. This enables assessment of levels of use of environmental stocks relative to the regenerative capacity of those stocks and the value of the associated ecosystem services (Vardon et al., 2018). Such an accounting system would also assist with the assessment and sustainable management of fisheries. This would be important for the Great Barrier Reef as of the 214 marine fish species evaluated, 72 are threatened by resource use (Table 5).

3. Lessons

The experience in Australia with ecosystem accounting in the Great Barrier Reef (ABS, 2017) and for forested regions (e.g. Keith et al., 2017) has demonstrated that structuring information in the form of

Table 5
Threatened Marine Fish, Great Barrier Reef Region, by Number of Species, Source of Threat and Threat Status Category, 2012.

Threat Status Category	Source of threat													
	Number of species	None	Residential/ commercial development	Agriculture/ aquaculture	Energy production/ mining	Transportation and service corridors	Biological resource use	Human intrusions/ disturbance	Natural systems modifications	Invasive species	Pollution	Geological events	Climate change/ severe weather	Other
Critically endangered	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Endangered	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Vulnerable	2	0	0	0	0	0	2	0	0	0	0	0	0	0
Near threatened	12	0	0	0	0	0	10	0	0	0	1	0	2	5
Least Concern	194	124	3	0	0	0	55	2	0	1	9	0	14	28
Data deficient	5	1	0	1	0	0	4	0	0	0	1	0	1	2
Total evaluated species	**214**	**125**	**3**	**1**	**0**	**0**	**72**	**2**	**0**	**1**	**11**	**0**	**17**	**35**
Total unevaluated species	**312**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**

na – not available.
Source: ABS, 2017.

accounts reveals interactions between human activities and ecosystems, and how they impact on the levels of ecosystem services used as well as the extent and condition of ecosystem assets. The work has clearly shown that accounts can provide policy-relevant information. Despite this demonstration of potential, the use of accounts in policy and management has been limited to date. A key reason for this has been a lack of understanding of accounts and accounting on the part of decision makers. Another barrier has been the misunderstanding that accounting for ecosystems is an attempt to value everything and is "the commodification of nature" and hence part of the dominant economic paradigm that has caused the problems (e.g. Monbiot, 2014). Others argue that if ecosystems are not valued then they are effectively given a zero value, and hence always be secondary to economic values (e.g. Schröter et al., 2014).

Given this, it is vitally important to explain ecosystem accounting to the general public, environmental non-government organisations, natural resource managers, including industry groups directly reliant on ecosystem services (e.g. forestry, see Forico, 2018; Yao et al., 2017) and government policy experts that the aim of accounting is not to value everything in the environment in monetary terms, but to recognise the interactions between the economy and environment. The accounts are not designed to support one particular world view but to provide data that enables the changes to be understood in terms of transactions between ecosystems and people.

Another key reason for lack of use is lack of detailed data. Accounts such as those for the Great Barrier Reef are too coarse to serve as a tool of direct environmental management, other than to be broadly suggestive of priorities. Ideally, accounts would be available at a scale sufficiently fine to reveal, for example, that a species population was under particular pressures, allowing policy intervention before significant damage was done.

It is also early days in terms of drawing on accounts in support of policy analysis, for example, analysis of options, and assessment of trade-offs involved in land use decisions. This occurred in the study of the Victorian Central Highlands, Australia by Keith et al. (2017) which used accounts to make explicit the trade-off between the supply of timber and the supply of water and carbon storage, as well as demonstrating that supply of water and carbon were compatible with biodiversity conservation, while timber harvesting was not. In contrast, the accounts for the Great Barrier Reef (ABS, 2017) did not investigate such trade-offs nor assess the compatibility of different land management activities with water quality or biodiversity conservation. This reflects the statutory role of the Australian Bureau of Statistics as defined in the *Australian Bureau of Statistics Act 1975* and the *Census and Statistics Act 1905*, which is to provide objective data to decision makers. This means that management options and possible trade-offs between different economic activities are not pre-supposed. A key benefit of the SEEA is that it enables multiple trade-offs to be investigated, not just simple two-way trade-offs, for policy or management decisions.

Four general types of policy analyses can be performed using the data presented in accounts:

(1) valuation of ecosystem services, both currently valued but hidden in other information, and previously unrecognised values, such as carbon storage, carbon sequestration, and water provision;
(2) valuation of the economic output of industries that use ecosystem services as their contribution to industry value added (IVA) (with the sum of all IVA equal to GDP for the entire economy);
(3) estimation of the potential gains and losses in IVA and ecosystem services under different scenarios, including changes to laws or the environment (e.g. climate change), and
(4) evaluation of combined physical and monetary metrics to compare different ecosystem services, for example allowing assessment of the benefits of biodiversity conservation being less or more than the valuation of an ecosystem service that is impacted by human activities.

Perhaps the key lesson is that the capacity to quantify ecosystem services and their contribution to industries helps to explicitly reveal the trade-offs made or required when use of services by different industries is in conflict or has resulted in a reduction in ecosystem extent or condition.

3.1. Ten "living" principles ecosystem accounting fit for policy

The work in Australia reflects generally the findings on the use of ecosystem service accounting internationally. In addition, the accounting work done in the Pacific Island nations, which was all based on the SEEA Central Framework, also pointed to key lessons for advancing the production and use of accounting by governments (see Bertrand et al., 2018; Naidu and Vardon, 2018). A range of the international experience was summarised in Vardon et al. (2017) and Ruijs and Vardon (2018) and distilled into 10 living principles for making ecosystem accounting fit for policy (Table 6).

An assessment of the 10 living principles and how they relate to the experience in Australia, mostly the Great Barrier Reeef, and how they might inform development of ecosystem accounting in Oceania is presented below. This is done under the sub-headings: Comprehensiveness, Purposefulness, Trustworthy and Mainstreamed. It is important to recognise that the 10 Principles were derived from experiences to date and hence were not available until after all of the examples reviewed here were published.

3.2. Comprehensiveness

Living principles 1 and 2 (Inclusive and collaborative) are drawn from the global experience that shows that the construction of ecosystem accounts compels different parties to work together and to look beyond the factors usually considered by each in isolation. The Great Barrier Reef accounts (ABS, 2017) involved significant engagement across stakeholder groups, with a range of agencies consulted, mostly for access to data and then for review of draft accounts (e.g. Australian Institute of Marine Science, The Department of Environment and Heritage protection, Queensland, The Great Barrier Reef Marine Park Authority, Bureau of Meteorology). This also occurred in the ecosystem accounts done for Victoria (i.e. Eigenraam et al., 2013, 2016; Varcoe et al., 2013; Keith et al., 2017), the Australian Capital Territory (Smith et al., 2017) and in Pacific Island countries (Naidu and Vardon, 2018). For example, the accounts for the Central Highlands of Victoria were produced first as a draft and then updated following comments received, some of which were made at a workshop. That said, while accounts can play a role in stimulating collaboration, they also remain a point of contention in some cases and in particular for the accounts of the Central Highlands of Victoria, which have featured prominently in public debate about the future of native forest logging (e.g. Gittens, 2019).

Living principle 3: Holistic. While ecosystem accounting can be holistic and cover a broad range of policy fields, including sustainable development, Australian experience to date is that the accounts generally cover particular natural resources (e.g. water, forests) or particular areas (e.g. Great Barrier Reef) and hence are not holistic as envisaged in the SEEA. The risk is that ecosystem accounting is treated in silos and separated from national accounting in other SEEA accounts (i.e. from the Central Framework).

3.3. Purposefulness

Living principles 4 and 5: Decision-centred and Demand-led. Actual and potential uses of accounts are very broad as described by Vardon et al. (2017). Ideally accounts would be produced in comprehensive form, able to inform, whether directly or by adaptation, any kind of decision, at any stages of the standard policy cycle: issue identification, policy development, implementation, monitoring and review (Vardon

Table 6
The 10 living principles for making ecosystem accounting fit for policy.

Comprehensive:	
1. Inclusive	Acknowledging the diverse stakeholders concerned with decisions affecting natural capital, responding to their information demands, respecting different notions of value, and using appropriate means of engagement.
2. Collaborative	Linking the producers of NCAs, the users of NCAs for policy analysis and the policy makers using the NCAs results, and building their mutual understanding, trust, and ability to work together.
3. Holistic	Adopting a comprehensive, multi/interdisciplinary approach to the economic and environmental dimensions of natural capital and to their complex links with policy and practice.
Purposeful:	
4. Decision-centred	Providing relevant and timely information for indicator development and policy analysis to improve and implement decisions with implications for natural capital. Scale and scalability of accounts and associated are an important aspect to consider in decisions
5. Demand-led	Providing information actually demanded or needed by decision makers at specific levels.
Trustworthy:	
6. Transparent and open	Enabling and encouraging public access and use of NCAs, with clear communication of the results and their interpretation including limitations of the data sources, methods, and/or coverage.
7. Credible	Compiling, assessing, and streamlining data from all available sources, and deploying objective and consistent science and methodologies.
Mainstreamed:	
8. Enduring	With adequate, predictable resourcing over time; continuous application and availability; and building increasingly rich time series of data.
9. Continuously improving	Learning focused, networked across practitioners and users, testing new approaches, and evolving systems to better manage uncertainty, embrace innovation, and take advantage of emerging opportunities.
10. Embedded	NCA production and use becoming part of the machinery of government and business, building capacity, improving institutional integration for sustainable development, and incorporating NCAs use in procedures and decision-support mechanisms.

Source: After Bass et al. (2017).

et al., 2016). To date, however, ecosystem accounts have almost universally been place- or issue-specific and generated by persons other than decision-makers. In Australia, the Great Barrier Reef is a key ecosystem asset and its management of broad public interest. However, the account was produced largely independently of the requirements of decision-makers (ABS, 2017) and a key lesson is that decision makers and decision-making processes needed to be identified earlier in the process. This could have also enabled decision makers to gain some familiarity with the accounting framework prior to production. This is also true for Port Phillip Bay (Eigenraam et al., 2016) and terrestrial areas in Victoria (e.g. Eigenraam et al., 2013; Keith et al., 2017; Varcoe et al., 2013). In the lone contrary example, the Commissioner for Sustainability and the Environment for the Australian Capital Territory asked for ecosystem accounts to be undertaken in support of her obligation to undertake State of the Environment reporting (Smith et al., 2017), which includes the making of policy recommendations.

3.4. Trustworthy

Living principles 6 and 7: Transparent and open, Credible. Transparency and openness are key to ecosystem accounting. In Australia, the ecosystem accounts prepared have been published with details of the data sources and methods, which is a key part of ensuring data quality. As ecosystem accounting is new, few people have a detailed understanding of the information they contain or how it can be used. In many cases the first-time decision makers know about the accounts is when they are produced. One of the key reasons the experimental accounts for the Great Barrier Reef were produced was to identify potential uses and initiate discussions with potential uses (ABS, 2017). Such consultation is likely to increase trust in future ecosystem accounts.

The development and testing of the SEEA via international processes, also helps make the accounts produced credible and defensible. The ongoing development of SEEA and its extensions into ecosystem accounting, will help to maintain and extend the credibility of accounting approaches in the future. The case of the ecosystem accounts for the Central Highlands is interesting because several different publications were produced for different groups of stakeholders: a policy brief for policy makers, a popular article for the general public, a scientific article to assure scientific soundness, and a full report containing all details of the data sources and methods. Conversely, the Australian Bureau of Statistics accounts for the Great Barrier Reef did not have multiple publications addressing different audiences. Here the ABS is constrained by its role in government as an information provider, rather than an advisor on policy. Multiple lines of communication should help understanding and at least make ecosystem accounts more accessible and hence more open and credible.

3.5. Mainstreamed

Living principles 8 and 9: Enduring and Continuously Improving. The enduring production of ecosystem accounts is yet to occur in Australia. While the ABS has published two accounts for the Great Barrier Reef (ABS, 2015, 2017) it is not clear if they will be produced again. Accounts from the SEEA Central Framework are regularly produced (ABS, 2018). However, while other accounts have a time series, they have been done as a one-off (Eigenraam et al., 2013, 2016; Keith et al., 2017; Varcoe et al., 2013). Because of this it is too early to identify any trend of continuous improvement in ecosystem accounting. It does seem evident that account production involves learning-by-doing and in that regard experimental techniques such as 'shadow budgeting' are available (Vardon et al., 2016a,b).

Living principle 10: Embedded. While there is generally good progress with production of accounts from the SEEA Central Framework, with systems in place for collecting and accessing data as well as assessing and assuring its quality, embedding ecosystem accounting in policy analysis requires more effort and commitment. A key issue is that for accounts to be used, they first need to be created and then understood and appreciated in terms of the benefits to policy and analysis. Since government decision making has functioned without ecosystem accounting to date, many agencies do not see the need for them. In some cases, government agencies do not want them as the information may reveal challenges to the status quo, as was the case with the ecosystem accounts for the Central Highlands of Victoria (Keith et al., 2017). Thus, sometimes policy agencies may be a barrier to the production of accounts.

As such, improving the understanding of ecosystem accounting within the government policy and management agencies is a key task, as is the creation of a culture of learning. Without such understanding and openness, it is almost certain that ecosystem accounts will not be used or embedded within government processes or in the analyses from outside on which they rely.

4. Conclusions and where to now?

The ecosystem accounting community is growing in terms of both the number of accounts being prepared and the number of people and organisations actively undertaking such work. Some of this work is growing from the accounting community, which is mostly based in national statistical offices, while other work is emerging from the research community or government agencies concerned with natural resource or environmental policy (e.g. line-agencies for forestry, water, agriculture or environment). The community is diverse, with accountants, economists, environmental scientists and others working together to create accounts. Several successful accounting exercises have been completed, which highlight the value of ecosystem services and ecosystem assets.

One aspect of interest is how different accounting projects have been led, organised and managed as well as how this has influenced the development and uptake of the accounting in decision making. Four models of account production are identified, and each has different strengths and weaknesses:

1. Projects led by statistical agencies. This generally ensures close linking with the System of National Accounts and associated economic data, a strong emphasis on data quality and a focus on ongoing account production. However, the downside is that accounts will often take several years to produce, in an environment that is usually separated from account users and their needs.
2. Projects led by government agencies concerned with natural resource or environmental policy. In this model, the accounts are produced to suit the needs of the particular agency and are generally focused on a specific natural resource (land, water, forests, etc.) or industry (e.g. agriculture, water, environment). This can help with linkages to analysis and policy applications but could lead to perceptions of bias in data completion and interpretation (e.g. that decisions are made based on data that was deliberately collected, presented and interpreted to align with a pre-determined course of action).
3. Projects led by non-government research agencies (e.g. universities). In these projects, the accounts are generally produced relatively quickly (12–18 months) and use the latest knowledge and information. Interpretation and analysis is also prominent under this model, but there is usually no view to on-going production as in government agencies.
4. Projects led by industries. An emerging area internationally is business-led environmental accounting, such as the Natural Capital Protocol of the Natural Capital Coalition[2]. Accounting for natural capital his has been used by the forestry industry (e.g. Forico, 2018). The advantage of this approach is that the producer and user of the account are one and the same meaning that the information produced should be able to be used in management of forests. The disadvantage is that, like accounts produced by government agencies responsible for a particular natural resource (e.g. production forests or national parks), may be biased deliberately to support predetermined courses of action.

The model for the production and use of national economic accounts is generally that the accounts are produced by a national statistical office, with the data then analysed and interpreted by other economic agencies both internal to government, such as treasuries and central banks, and external to it, including businesses, academics, media commentators and community organisations. Ultimately, the production and use of the ecosystem accounts could mirror the model of the national economic accounts but this is unlikely to occur for some time as the field is still rapidly evolving and international standardisation some years away.

If the model for the national economic accounts was to be extended to ecosystem accounting under the SEEA, governments would need to resource statistical agencies to produce such accounts in comprehensive form on an ongoing basis. This alone is a significant challenge. But the more significant challenge will be to build the necessary understanding of the operation and benefits of SEEA, including the ecosystem services paradigm. This calls for collaboration, not only between producers and users, but between countries, as there is much to be learned any many potential pitfalls. In this regard, the World Bank, which promotes accounting through its Wealth and Valuation of Ecosystem Services programme following a review of activity (Vardon et al., 2016b) has established a Policy Forum (see Vardon et al., 2017, Ruijs and Vardon, 2018) at which the experience in Pacific was covered to some extent (Naidu and Vardon, 2018). Successful development and application of ecosystem accounting in Oceania is likely to depend on initiatives such as this being expanded or replicated.

[2] See Natural Capital Coalition https://naturalcapitalcoalition.org/natural-capital-protocol/

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