29 October 2015

Progress, challenges and opportunities for biodiversity accounting

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Paper for the 21st Meeting of the London Group on Environmental Accounting

The Hague

The Netherlands

2-4 November 2015

Summary

Biodiversity accounting is probably the most difficult area of accounting encountered so far. This is due to both theoretical and practical factors, including the need for a wide range of professions to work together to address the topic (e.g. accountants, ecologists, economists, land and sea managers and public sector decision-makers).

All have different entry points and aims for biodiversity accounting as well as their own terminologies. This can make discussions challenging and there is a need for more clarity and precision in the discussions of biodiversity accounting.

To assist collaborations between diverse groups of professionals we do four things:

(1) Review key aspects on the measurement of biodiversity and ecosystem accounting drawing on past and recent literature;
(2) Distinguish four types of accounts related to biodiversity (ecosystem extent accounts, ecosystem condition account, ecosystem diversity accounts and species diversity accounts).
(3) Present some preliminary work on including aspects of biodiversity in ecosystem accounts for the Central Highlands of Victoria, Australia and;
(4) Identify six challenges and five opportunities for accounting for biodiversity within the System of Environment-Ecosystem Accounting based on on-going investigations in Australia by the authors and a range of other recently published work.

The Challenges

(1) Improving primary data sources
(2) Determining the contribution of biodiversity to the value of service flows and assets
(3) Explaining the relationships between biodiversity, ecosystem condition and ecosystem services
(4) Identification and treatment of associate thresholds and reference condition
(5) Developing practical approaches to the delineation of accounting units and the impacts of these for aggregation and scale effects.
(6) Continuing to develop the understanding of biodiversity and accounting across professions

The Opportunities

(1) Incorporating existing biodiversity data and indices into ecosystem accounts
(2) Incorporating into ecosystem accounts existing national and international classifications (e.g. IUCN Red List)
(3) Appling ecosystem accounting to the Aichi Targets
(4) Appling ecosystem accounting to threaten species and protected area management
(5) Using ecosystem accounting in specific policy tools (e.g. biodiversity offsets and payments for ecosystem services)

1. Introduction

A range of professions (e.g. accountants, ecologists, economists, land and sea managers, etc.) must work together closely to turn the promise of ecosystem accounting into practical information that can be used by decision-makers in public and private sectors.

Each profession has a different entry points and aims for biodiversity accounting as well as their own terminologies, practices and literature. This can make discussions challenging with experts in different areas having to rapidly come to terms with new areas of knowledge.

Over the past year or so a range of work on accounting for biodiversity has emerged. A very useful note was prepared by UNEP-WCMC (2015) expanding on the material included in the System of Environmental Economic Accounting - Experimental Ecosystem Accounting (SEEA-EEA)(UN et al 2014). Several projects have published ecosystem accounts or include aspects or measures of biodiversity that are relevant to accounting (e.g. ABS 2015, Burns et al. 2014, Eftec 2015, Remme et al. 2014, Schröter et al 2015, Varcoe et al. 2015). The corporate sector has also address accounting for biodiversity in the past (e.g. TEEB) and recently (e.g. Jones 2014).

In Australia a workshop title "Metrics for Biodiversity Accounting and Policy was held at the Centre of Excellence for Environmental Decisions, University of Queensland, 26-28 November 2014. The workshop brought together national and international experts and the attendees are listed in Acknowledgements (Section 8). Additionally, other investigations of the application ecosystem accounting are in progress (e.g. on Mountain Ash Forests in Victoria, biodiversity offsets, butterflies, policy applications).

The growing body of work has brought to light a number of issues with biodiversity measurement and ecosystem accounting. This includes how biodiversity is conceptually included in the SEEA-EEA as well as some of the practical issues concerning the data sources and methods needed to generate accounts and make them useful for management and policy decisions.

While the SEEA-EEA and SEEA Central Framework can potentially make substantial contributions to government policy and management of the environment or economy, this has not yet occurred. International initiatives like the new adopted Sustainable Development Goals offer an opportunity to apply the SEEA. These are not addressed here. However, the Aichi Targets under the Convention on Biological Diversity (CBD) offer an opportunity to apply accounting to issues specifically related to biodiversity (Section 7).

2. Terminology and definitions

A fundamental issue in developing ecosystem accounts is the use of the terms "biological diversity" or "biodiversity". These terms are often used in shorthand and can lead to some confused discussions if the intended meaning is not properly understood.

Biological diversity is defined in the CBD as:

> "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.[1]"

[1] Article 2. Use of Terms http://www.cbd.int/convention/articles/default.shtml?a=cbd-02

The SEEA-EEA adopts this this definition. Note that in the definition in the CBD, ecosystem *diversity* is a subset of biological *diversity*, while in the SEEA-EEA biodiversity *accounting* is a subset of ecosystem *accounting*.

The reason for this is apparent in the definition of ecosystems, again from the CBD:

> "Ecosystem" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit[1].

Again the SEEA-EEA adopts CBD definition. In the CDB definition living components (i.e. communities of plants, animals and micro-organisms) are parts of ecosystems, which aligns with the accounting structures in SEEA-EEA that also include the non-living components (land, soil, water, etc.).

The key point is that it is important to understand what different people mean when they use the terms ecosystems and biodiversity as often they are used loosely.

3. Accounts for biodiversity

It is important to be clear about what aspect of biodiversity or ecosystems are being measured in the accounts. The SEEA-EEA describes four asset accounts related to biodiversity:

(1) Land cover (a proxy for ecosystem extent);
(2) Ecosystem condition;
(3) Species abundance and;
(4) Threatened species (pp. 90-94 and 100-104).

To encourage deeper discussions and understanding we distinguish the accounts slightly differently:

(1) Ecosystem extent accounts;
(2) Ecosystem condition account;
(3) Ecosystem diversity accounts; and
(4) Species diversity accounts.

The first two accounts are as per SEEA-EEA, but with a modification to the arrangement of the condition account. In the SEEA-EEA ecosystem condition account biodiversity is listed as one of the characteristics of condition, with species richness and relative abundance given as examples of indicators. Vegetation is also shown as one of the characteristics of condition, with Leaf area index, biomass, mean annual increment, given as examples of indicators. This representation in the SEEA-EEA separates vegetation structure and function from biodiversity and this probably needs to change to more clearly recognize the three levels biodiversity – ecosystem diversity, species diversity and genetic diversity – as well how biodiversity is measured (discussed below in Section 4).

The accounts for species abundance and threatened species are both what we are distinguishing as species diversity accounts. Accounts for ecosystem diversity are not included in the SEEA-EEA, but would be a measure of the diversity of ecosystems within a particular area (e.g. the number and extent of different ecosystems).

Biodiversity *per se* is not included as an ecosystem service in the SEEA-EEA, although it was in the TEEB and has been in some investigations (e.g. Varcoe et al. 2015) and conceptions (e.g. Mace et al. 2012). Explaining why biodiversity is not a service is a key challenges and we return to this later (See Sections 6).

Accounting conventions
Accounting for biodiversity requires that there is agreement on how particular changes are recorded. The classifications specific to biodiversity and the general structure of environmental accounts provide a standard structure for tables with measures of biodiversity. However, for some particular cases further understanding and agreement on treatment is needed. This includes accounting for species which are: newly discovered; rediscovered; separated from an existing species; subsumed into other species; wrongly identified; occur only in zoos and other types of captivity; reintroduced or relocated; migratory or nomadic; and poorly known.

Accounting for these examples is not necessarily difficult but agreement is needed on the treatment so that common approaches are used. A key aspect of this is the paucity of regular data for most species. The inclusion of a category "Data Deficient" in the IUCN Red List is an indication of the challenges with data. What is acceptable accounting practice in the absence of complete information, and in particular, the attribution of cause of changes is a matter to resolve.

Accounting for different groups of species also needs to be addressed. For example, non-native species (e.g. weeds and feral animals) are managed in different ways to native species and hence need to be separated. There is a related issue of non-desirable species, for example, species that are pests or carriers of disease. This is the related to the notion of ecosystem dis-services, which appears on the SEEA-EEA research agenda and highlighted by UNEP-WCMC (2015).

4. Measurement of biodiversity

Biodiversity is defined by the CBD and SEEA-EEA as "variability among living organisms" and includes diversity within species (i.e. genetic diversity), diversity between species, and diversity of ecosystems. A strict interpretation of this definition would imply that biodiversity should be measured primarily in terms of biological variability. However the SEEA-EEA conforms with a growing acceptance (including by the CBD itself) that biodiversity measurement can also include measures relating to the amount of a given biological entity (e.g. the abundance of a species), alongside measures of the variability between entities (e.g. species richness). The main focus of the SEEA-EEA so far has been on biodiversity at the species level.

Key measurements of species-level biodiversity are (Pereira et al. 2013; Tittensor et al. 2014):

(1) Species diversity or richness (i.e. total number of species in a particular area or region);
(2) Species abundance (i.e. the number of individuals of each species);
(3) Species distribution (i.e. the area over which a particular species occurs);
(4) Species traits, including reproductive rates (the rate at which a species grows in abundance);
(5) Species status

Species status or extinction risk is a concept derived from changes over time in species distribution and abundance. Extinction risk is calculated based on changes in species distribution and abundance and species growth rate (McCarthy et al. 2014).

The measurement of species-level biodiversity has some apparent corollaries with the measurement of biodiversity at the ecosystem level. For example, species abundance is like ecosystem area and species distributions and ecosystem distributions are both represented spatially (i.e. on maps). Ecosystem diversity, the number of distinct ecosystems in a particular area (Lewandrowski et al. 1999), is like the number of species (or species richness) in a particular area. This could be extended to genes as well.

The potential to broaden measurement of biodiversity within the SEEA-EEA has been demonstrated by recent advances made in establishing a system of Essential Biodiversity Variables for the planet, in an initiative led by the Group on Earth Observations Biodiversity Observation Network (GEO BON) (Pereira et al. 2013; Skidmore et al. 2015). This builds on a well-established conceptualization of biodiversity (Noss 1990) in which the three levels of biological organization (genetic, species, ecosystem) are viewed as intersecting with three attribute dimensions:

- Composition (i.e. the species)
- Structure (e.g. for animals age-sex structure, for plants height and growth form)
- Function.

Measurement of function crosses over into the realm of ecosystem services measurement and accounting. The ecosystem services as defined in the SEEA-EEA, which are the human benefits, are only part of function, since, for example water filtration services used by fish that remain in the wild would not be counted as service, but would be measured as a function. If the fish was caught and eaten then the fish would be a food provisioning service, while water filtration function could be considered an intermediate ecosystem service (but these are not defined in the SEEA-EEA).

Table 1 combines the notions of levels of biodiversity and measurement of biodiversity. An extra row is added for indices that combine measure either across measurement aspects. Indices that span diversity levels are also possible. By assessing the available metrics in this matrix, the suitability of the metrics for particular types of ecosystem accounts related to biodiversity should become clearer.

Table 1 Measurement of the different levels of biodiversity

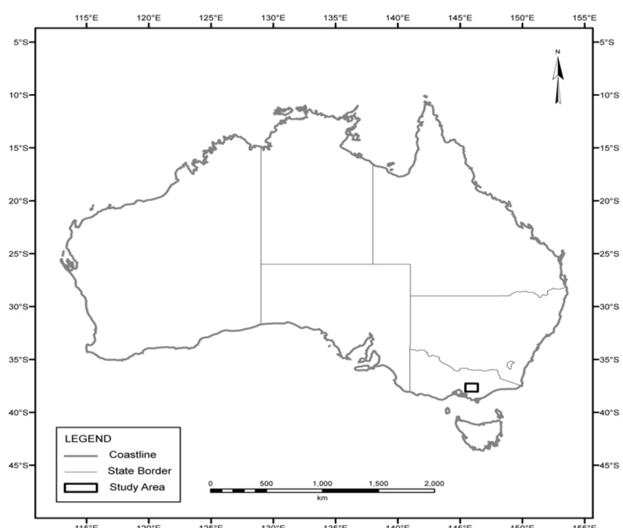
	Level of diversity		
	Genetic-level biodiversity	Species-level biodiversity	Ecosystem-level biodiversity
Composition	Gene	Species richness Species abundance Species distribution	Ecosystem “richness” Ecosystem area Ecosystem distribution
Structure		Age-sex structure Growth form Vegetation height	
Function		Ecosystem services	Ecosystem services
Indices combining composition, structure and function		Species status	Ecosystem status

The use of indices in biodiversity accounting is covered in the SEEA-EEA and the UNEP-WCMC (2015) review. Specific reference is made to the: Biological Intactness Index (Scholes and Briggs 2005); GLOBIO3 (Alkemade et al. 2009); Living Planet Index (Loh et al 2005, Collen et al. 2009); Natural Capital Index (ten Brink and Tekeleburg 2002); the Swedish Nature Index (Certain et al 2011) and; the Red List Index (Butchart 2007, Bubb et al. 2009, Collen et al. 2011). New metrics, such as those proposed for biodiversity offsets in Australia (Gibbons et al 2015) might also prove useful.

5. Accounting for the Central Highlands of Victoria

The Central Highlands of Victoria, Australia (Fig. 1) contain a range of ecosystems, including Mountain Ash Forests which are an iconic and critically endangered ecosystem (Burns et al. 2014). The Mountain Ash (*Eucalyptus regnans*) is the world's tallest flowering plant (Ashton 1975), stores the largest amount of carbon per hectare of forest (Keith et al 2009) and also provides habitat for the endangered Leadbeater's Possum (*Gymnobelideus leadbeateri*), the faunal emblem of the State of Victoria. The forest is used for a range of activities including timber production, water supply and recreation (Viggers et al. 2014).

Fig 1. Location of the Central Highlands of Victoria, Australia



Accounts for the Central Highlands are being prepared to test the SEEA-EEA and provide information to support decision-making. In this case the decisions relate to the proposed expansion of the national park area in the region via the establishment of the *Great Forest National Park*[2]. The preparation of the accounts draws on a range of broad scale data sources (e.g. land cover maps[2], Atlas of Living Australia[3]), recent land and ecosystem accounts for Victoria (ABS 2013, Eigenraam et al 2013 and Varcoe et al. 2015), previously published studies (e.g. Burns et al 2014, Keith et al. 2009, 2014, 2015) as well as long-term site-level data on species and ecosystem diversity of the region.

The accounts being prepared for the Central Highlands are:

- Carbon asset account,
- Water asset account
- Timber asset account
- Ecosystem extent account
- Ecosystem condition account
- Ecosystem and species diversity accounts
- Ecosystem service account (including timber provisioning, water provisioning water filtration, carbon sequestration and cultural and recreational services).

Final accounts are expected within six months. Preliminary data and accounts are presented here. Fig. 2 shows the land cover for the year 2014, while Table 2 shows the age-class of forested land. The age-class of forests reflects the structure of the forest that is related to the generation of particular ecosystem services (e.g. timber and water provisioning) and the habitat suitable for Leadbeater's Possum (Fig. 3).

Age-class of forest is determined by the time since stand-replacing disturbance event; that is, wildfire or clearfell logging for montane ash and rainforest; and clearfell logging for wet mixed, open mixed, woodland and montane woodland.

The age classes correspond to the congruence of times since major disturbance events such as wildfire, inflection points in the response of water yield to age, and harvesting age. Major wildfires occurred in 1939, 1983 and 2009. After disturbance, water runoff increases for 3 – 5 years and then decreases until about 30 years, after which the yield begins increasing again (Kuczera 1987, Brookhouse et al. 2013). The nominal timber harvesting age is 80 years, although the median age of harvesting is 68 years (Keith et al. 2015).

The relationship between forest age and the ecosystem services of timber and water provisioning mean that the condition of forests may be approximated by age since disturbance by clearfell logging or wildfire (high severity stand-replacing fire).

Fig. 3 shows a declining in abundance of Leadbeater's Possum between 1983-84 and 2014-15. The data are derived from monitoring by stag-watching for 1 hour at dusk to detect the occurrence of arboreal marsupial animals in hollow trees within 1 ha sites. The number of sites monitored each year ranged from 19 to 85. Sites were classified according to age of the forest (as per Table 1). Regenerating sites of a given age may have some older remnant trees, either living or dead, that provide hollows suitable for Leadbeater's Possum and other cavity-using animals (Gibbons and Lindenmayer 2002). The majority of sites are 1939 regeneration and so the mean value follows a similar pattern to this age class.

[2] See http://www.greatforestnationalpark.com.au/
[3] See https://www.data.vic.gov.au/data/dataset/victorian-land-use-information-system-2014-2015
[3] See https://www.ala.org.au/

Fig 2. Land cover in the Central Highlands, 2014

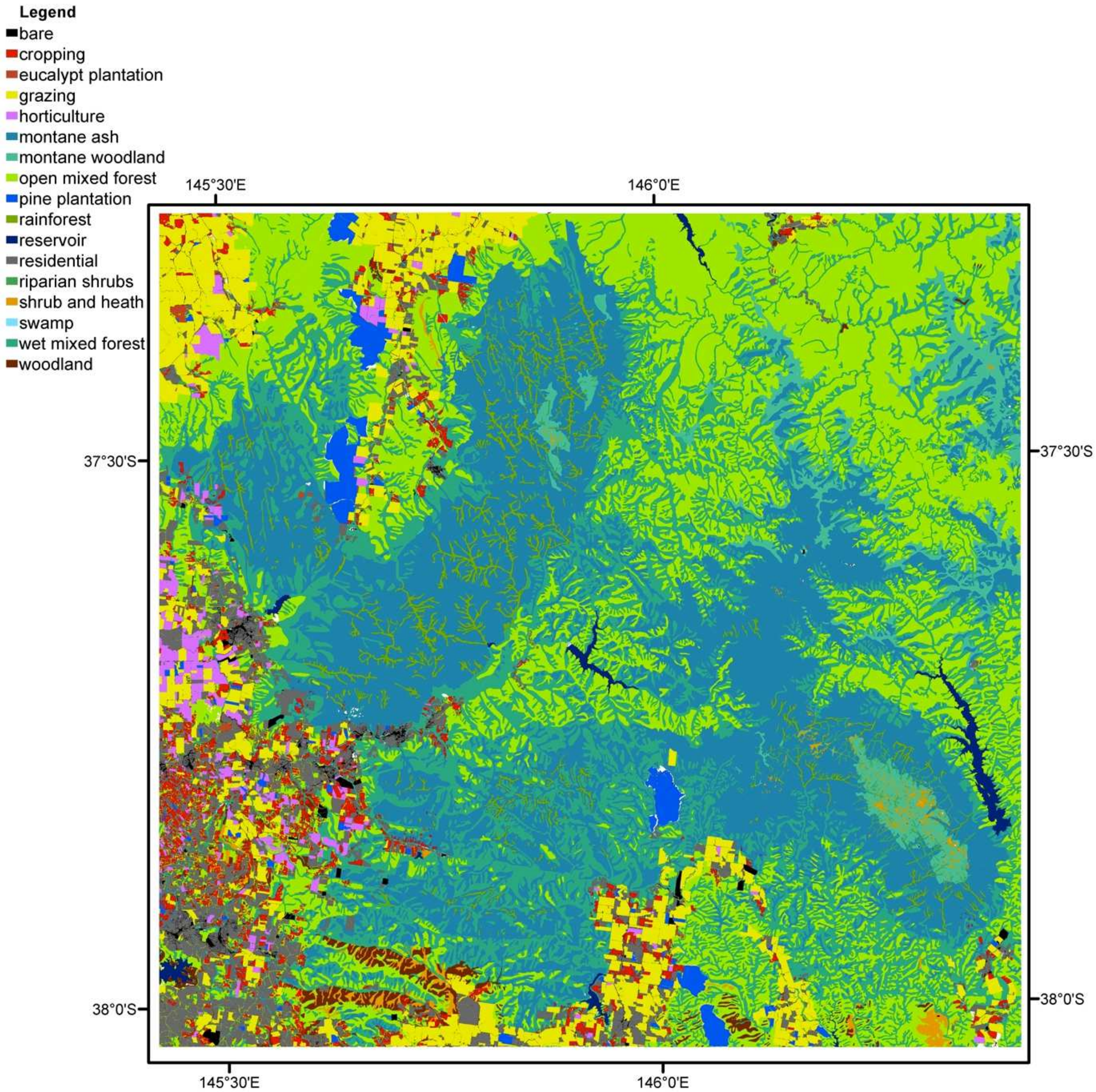
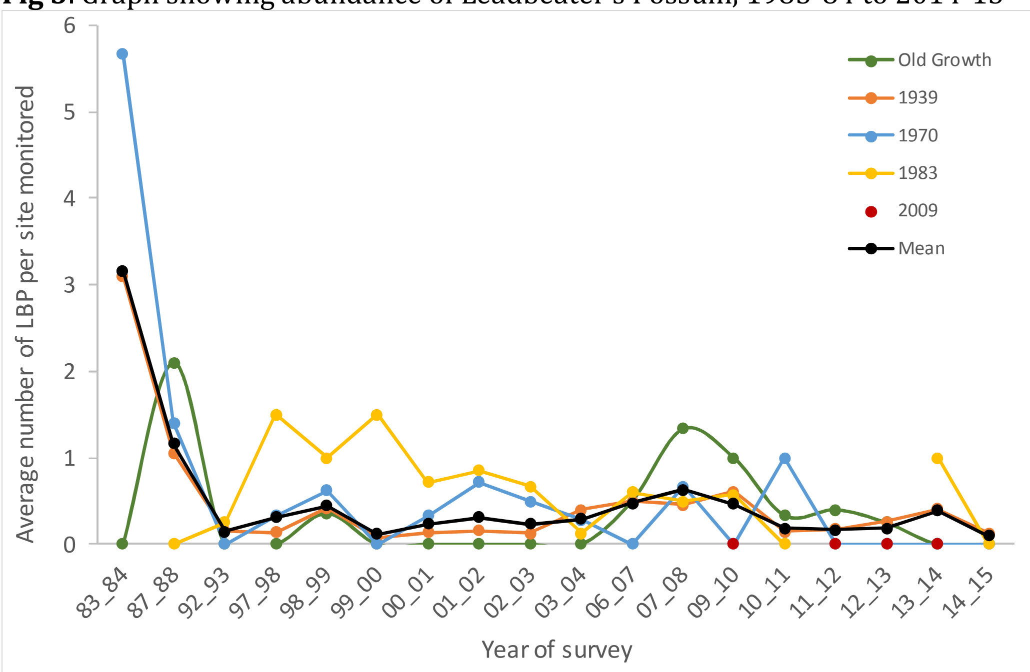


Table 2. Central Highlands, land cover (ha) by age class (year of last disturbance)

	Age class			
	<1939	1939<1983	1983<2009	>2009
Rainforest	5069	113	226	7123
Montane ash	214	88589	36241	63655
Wet mixed forest	138397	17058	13282	2571
Open mixes forest	167442	15353	4506	554
Woodland	6142	190	30	0
Montane woodland	22405	937	279	85

Fig 3. Graph showing abundance of Leadbeater's Possum, 1983-84 to 2014-15



The relationship between forest age and occurrence of Leadbeater's Possum mean that the condition of forests as approximated by age since disturbance by fire or logging[4], has meaning for this species and probably for other species too. There are differences in the condition of the forest depending on whether the regeneration was after fire or logging. After clearfell logging, regeneration is even-aged with few residual trees. In comparison, after wildfire the dead and damaged trees remain and provide habitat. Most old forests have experienced some form of non-stand-replacing disturbance, such as low severity fire, wind-throw or animal diggings, which allows regeneration of understory. Habitat for Leadbeater's Possum requires old-growth trees to provide hollows for nesting and younger understory as a food source. Different responses of animal populations after the fires in 1939 and 2009 are due to the fact that the earlier fire burnt mainly old-growth forest

[4] There are differences in forest condition with age for a logging or fire disturbance, particularly in relation to remaining stag trees.

where regeneration provided both trees with hollows and young understory, whereas the latter fire burnt mainly 70-year-old regenerating forest that had few trees with hollows.

The cultural services provided by the iconic Leadbeater's Possum are difficult to quantify, but it would seem likely that they would be greatly diminished if the species were to become extinct.

Annex 1 lists the threatened species in the Central Highlands of Victoria. It provides a comparison of IUCN Red List, Environmental Protection and Biodiversity Conservation Act 1999 (Australian law) and Flora and Fauna Guarantee Act 1988 (Victorian law), and the Advisory List of Threatened Vertebrate Fauna and Flora in Victoria 2013 (Victorian law). Annex 1 shows slight differences between the status of different species. This is probably due to the slightly different criteria used in each of the listing processes as well as the timing and data used for each assessment.

Conclusions from Central Highlands

The preliminary work in the Central Highlands has shown that it is possible to blend large and small-scale data to create ecosystem accounts. The work is not yet finished but clearly indicates that it is possible to include ecosystem structure in the assessment of ecosystem condition and to relate this to the production of ecosystem goods and services.

In particular, consolidating a wide range of information for the Central Highlands into a set of ecosystem accounts will better reveal the types of trade-offs between the condition of the forests (as measured by structure/age-class) and the services they can provide. In this case there is competition for the management of the forests between the timber provisioning, water provisioning, carbon sequestration and cultural and recreational services.

The work so far has also highlighted problems with primary data sources. In particular,the combination of administrative data based on the cadaster (which denotes areas of ownership or "land parcels") with land cover data based on remote sensing using gridded data, and sometimes data collected at different times. The data from the cadaster includes information on the owners, a land use classification and an assessed value (e.g. for the purpose of levying rates). This was not reported above, but in joining two data sets, one using cadastral parcels as the basic statistical unit and the other using grid cells as the basic statistical unit, anomalies arise. These issues are important to sort out as the land cover data provides the general information on the production of services, while the cadastral data provides a link to the use of services and the beneficiaries.

Some accounting issues have also been uncovered. For example, how would the re-discovery of species be treated in species diversity accounts? Leadbeater's Possum was thought extinct but was re-discovered. Not necessarily a difficult issue but one requiring agreement on how to be recorded in species level accounts.

A second accounting issue is the possible treatment of biodiversity as an ecosystem service. TEEB, Varcoe et al. 2015 and others include biodiversity as an ecosystem service. The provision of habitat for Leadbeater's Possum by forests is outside of the SEEA-EEA definition of ecosystem services, where the service must be consumed by people in order to exist. As such within the SEEA-EEA, Leadbeater's Possum cannot receive an ecosystem service. The service in the SEEA-EEA would be a cultural (iconic species) or recreational service (going to view the possum). Explaining the SEEA-EEA accounting to ecologists and biodiversity managers will be a key challenge going forward.

6. Challenges

Improvement of primary data sources

Perhaps the single biggest challenge for ecosystem accounting and biodiversity accounting in particular is the availability of primary data. Lack of data on biodiversity is a fundamental issue that needs to be addressed and is explored in more detail elsewhere (e.g. Lindenmayer et al. 2012). Reliable indices and accounts can only be compiled with adequate basic data on ecosystems and species. Basic information on trends in species distribution and abundance is usually lacking. Often data that have been collected are inaccessible, and the data that are available are of variable, sometimes unknown, quality. There are also many gaps in the primary data, in terms of geographic coverage (e.g. remote areas are not well represented), time-series (e.g. there are missing years) or species groups (e.g. invertebrates are poorly covered).

Because of the data gaps and deficiencies with primary data sources, particularly the distribution, abundance and age-sex-structure of species, proxy measures are needed to estimate the condition, trend and value of biodiversity. Several indices are available (Section 4) but which is the most suitable for accounts at particular scales (i.e. local through to global) has not yet been determined (identified as an opportunity in Section 7). Related to the indices is the usefulness of global data sets for biodiversity accounting. In particular, what role can they play and how can global data sets be used in conjunction with local information on species level biodiversity.

Additionally, economic information is also needed to enable the calculation of the value of the contributions of biodiversity to ecosystem services and assets (=natural capital).

Determining the contribution of biodiversity to the value of service flows and assets

Valuation is key part of the integration of ecosystems and biodiversity with the system of national accounts (e.g. Aichi Target 2, discussed below). Hamilton (2013) summarized much of the work biodiversity valuation including Heal (2000), Polasky et al (2005), Walker et al. (2010) and Mace et al. (2012).

For integration into the national accounts, the monetary values used in ecosystem accounting must be consistent with the exchange values used in in the SNA and SEEA (Obst et al. 2015).

There are at least three general approaches to valuation consistent with the exchange values used in the SNA and SEEA which can be explored: (1) use a net present value of the ecosystem services to which biodiversity contributes; (2) use hedonic pricing techniques to determine the contribution of biodiversity to the value of "land" or other assets traded in the market and; (3) use market based instruments to discover the value.

Net present value and hedonic pricing are well-established techniques, while the use of market-based instruments is occurring in a number of settings. Payments for ecosystem services and biodiversity-offset programs are the two such instruments and reveal the price of both ecosystem services and assets (=natural capital). The use of market-based instruments is discussed below as one of the five opportunities.

Explanation of the relationship of biodiversity to ecosystem condition and ecosystem services

The case study of the Central Highlands begins to show the relationships between biodiversity, ecosystem condition and ecosystem services. In addition, UNEP-WCMC (2015) reviews a range of material that also makes these links.

Ecosystem services are described in the SEEA-EEA. The flow of ecosystem services to which biodiversity may contribute is not separately identified. In some cases, the contribution of species level diversity to ecosystem services is clear, such as the harvest of particular species (e.g. fish or timber as provisioning services) or the cultural and recreation services provide by iconic species. For example, Leadbeater's Possum as the faunal emblem of Victoria. In the case of regulating services, such as water or air filtration, the contribution of biodiversity is important. In the case of the Central Highlands the structure diversity of the forests are clearly linked to water and timber provisioning service.

A key task is linking the generation of ecosystem services to the users of the services (i.e. the beneficiaries). The link to beneficiaries is an important step and is sometimes missing for ecosystem accounts, which by and large focus on the areas producing services. The problem of linking ecosystem assets and ecosystem services is exacerbated if benefits and beneficiaries are widely dispersed.

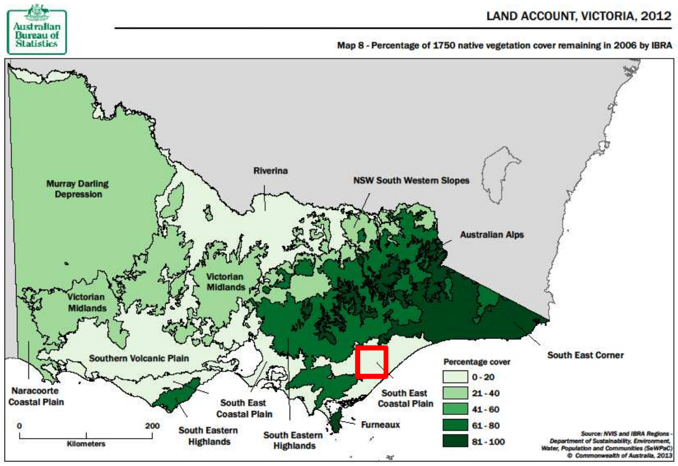
Identification and treatment of associated thresholds and reference condition

In biodiversity and other sciences the existence of thresholds, and non-linear responses more generally, to particular changes are well known. An example, relevant to biodiversity accounting is the species area curve (e.g. Brooks et al. 2002). In this the number of species likely to be lost accelerates enormously after around 30% of the original land cover is lost. For the forests of the Central Highlands of Victoria, the amount of water or timber that can be provided is a non-linear relationship to age of the forest. Key thresholds need to be able to be distinguished in the accounts, so that policy or management responses can be triggered.

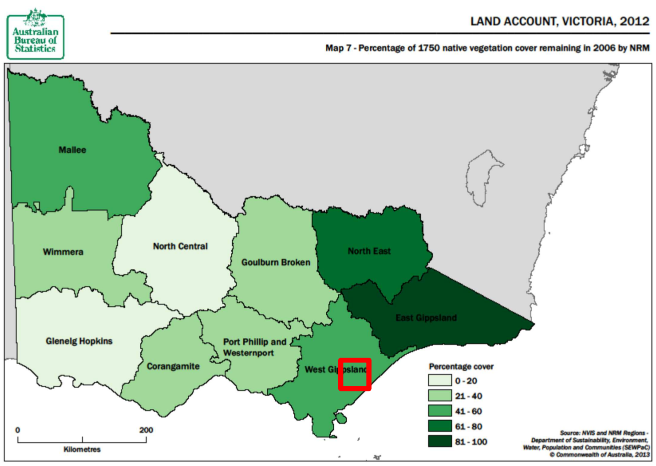
Reference condition is a notion widely advocated. This is commonly taken to be 'natural' or 'pre-industrial' and the date of 1750 has been used in Australia (e.g. ABS 2013). Whatever the reference condition or date, the information required for the time is the type, extent and condition of ecosystems and for biodiversity at the species level the make-up in terms of total number of species, species distribution, species abundance and age-sex structure of opening stock of biodiversity. Debate over what is 'natural' has been an on-going issue in the discussion of reference condition. While this could be resolved, an approach to explore would be the effect of the information derived from the accounts by choosing different reference condition dates. In this the time chosen could perhaps be better described as a common benchmark from which changes occur.

Figure 4. Geographic aggregation of data.

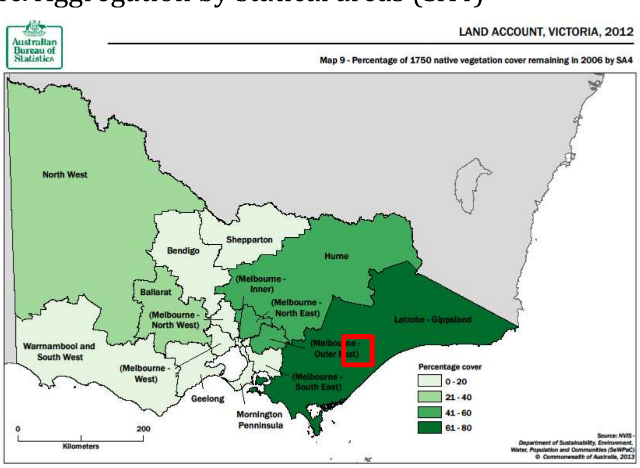
4a. Aggregation by bioregion



4b. Aggregation by natural resource managment areas



4c. Aggregation by statical areas (SA4)



Development of practical approaches to the delineation of accounting units and the impacts of these for aggregation and scale effects.

Accounting for biodiversity at local, national and international levels requires the scaling and geographic aggregation of information. These issues are reviewed in the SEEA-EEA and the UNEP-WCMC (2015). The issue of spatial aggregation is considered in these but given relatively little attention. In this, same source data aggregated to different geographies can produce different results. This is the Modifiable Areal Unit Problem (e.g. Openshaw 1983), previously identified in relation to biodiversity accounting by Bond at al. (2013). The problem is illustrated in Figure 4 which shows the percentage of native vegetation remaining in 2006 compared to 1750 for three different geographic aggregations: bioregions (Fig 4a); natural resource management regions (Fig 4b) and; statistical areas (Fig 4c). The red box shown in each aggregation is the same area, but the value changes. For the bioregion the score is 0-20, for the natural resource management region it is 41-60 and for the statistical area it is 61-80. All aggregations are "correct" but each would lead you to consider different courses of policy or management action within the red box.

Continuing to develop the understanding of biodiversity and accounting across professions

Multi-disciplinary work is difficult to progress and finance but is needed to address challenges in the world today (Ledford 2015). It is particularly needed for biodiversity accounting and its relationship to ecosystem services (Mace et al. 2012).

Applying the existing data, classifications (e.g. IUCN Red List), indices (e.g. Nature Index) and the Aichi Targets to ecosystem accounting, identified as an opportunity below (section 7), could provide a tangible focus or reason for scientists, economists, accountants, land managers and public officials to work together on the development and use of accounts for biodiversity.

7. Opportunities

Incorporating existing biodiversity data and indices of biodiversity into ecosystem accounts

While there is a major challenge with primary data, there are still opportunities to work with a range of existing data and indices in the production of accounts. The UNEP-WCMC (15) reviewed a large number these. While the data are not complete and the indices may be imperfect they are probably sufficient to produce experimental ecosystem accounts. The primary data and indices used in the accounts can be improved over time. This is seen in the data and accounts for others thematic accounts (e.g. water) (Vardon 2012).

Within Australia, the data in the Atlas of Living Australia, Dynamic Land Cover as well as information held by State Governments (e.g. Victorian Biodiversity Atlas) and non-government organisations like Birds Australia are all potentially useful. Some of these have already been used in accounts (e.g. ABS 2015, Eigenraam et al. 2013, Varcoe et al 2015, Section 5 above). Data are also available from long-term studies by academics, such as that for the Central Highlands of Victoria (see Section 5).

For the indices, understanding what aspects of diversity are being measured and to which level of diversity is being assessed (Table 1) is critical for the construction and interpretation of accounts.

Incorporating existing national and international classifications of extinction risk and threats into ecosystem accounts

The development and consistent application of classifications is a mainstay of accounting. In the SEEA-EEA and UNEP-WCMC (2015) review a range of classifications are identified for testing. For example, the IUCN's Red List of Threatened Species and the Red List of Ecosystems. The use of the classifications for the Red List of Threatened Species is covered in the SEEA-EEA and already used in some investigations (e.g. ABS 2013, ABS 2015, Bond et al. 2013). There is debate about the criteria for the Red List of Ecosystems (Boitani et al. 2015) but it is hoped that appropriate criteria can be developed, agreed and be useful for accounting.

The IUCN Red List classifications of extinction risk and the associated criteria were designed for global assessment of species status but national criteria and processed for the status of species are likely to be the starting point for most countries embarking on accounts. As such, concordances between national criteria and the IUCN Red List criteria will be needed. In looking at the various listings of threatened species in the Central Highlands of Victoria (Annex 1) it is clear while there are similarities between regional, national and international classifications of the risk of extinction of the same species, there are also differences which need to be understood.

Other IUCN classifications are also probably useful for biodiversity accounting. For example, the IUCN Protected Area Classification[5] and the IUCN Threats Classification Scheme[6]. The IUCN Threat Classification Scheme could be mapped to the industries (agriculture, mining, manufacturing, etc.), sectors (corporate, government, not-for-profit and households) and production of particular goods and services (i.e. the Central Product Classification) used in the SNA and SEEA. Such mapping will allow the economic drivers of change to be linked the information on extinction risk and threats to protected areas and species.

The different classification of ecosystems or types of land cover also needs to be reviewed and tested. The SEEA-EEA includes a broad land cover classification. This classification is unlikely to be helpful for anything other than the most basic of analyses or comparisons between countries. A range of national and international classifications on ecosystems and land cover are available, for example: Ecoregions of WWF [7]; Land cover classification of FAO[8]; Global Land cover of USGS[9]; and the asset classification of Landers and Nahlik (2013). A feature of the Landers and Nahlik (2013) classification is that its links to both ecosystems services and beneficiaries. The most appropriate classifications for ecosystem and biodiversity accounting are not yet known and are likely to vary from case to case.

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[5] IUCN Protected Area Categories http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/
[6] IUCN Threats Classification Scheme http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme
[7] Global 200 Ecoregions – Major habitat types. http://wwf.panda.org/about_our_earth/ecoregions/about/cited_literature.cfm
[8] Land cover classification System (LCCS) http://www.fao.org/docrep/003/x0596e/x0596e00.HTM
[9] Global Land Cover Charaterization http://edc2.usgs.gov/glcc/glcc.php

International land cover classifications are generally broad and derived mostly from satellite data. National classifications will undoubtedly be more detailed and are best suited to national decision-making. However, in order for accounts to be internationally comparable, concordances with more general international classification will be needed. Such comparisons could be useful for international organisations, NGOs and others in making investment decisions.

Appling ecosystem accounting to the Aichi Targets

Under the CBD 20 biodiversity targets were established, known as the Aichi biodiversity targets[10]. Many of the targets may be addressed via environment or ecosystem accounting (Table 4).

The aim of Aichi Target 2 is to place biodiversity into the mainstream decision-making frameworks of policy-makers (Rode et al. 2012). It is also implicit that biodiversity is to be incorporated into national accounting (i.e. the SNA), which among many things, produces the indicator GDP (Gross Domestic Product)(see UN et al. 2009). The SNA is one of the chief sources of information for governments and others about the functioning of the economy. It has a central place in the economic analyses feeding into government and corporate decision-making and policy development. It is an integrated economic information system that is unparalleled in environmental information.

By integrating biodiversity information into the SNA, biodiversity can considered in the main economic policy, resource allocation and planning tools used in decisions of governments. To achieve Aichi Target 2 the obvious path is to join existing ecological and economic understanding to the accounting concepts and structures of the SNA via the SEEA-EEA. However, the process for doing this is unclear.

[10] See Aichi Biodivieristy Targets http://www.cbd.int/sp/targets/

Table 4 Links between Aichi Targets and environmental and ecosystem accounts

Aichi Target	Relevant environmental and ecosystem accounts that would
1. By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.	-
2. 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.	All SEEA National Balance Sheet showing value of natural resources along with the value of other assets (SNA and SEEA CF) Ecosystem service accounts showing both physical levels and monetary values of services (SEEA-EEA)
3. By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions.	Environmental activity accounts (SEEA CF) – these accounts cover environmental protection expenditure, taxes, subsidies, etc.
4. By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.	Physical asset and supply-use accounts for water, timber, aquatic resources, minerals and energy (SEEA CF) Ecosystem extent and condition accounts (SEEA-EEA)
5. By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.	Land cover/ecosystem extent accounts (SEEA CF/SEEA-EEA) Ecosystem condition accounts (SEEA-EEA)
6. By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.	Physical asset and supply-use accounts for aquatic (SEEA CF) Ecosystem condition account (SEEA-EEA) Biodiversity accounts (SEEA-EEA) - species diversity account
7. By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.	Land cover/ecosystem extent and land use accounts (SEEA CF/SEEA-EEA) Biodiversity accounts (SEEA-EEA) - species diversity account
8. By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity	Ecosystem condition accounts (SEEA-EEA)
9. By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.	Possible links to Biodiversity accounts (SEEA-EEA) and Environmental activity accounts (SEEA CF)
10. By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.	Water emissions account (SEEA CF) Ecosystem condition account (SEEA-EEA) Ecosystem services account (SEEA-EEA)
11. By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes	Land cover/ecosystem extent and land use accounts (SEEA CF/SEEA-EEA) Ecosystem condition account (SEEA-EEA) Ecosystem services account (SEEA-EEA)
12. By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained	Biodiversity accounts (SEEA-EEA) – species diversity account

13. By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.	Biodiversity accounts (SEEA-EEA) – genetic diversity account. Not described in SEEA-EEA but feasible
14. By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable	Ecosystem condition account (SEEA-EEA) Ecosystem services account (SEEA-EEA)
15. By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.	Land cover/ecosystem extent account (SEEA CF/SEEA-EEA Ecosystem condition account (SEEA-EEA) Carbon asset account (SEEA-EEA) Ecosystem services account (SEEA-EEA)
16. By 2015, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation.	Biodiversity accounts (SEEA-EEA) – genetic diversity account. Not described in SEEA-EEA but feasible Ecosystem services account (SEEA-EEA)
17. By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.	-
18. By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.	-
19. By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.	Possible roles for: Ecosystem condition account (SEEA-EEA) Ecosystem services account (SEEA-EEA)
20. By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011-2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization, should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.	Environmental activity accounts (SEEA CF)

One process available is the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES). IPBES:

> "provides a mechanism recognized by both the scientific and policy communities to synthesize, review, assess and critically evaluate relevant information and knowledge generated worldwide by governments, academia, scientific organizations, non-governmental organizations and indigenous communities.[11]"

So far the development of the IPBES has not significantly engaged with the processes surrounding SEEA-EEA but there may be opportunities going forward, particularly given the increasing likelihood that the recently commenced IPBES Regional Assessments, and upcoming Global Assessment, of Biodiversity and Ecosystem Services will serve as key

[11] About IPBES http://www.ipbes.net/about-ipbes.html

foundations for the CBD's next Global Biodiversity Outlook assessing achievement of the Aichi targets in the lead-up to 2020.

Using ecosystem accounting in threatened species and protected area management

The management of threatened species and protected area management are cornerstones of conservation and policies, laws, practices and institutions have evolved for this purpose. Typically scientists and public officials involved in threatened species and protected area management have little knowledge of environmental or ecosystem accounting and how it could be applied.

Ecosystem accounting can help to show the benefits arising from protected areas. This was done for State of Victoria (Varcoe et al. 2015). Ecosystem accounting may also prove helpful for deciding on areas for the establishment of additional protected areas, as is being tested with the accounts being developed for the Central Highlands of Victoria (Section 5).

Accounting can also help to target particular areas, habitats or species for assistance. For example, habitats underrepresented in the protected area network (Aichi Target 11), and possible cost effective solutions for increasing these (e.g. expanding the protected area networks or implementation of schemes for the protection of habitats on private lands).

For threatened species, information on species distribution and abundance can be coupled with environment protection expenditures to help assess the efficiency of expenditures, and the optimum points of intervention (e.g. waiting until near extinction to act is likely to be more costly than action taken when declines are first apparent). This can be linked to Aichi Target 3.

Using ecosystem accounting to specific policy tools (e.g. biodiversity offsets and payments for ecosystem services)

There are more than 300 programs for payments for ecosystem services (Blackman and Woodward 2010) with a combined value of payment in excess of US$6.5 billion (OECD 2010). Linking accounts to these programs is a key opportunity.

As a specific example, biodiversity offsetting is a policy instrument that seeks to achieve sustainable development (Gibbons et al 2015). Biodiversity offsets are defined by the Business and Biodiversity Offsets Programme (BBOP 2012) as:

> "…measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development..."

Biodiversity offsetting is being implemented widely (ICMM and IUCN 2012, Madsen 2011). Offsetting, when applied to issues such as pollution or carbon dioxide is intended to represent a flexible alternative to command and control regulation because it theoretically allows development to continue or expand without detrimental net effect on the environment (e.g. Reid 2011). However, it has been argued that biodiversity can only be offset in a restricted range of circumstances because of the poor fungibility[12] of biodiversity, and thus no net loss is likely in only a narrow range of development scenarios (e.g. Gibbons et al. 2015). Thus, biodiversity offset policies have the potential to lead to the net loss of biodiversity if applied inappropriately (e.g. Curran et al. 2013).

In accounting terms, biodiversity offsetting represents a trade-off between assets in time and space. For example, a particular ecosystem may be lost in one place due to a development but is replaced by the protection and management of another ecosystem asset in another place, with no net loss of biodiversity over a defined time. Biodiversity offsetting in effect provide an exchange value for biodiversity, thus addressing one of the key challenges in ecosystem accounting.

Ecosystem accounting can also help with the analysis of specifically proposed biodiversity offsets as well as providing an on-going framework for monitoring to check that that over time these is no net loss of biodiversity. The monitoring would be to ensure that the overall extent and condition of ecosystems remains the same and extinction risks are not increased.

Biodiversity offsets are determined on the basis of equivalence of assets—there is no consideration of the service flows associated with the. The service flows from ecosystem assets with comparable composition, structure and function could be very different due to the ability of people to access these services. For example, Carnaby's Black Cockatoo (*Calyptorhynchus latirostris*) is a threatened species[13] in the city of Perth, Australia that is under threat from urban development. Biodiversity offsets for this species focus on habitat restoration beyond the urban area, diminishing the availability of amenity and tourism values of this species to residents and visitors to Perth. In another hypothetical example, a particular woodland on the edge of a city may be comparable in terms of its composition structure and function to another woodland in a remote place, but the services flows would be different. For example, regulating services like water and air filtration may not exist in remote areas as there are no beneficiaries.

8. Acknowledgements

We would like to thank a range of colleagues for discussion over the years and various ideas that have found their way into the paper. In particular, the participants in the workshop on "*Metrics for Biodiversity Accounting and Policy*" held at the Centre of Excellence for Environmental Decisions at the University of Queensland November 2014: Suzi Bond; Ben Collen; Hedley Grantham; Lars Hein; Mark Lound; Michael McCarthy; Jane McDonald; Emily Nicholson; Hugh Possingham and; Kerrie Wilson. (Simon Ferrier and Michael Vardon also participated in the workshop).

We would also like to thank: Carl Obst; Peter Burnett; Mark Eigenraam; Rocky Harris, Michael Bordt; Nicholas Bertrand; John Power; Glenn-Marie Lange; Ken Bagstad; David Salt; Emma Burns; Georgina Mace, and; Jacqueline Birt.

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[12] **Fungibility** is the property of a good or a commodity whose individual units are capable of mutual substitution. That is, it is the property of essences or goods which are capable of being substituted in place of one another. https://en.wikipedia.org/wiki/Fungibility

[13] http://www.environment.gov.au/biodiversity/threatened/publications/factsheet-carnabys-black-cockatoo-calyptorhynchus-latirostris

We also acknowledge funding from the Fujitsu Laboratories Ltd contributing to the study in the Central Highlands of Victoria and the World Bank for work on policy applications of ecosystem accounting.

John Stein prepared Figs 1 and 2.

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Annex 1. List of threatened species in the Central Highlands of Victoria

Species	Common name	Source	EPBC category	IUCN Red List	FFG Act	Vic Advisory List
Mammals						
Antechinus minimus maritimus	Swamp Antechinus	2			Listed	Near Threatened
Burramys parvus	Mountain Pygmy-possum	2	Endangered 16/7/2000	Critically Endangered	Listed	Critically Endangered
Dasyurus maculatus maculatus	Spotted-tailed Quoll	1, 2, 4, 5	Endangered 14/5/2004			
Gymnobelideus leadbeateri	Leadbeaters Possum	1,2,3,4,5	Critically Endangered 2/5/2015	Endangered	Listed	Endangered
Isoodon obesulus obesulus	Southern Brown Bandicoot	4	Endangered 29/3/2001		Listed	Near Threatened
Miniopterus schreibersii	Common Bent-wing Bat	2, 4, 5		Near Threatened	Listed	
Miniopterus schreibersii oceanensis	Eastern Bent-wing Bat	4		Least concern	Listed	
Perameles gunnii	Eastern Barred Bandicoot	1, 3, 4	Endangered 16/7/2000	Near Threatened	Listed	Extinct in the wild ?
Petaurus norfolcensis	Squirrel Glider	2		Least concern	Listed	Endangered
Phascogale tapoatafa	Brush-tailed Phascogale	2, 5		Near Threatened		Vulnerable
Pseudomys fumeus	Smoky Mouse	1,2,3,4,5	Endangered 16/7/2000	Endangered	Listed	Endangered
Rhinolophus megaphyllus megaphyllus	Eastern Horseshoe Bat	3, 4			Listed	Vulnerable
Sminthopsis leucopus	White-footed Dunnart	4		Vulnerable	Listed	Near Threatened
Reptiles						
Lissolepis coventryi	Eastern Mourning Skink	2, 3, 4			Listed	Vulnerable
Pseudemoia cryodroma	Alpine Bog Skink	1, 2			Listed	Endangered
Pseudemoia rawlinsoni	Glossy Grass Skink	2, 4				Vulnerable
Vermicella annulata	Bandy-bandy Snake	2			Listed	Vulnerable
Amphibians						
Litoria raniformis	Southern Bell Frog	1, 4	Vulnerable 16/7/2000	Endangered	Listed	Endangered
Litoria spenceri	Spotted Tree Frog	2	Endangered 16/7/2000	Critically endangered	Listed	Critically endangered

Litoria verreauxii alpina	Alpine Tree Frog	1, 5	Vulnerable 16/7/2000		Listed	Critically endangered
Philoria frosti	Baw Baw Frog	1, 2	Endangered 16/7/2000	Critically endangered	Listed	Critically endangered
Pseudophryne bibronii	Brown Toadlet	3, 4		Near Threatened	Listed	Endangered
Pseudophryne semimarmorata	Southern Toadlet	3, 4				Vulnerable
Fish						
Gadopsis marmoratus	River Blackfish	2, 3, 4, 5			Listed	Critically endangered
Galaxias fuscus	Barred Galaxia	1,2,3,4,5	Endangered 16/7/2000	Critically endangered	Listed	Critically endangered
Galaxias rostratus	Flathead Galaxias	2		Vulnerable		Vulnerable
Galaxiella pusilla	Dwarf Galaxias	1, 2	Vulnerable 16/7/2000	Vulnerable	Listed	Endangered
Nannoperca obscura	Yarra Pygmy Perch	4	Vulnerable 1/3/2010	Vulnerable	Listed	Vulnerable
Prototroctes maraena	Australian Grayling	2, 4	Vulnerable 16/7/2000	Vulnerable	Listed	Vulnerable
Birds						
Actitis hypoleucos	Common Sandpiper	4				Vulnerable
Anas (Spatula) rhynchotis rhynchotis	Australasian Shoveler	4				Vulnerable
Anseranas semipalmata	Magpie Goose	4			Listed	Near Threatened
Anthochaera phrygia	Regent Honeyeater	1,2,3,4	Critically Endangered 8/7/2015	?	Listed	Critically endangered
Ardea (Casmerodius) modesta	Eastern Great Egret	3, 4			Listed	Vulnerable
Aythya (Nyroca) australis	Hardhead Duck	3, 4				Vulnerable
Biziura lobata	Musk Duck	3, 4				Vulnerable
Botaurus poiciloptilus	Australasian Bittern	3	Endangered 3/3/2011	Endangered	Listed	Endangered
Burhinus (Burhinus) grallarius	Bush Stone Curlew	3		Near Threatened	Listed	Endangered
Calamanthus pyrrhopygius	Chestnut-rumped Heathwren	3			Listed	Vulnerable

Chthonicola sagittata	Speckeld Warbler	3			Listed	Vulnerable
Chthonicola sagittata	Speckled Warbler	4			Listed	Vulnerable
Egretta garzetta nigripes	Little Egret	4			Listed	Endangered
Excalfactoria chinensis victoriae	King Quail	4			Listed	Endangered
Falco (Hierofalco) subniger	Black Falcon	3				Vulnerable
Geopelia cuneata	Diamond Dove	4			Listed	Near Threatened
Grantiella picta	Painted Honey eater	3, 4		Near Threatened	Listed	Vulnerable
Ixobrychus dubius	Little Bittern	4			Listed	Endangered
Lewinia pectoralis pectoralis	Lewin’s Rail	4			Listed	Vulnerable
Lichenostomus melanops cassidix	Yellow-tufted (Helmeted) Honeyeater	4	Critically Endangered 6/11/2014		Listed	Critically endangered
Lophoictinia isura	Square-tailed Kite	2, 4		Least Concern	Listed	Vulnerable
Melanodryas (Melanodryas) cucullata cucullata	Hooded Robin	4			Listed	Near Threatened
Neophema pulchella	Turquoise Parrot	2, 4		Least Concern	Listed	Near Threatened
Ninox (Hieracoglaux) connivens connivens	Barking Owl	4, 5			Listed	Endangered
Ninox strenua	Powerful Owl	2, 3, 4, 5		Least Concern	Listed	Vulnerable
Oxyura australis	Blue-billed Duck	3, 4		Near Threatened	Listed	Endangered
Porzana pusilla palustris	Baillon's Crane	4			Listed	Vulnerable
Stagonopleura guttata	Diamond Firetail Finch	3, 4		Near Threatened	Listed	Vulnerable
Stictonetta naevosa	Freckled Duck	4		Least Concern	Listed	Endangered
Turnix pyrrhothorax	Red-chested Button Quail	4		Least Concern	Listed	Vulnerable
Tyto (Megastrix) novaehollandiae novaehollandiae	Masked Owl	4			Listed	Endangered
Invertebrates						
Acrodipsas myrmecophila	Small Ant-blue Butterfly	3, 4			Listed	Critically Endangered

Archaeophylax canarus	Caddisfly	2			Listed	
Austrogammarus australis	Dandenong Freshwater Amphipod	3, 4		Extinct ?	Listed	Endangered
Austrogammarus haasei	Sherbrooke Amphipod	3, 4			Listed	Vulnerable
Canthocamptus dedeckkeri	Harpactacoid Copepod	5		Vulnerable		Vulnerable
Engaeus curvisuturus	Curve-tail Burrowing Cray	4		Endangered	Listed	Endangered
Engaeus tuberculatus	Tubercle Burrowing Cray	3				Endangered
Engaeus urostrictus	Dandenong Burrowing Cray	4		Endangered	Listed	Critically Endangered
Engaeus victoriensis	Foothill Burrowing Cray	3				Endangered
Hemiphlebia mirabilis	Ancient Greenling Damselfly	3		Endangered	Listed	Endangered
Pasma tasmanica	Tasmanica Skipper Butterfly	4				Vulnerable
Plectrotarsus gravenhorstii	Caddisfly	4				Vulnerable
Pseudalmenus chlorinda zephyrus	Silky Hairstreak Butterfly	4				Vulnerable
Riekoperla darlingtoni	Mount Donna Buang Wingless Stonefly	3, 4, 5		Vulnerable	Listed	Critically Endangered
Riekoperla intermedia	Stonefly	2			Listed	Endangered
Synemon plana	Golden Sun Moth	4	Critically Endangered 20/11/2002		Listed	Critically Endangered
Temognatha sanguinipennis	Jewel Beetle	3, 4				Vulnerable
Plants						
Acacia verniciflua	Stinkwood Bush	4				Vulnerable
Adiantum capillus-veneris	Dainty-Maiden-hair Fern	3, 4			Listed	Endangered
Astelia australiana	Tall Astelia	2, 4	Vulnerable 16/7/2000		Listed	Vulnerable
Asterolasia asteriscophora subsp. albiflora	White Star-bush	4			Listed	Endangered

Botrychium australe	Austral Moonwort	2, 3			Listed	Vulnerable
Caladenia concolor	Crimson Spider Orchid	2			Listed	Endangered
Caladenia oenochila	Wine-lipped Spider-orchid	4				Vulnerable
Caladenia reticulata	Veined Caladenia	4				Vulnerable
Callitriche umbonata (cyclocarpa)	Water Starwort	4			Listed	Vulnerable
Cardamine astoniae	Spreading Bitter-cress	4				Vulnerable
Cardamine lilacina	Lilac Bitter-cress	4				Vulnerable
Carex inversa	Knob Sedge	4			Listed	Vulnerable
Correa reflexa	Common Correa	4				Vulnerable
Cyathea cunninghamii	Slender Tree Fern	2, 4, 5			Listed	Vulnerable
Cyathea x marcescens	Skirted Tree-fern	4				Vulnerable
Dianella amoena	Grassland Flaxlily	4	Endangered 11/7/2000		Listed	Endangered
Dianella revoluta	Black-anthered Flaxlily	4				Vulnerable
Distichium capillaceum	Fine Fringe-moss	4				Vulnerable
Diuris behrii	Golden cowslip	4				Vulnerable
Diuris palustris	Swamp Diuris	2			Listed	Vulnerable
Erigeron pappocromus	Violet Fleabane	2				Vulnerable
Eucalyptus crenulata	Buxton Gum	1	Endangered 16/7/2015		Listed	Endangered
Euphrasia collina ssp. muelleri	Purple Eyebright	1	Endangered 16/7/2000		Listed	Endangered
Ficus coronata	Sandpaper Fig	4			Listed	Vulnerable
Gahnia grandis	Brickmakers Sedge	2				Vulnerable
Gahnia grandis	Brickmakers Sedge	4				Vulnerable
Glycine latrobeana	Clover Glycine	1, 3, 4	Vulnerable 16/7/2000		Listed	Vulnerable

Grammitis magellanica subsp. nothofageti	Beech Finger-fern	4				Vulnerable
Grevillea barklyana ssp barklyana	Gully Grevillea	2, 4			Listed	Vulnerable
Grevillea parvula	Genoa Grevillea	4				Vulnerable
Grevillea polychroma	Royal Grevillea	4				Vulnerable
Hovea asperifolia	Rosemary Hovea	4				Vulnerable
Huperzia varia	Long Clubmoss	2				Vulnerable
Lastreopsis decomposita	Trim Shield-fern	4				Vulnerable
Microseris lanceolata	Murrnong	4				Vulnerable
Nematolepis squamea	Harsh Nematolepis	4	Vulnerable 11/7/2000		Listed	Vulnerable
Nematolepis wilsonii	Shiny Nematolepis	4, 5	Vulnerable 11/7/2000		Listed	Vulnerable
Olearia pannosa subsp. cardiophylla	Velvet Daisy-bush	4			Listed	Vulnerable
Olearia rugosa	Wrinkled Diasy-bush	4				Vulnerable
Pedinophyllum monoicum	Southern Pedinophyllum	4, 5			Listed	Vulnerable
Persoonia arborea	Tree Geebung	2, 4, 5				Vulnerable
Pomaderris vacciniifolia	Round-leaf Pomaderis	4	Critically Endangered 15/1/2014		Listed	Endangered
Prasophyllum frenchii	French’s Leek Orchid	1, 4	Endangered 16/7/2015		Listed	Endangered
Prasophyllum lindleyanum	Green Leek Orchid	4				Vulnerable
Prasophyllum pyriforme	Graceful Leek Orchid	4				Endangered
Pterostylis cucullata	Leafy Greenhood	1, 5	Vulnerable 16/7/2000		Listed	
Pterostylis truncata	Brittle Greenhood	4			Listed	Endangered
Pultenaea blakelyi	Blakely's Bush-pea	4				Endangered
Senecio psilocarpus	Smooth-fruited Groundsel	4	Vulnerable 11/7/2000			Vulnerable
Thelymitra circumsepta	Naked Sun Orchid	4				Vulnerable

Thismia rodwayi	Fairy Lantern	2, 4				Listed	Vulnerable
Thuidium laeviusculum	Forest Weft-moss	4					Vulnerable
Tmesipteris elongata	Elongate Fork-Fern	2, 4					Vulnerable
Zieria cytisoides	Downy Zieria	4					Vulnerable

Data sources:
1. VicForests Sustainability Report of threatened fauna and flora listed under EPBC and IUCN Red List, in Victorian lands under VicForests jurisdiction. Conservation status derived from Atlas of Living Australia for EPBC, IUCN, FFG and Victorian Advisory Body.
2. VicForests Operating Procedures Regulatory Handbook fauna and flora prescriptions for the Central Highlands Forest Management Area, list of species. Conservation status derived from Atlas of Living Australia for EPBC, IUCN, FFG and Victorian Advisory Body.
3. Atlas of Living Australia local region Yarra Ranges, species filtered by ‘state conservation - endangered’, and where species habitat occurred in the Central Highlands study region.
4. Atlas of Living Australia local region Baw Baw, species filtered by ‘state conservation - endangered’, and where species habitat occurred in the Central Highlands study region.
5. Parks Victoria Plan of Management for Yarra Ranges National Park, appendices of threatened flora and fauna.

Notes:
All species from these lists were checked in the Atlas of Living Australia for their conservation status and included if it was 'vulnerable' or more in any classification system.

Change in EPBC category: Leadbeaters Possum, Regent Honeyeater and Yellow- tufted Honeyeater were changed from Endangered to Critically Endangered in 2015. Assume that the Endangered listing was in 2000, but there is no record of first listing. Pomaderris was a new listing of Critically Endangered in 2014.

All other species listed have no record of their listings being amended, hence assume that there has been no change to their classifications.