Proposed biodiversity accounts for Australia

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1. Introduction

1. In concept, biodiversity is partly within the scope of the SEEA Central Framework. While in physical terms all biodiversity is included (its components are all environmental assets), in monetary terms only those components of biodiversity that meet the System of National Accounts asset or production boundaries are in scope.

2. This paper has been prepared to outline the key concepts and provide draft tables to more fully account for biodiversity. It builds on the papers[1] presented at the 2nd Expert Meeting on Ecosystem Accounts in (London - December 2011) as well as the "outcome" paper prepared for the SEEA part 2 Editorial Board meeting (New York - March 2012).

3. Before examining the key concepts and proposing draft accounting tables we briefly summarise the policy relevance and some of the key issues in accounting for biodiversity. This includes accounting for biodiversity in the context of ecosystem accounting (which we understand to be a spatially defined area, containing biodiversity other environmental assets and the interactions between these assets and the flows from the assets).

2. Policy relevance and use

4. There are several international agreements concerning biodiversity and conservation of biodiversity. Perhaps the most important is the Convention on Biological Diversity (Secretariat of the Convention on Biological Diversity 2003). At the 2010 Conference of the Parties to Convention on Biological Diversity (COP 10) many targets relating to biodiversity where set under broad goals including to:
    - Address the underlying causes of biodiversity loss…
    - Reduce the pressures on biodiversity and promote sustainable use
    - Improving the status of biodiversity by safeguarding ecosystems, species and genetic diversity (COP 10)

5. Biodiversity accounts first and foremost can be used to set and track progress towards (or away from) policy targets. Policy targets may include:
    - Protection threatened species or threatened species habitat
    - Maintain and improve ecosystem health
    - Avoidance of extinctions
    - Protection of representative examples of all ecosystems
    - Protect areas of high biodiversity values such as hotspots
    - Sustainable use of wild harvested populations

6. There is greater scrutiny to demonstrate a return on investment for public expenditure on the environment (Australian National Audit Office 2008), which is becoming relevant to all environmental policy decisions as we attempt to optimise scarce finances or resources for environmental protection (Harper and Hawksworth 1994). Linking expenditure on different biodiversity conservation activities to changes to the actual change in biodiversity will have significant policy implications.

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[1] Key Concepts for Accounting for Biodiversity (J. McDonald); Developing a Diagnostic Species and Biotope Index for Europe (E. Ivanov, R.

7. Other applications of biodiversity accounting which may have a direct relevance to biodiversity policy include: identification of high quality areas (Wright, Moss et al. 1984; Parrish, Braun et al. 2003; Karr 2005) and the diagnostic capacity (Karr 2005) afforded in the long term as we interpret measured biodiversity change in the context of known human impact.

8. How biodiversity is defined greatly influences its place (and scope) in accounting. Biodiversity has been defined as 'the variability among living things and the ecosystem they inhabit' (Secretariat of the Convention on Biological Diversity 2003). The scientific community has conceptualised biodiversity as a hierarchy of genes, species and ecosystems (Norse 1986; Office of Technology Assessment 1987). These levels and the diversity of these levels are represented in Figure 1.

Defining biodiversity

9. How biodiversity is defined greatly influences its place (and scope) in accounting. Biodiversity has been defined in practical terms as 'the variability among living things and the ecosystem they inhabit' (Secretariat of the Convention on Biological Diversity 2003).[2] The scientific community has categorised levels of biodiversity: genes, species and ecosystems (Norse 1986; Office of Technology Assessment 1987). These levels and the diversity of these levels are represented in Figure 1.

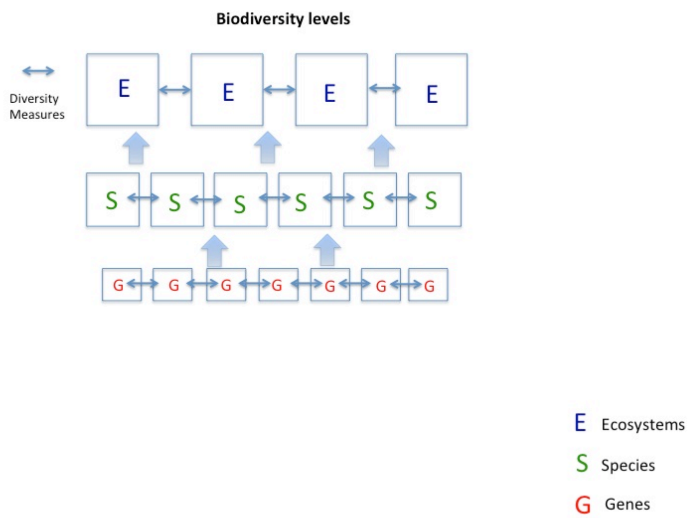

Figure 1. The three recognised levels of biodiversity (ecosystems, species and genes). Horizontal arrows diversity within levels. Upward arrows indicate that each level is embedded in higher levels.

10. For the purposes of this accounting framework we consider only species and ecosystems (Table 1).

[2] This is essential from a management perspective, but for accounting purposes, the narrower definition 'the variability among living things' would seem necessary.

Table 1: Levels of biodiversity and the scope of accounting

Types of BIODIVERSITY					
	LEVEL of biodiversity	**COMPONENT of biodiversity**	**Examples of economic COMPONENTS**	**Examples of non-economic COMPONENTS**	**Measures of Biodiversity**
Biodiversity	Ecosystem	Diversity of ecosystems Individual ecosystems	Harvested ecosystems such as forests for timber and fish from oceans Ecosystem services	Native forests Rivers Ecosystem services	Area of ecosystem Condition of ecosystem 1. Structure 2. Composition 3. Process and function 4. Internal diversity
	Species	Diversity of species Individual species	Commercial species such as fish and trees for timber. Domestic species.	Non-commercial species such as threatened species	1. Species Richness 2. Abundance of individual species 3. Functional trait of species 4. Composition of species 5. Distribution
	Genes	*Not within accounting scope*			

11. Policy objectives will often, although not always, target specific components of biodiversity and subsets of biodiversity (2 and 3 in Figure 2 and 3). These all relate to components or subsets of biodiversity. Instead of trying to capture biodiversity in all its complexity, a more pragmatic approach may be to capture parts of biodiversity that are policy relevant. A limitation with this approach is that at a higher level there are international agreements to reduce biodiversity loss (Secretariat of the Convention on Biological Diversity 2003). The optimal amount of biodiversity may be achieved by an ecosystem approach.

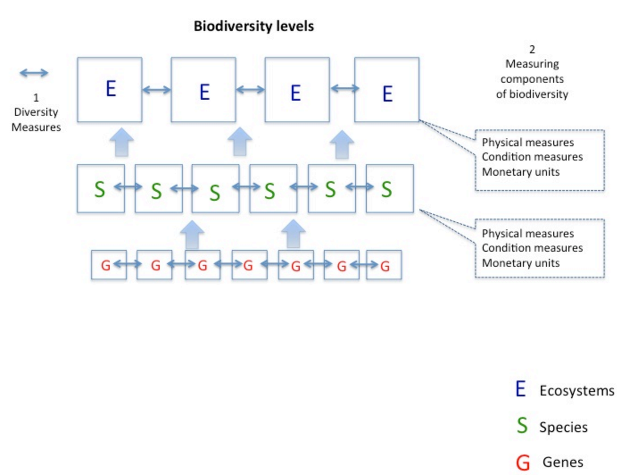

Figure 2: An individual ecosystem and individual species can be considered a component of biodiversity. These can be accounted for individually with physical, condition or monetary units.

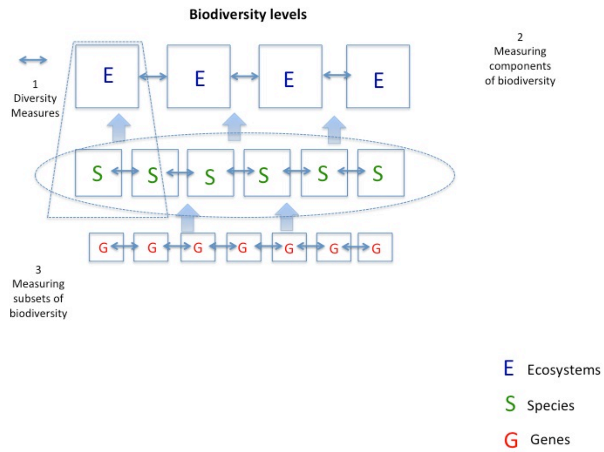

Figure 3: Subsets of biodiversity can be measured in an attempt to 'represent' biodiversity or respond to a particular policy objective.

12. All of these levels (or components) of biodiversity can be included in environmental accounting but for practical purposes it is likely that the higher levels of this hierarchy such as populations, species and ecosystems will be the focus. For example, genes are not considered here.

3. Some issues for biodiversity accounting

Biodiversity as an asset

13. In this paper we concentrate on biodiversity as an asset. Accounting for biodiversity with an asset account is arguably the most straightforward and intuitive method of accounting, and most likely to appeal to the scientific (and wider) audience.

14. At the 2010 Conference of the Parties to Convention on Biological Diversity (COP 10) a target relating to the recording of value of biodiversity was included: Target 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." (COP 10)

15. In addition, a policy goal of preserving biodiversity is part of environmental policy and national legislation of most major economies. These are a reflection of the values society places on biodiversity assets (and the land asset in which they are contained) and provide a clear indication that humanity derives some benefit from the persistence of biodiversity.

Classifying species distribution and abundance

16. Categorising distribution and abundance of species is a key issue for biodiversity accounts. It can be measured in absolute terms (i.e. number per hectare) in species. Abundance of species can also be described in relative terms: this can be relative to the abundance of other species (e.g. pigeons are common, Peregrine Falcons are rare) or in terms of current abundance relative to former abundance, which is the IUCN Red List approach (described in more detail below).

17. In the accounts below two categorisations are used. The categories used for the regional data are drawn from a state based data system and the Australian data are based on the IUCN classification. In both cases the same concept, species abundance now relative to the past, is used.

18. The IUCN Red List classification has been adopted for the purpose of this paper as the data are available for Australia as well as much of the world. As such it has the potential for global comparisons. It is also considered the most objective system for evaluating extinction risk at a

national and global scale (Szabo, Butchart et al. 2012). The criteria for the classification have not been examined in detail, but the use of standard criteria with quantitative thresholds, would seem to be the best approximation of the needs of biodiversity accounting.

Terrestrial biodiversity

19. In this paper, the focus is mostly on terrestrial biodiversity. While the structure of the accounts presented below is for terrestrial species, it is likely to be applicable to marine species, but this has not yet been tested and some additional work will be needed.

Measuring the condition of biodiversity and relating it to ecosystem condition

20. Condition accounts have the capacity to capture more of the biodiversity than simple physical accounts. Condition accounts contain measures relative to a biologically relevant baseline which places the measures in biological context and allows the comparison between species, sets of species and geographic areas.

21. Biodiversity condition accounts could feed into the other biodiversity accounts. As described above biodiversity can be used as one of the measures of the condition of ecosystems, and may be accounted for as an ecosystem service (intermediate and final).

22. Employing biodiversity accounting to measure the condition of ecosystems is the focus of the work of Weber (EEA 2011) and outlined in the experimental framework for ecosystem capital accounting in Europe and methods are being developed as part of the Australian Environmental Accounts model based on ecosystem condition (Cosier and McDonald 2010; Cosier 2011; EEA 2011). Biodiversity condition accounts are compatible with the intended structure of an ecosystem condition account because it requires a metric of 0-100 to add to other indicators. It is important that the measure of biodiversity is fit-for-purpose to reflect the condition of ecosystems i.e. not all species or components of biodiversity are sensitive to changes in the condition ecosystems.

23. Equally the metrics built in a condition account are amenable to ecosystem services accounting. A biodiversity flow could be accounted for by the change in condition metric, especially if it were connected to an ecosystem or habitat (see Section 9 -The link between habitat and biodiversity).

24. Attempts to date to quantify a biodiversity flow from ecosystems include the UK Ecosystem Assessment new subcategory of 'wild species diversity' (UK National Ecosystem Assessment 2011) . Other examples include the Habitat Hectares metric, which has been used as a surrogate for biodiversity in Victoria, Australia (Parkes, Newell et al. 2003). This is an index of vegetation condition, extent and connectivity relative to an 'undisturbed' benchmark. An Environmental Benefits Index is another method of measuring bundles of services of which habitat for flora and fauna is one (Eigenraam, Vardon et al. 2011).

4. Draft biodiversity accounts

25. This section contains draft biodiversity accounts populated with data for Australia. In many cases cells are empty as data needed to populate them were unavailable to the authors at the present time but at least some of the information is thought to exist and may be available given more time.

26. The accounts can be developed and used for different spatial levels (i.e. national, state/provincial and local) and for all species or for groups of species. Examples of national and local tables (for natural resource management regions) as well as for a particular taxonomic group are presented.

27. Specifically, the accounts presented are:

- Status of terrestrial species, Australia, 2011 (Table 2)
- Terrestrial species asset account for Australia, 2010 to 2011 (Table 3)
- Native and introduced species asset account for the Burdekin NRM (Table 4)
- Asset account for Australian Parrots, 1995-96 and 2008-09 (Table 5)
- Native species condition asset account (Australian Native Birds) (Table 6)

28. The accounts use species and species status as the basis of the tables. Species and species status are defined according to accepted international classifications: species according to Linnaean system of classification and status according to the IUCN Red List, both of which are outlined briefly below. The spatial areas used in this exercise are the natural resource management regions of Australia. Other spatial units could be used in Australia and countries will need to determine the most appropriate spatial units below the national level for data aggregation and presentation.

29. Linnaeus classified life into kingdoms, classes, orders, families, genera, and species, and thus created the foundation for biological nomenclature, particularly with his simplified binomial naming system (genus and species). The classification has been evolving since its inception in the 18th Century. The tables presented use species as the 'units' of biodiversity, and the concept of species follows the Linnaean system of classification. http://www.nhm.ac.uk/nature-online/science-of-natural-history/biographies/linnaeus/index.html and http://en.wikipedia.org/wiki/Linnaean_taxonomy

30. *IUCN Red List of Threatened Species* is an objective global approach for evaluating the conservation status of plant and animal species. The goal of the IUCN Red List is to provide information and analysis on the status, trends and threats to species in order to inform and catalyse action for biodiversity conservation. http://www.iucnredlist.org/about/red-list-overview

31. Natural Resource Management (NRM) regions were established in the early 2000's by the Australian Government, in association with State and Territory governments. They identified 56 regions covering all of Australia which form the basic spatial unit for the funding, monitoring and reporting of Australian environmental data and issues. These 56 NRM regions are boundaries based predominately on catchments or bioregions. For each NRM region there is a regional management body (or Catchment Management Authority) that has a partnership with the Australian Government to manage the NRM and deliver environmental outcomes at the regional level, over the period until June 2013. For each NRM region, administrative Biodiversity Summaries have been developed. For details see http://www.environment.gov.au/heritage/anhat/summaries/index.html

Structure of accounts

32. The physical biodiversity asset account follows the general form of assets accounts from the SEEA Central Framework, with opening stock, additions, reductions and closing stock The rows of the account are:

- ***Opening stock*** is the status of species at the stated point in time (e.g. 2010),
- ***Additions from lower threat categories***, which indicates an increased risk of extinction for species;
- ***Additions from higher threat categories,*** which indicates a reduced risk of extinction for species;
- ***Additions from discoveries of new species***, which includes the detection of species that were previously unknown to science;

- ***Additions from reclassifications*,** where one existing species is now recognised as two or more distinct species;
- ***Additions from updated assessments***, where a species remains in the same IUCN category but shows up as a new addition in the IUCN year list because it has been removed from previous list years;
- ***Additions from new additions to the IUCN list***, where a species has been assessed for the first time.
- ***Reductions to lower threat categories***, which indicates a reduced risk of extinction for species;
- ***Reductions to higher threat categories***, which indicates an increased risk of extinction for species;
- ***Reductions from reclassifications***, where two or more existing species are now recognised as one species;
- ***Reductions from updated assessments***, where a species has previously been unlisted by the IUCN in the opening stock year;
- ***Net change*** the additions less reductions
- ***Closing stock*** is the status of species at the later stated point in time (e.g. 2011).

33. The IUCN Red List categories in the columns are:

- ***Extinct*** is when there is no reasonable doubt that the last individual of a species has died;
- ***Extinct in the wild*** is when a taxon is known to only survive in cultivation, in captivity or as a naturalised population (or populations) well outside the past range;
- ***Critically endangered*** is when a taxon is considered to be facing an extremely high risk of extinction in the wild;
- ***Endangered*** is when a taxon is considered to be facing a very high risk of extinction in the wild;
- ***Vulnerable*** is when a taxon is considered to be facing a high risk of extinction in the wild;
- ***Near Threatened*** is when a taxon is close to qualifying for or is likely to qualify for a threatened category in the near future;
- ***Least concern*** is when a taxon is widespread and abundant;
- ***Data deficient*** is when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status (data deficient is therefore not a category of threat); and
- ***Not evaluated*** is when a taxon has not yet been evaluated against the IUCN threat criteria.

Physical accounts for biodiversity

34. The starting point for terrestrial biodiversity asset accounts is provided in Table 2. It shows the number of species by Kingdom for Australia in 2011. It is important to note that all kingdoms have been assessed according to the IUCN threat categories. For example, the rows for Fungi and Protista are empty. This also highlights the fact that for different kingdoms there is a different degree or completeness of knowledge. The best-known groups are the vertebrate animals and these may be a proxy for all species (or of biodiversity).

35. Table 3 shows an asset account for the period 2010 and 2011. The opening stock is for a particular point in time and in this case is taken to be 31 December 2010, while the closing stock is for 31 December 2011. In this time there were no reductions to the Red List categories for Australia, and most of the additions were from the inclusion of 189 species to the category of Least Concern.

Table 2. Status of terrestrial species, Australia, 2011

	IUCN Red List categories									
	Extinct	Extinct in the wild	Critically endangere d	Endangere d	Vulnerable	Lower risk	Near threatened	Data deficient	Least concern	**TOTAL**
Animals										
Mammals	19	0	10	20	25	0	32	36	205	**347**
Birds	0	0	2	20	29	0	28	0	605	**684**
Reptiles	0	0	8	10	25	0	10	12	137	**202**
Amphibians	3	0	15	18	14	0	9	11	153	**223**
Insects	0	0	9	11	18	0	10	18	69	**135**
Subtotal										
Fungi	0	0	0	0	0	0	0	0	0	**0**
Protista	0	0	0	0	0	0	0	0	0	**0**
Plants	1	0	4	17	46	7	24	3	322	**424**
TOTAL	**23**	**0**	**48**	**96**	**157**	**7**	**113**	**80**	**1491**	**2015**

36. Table 4 is the account for 2000 and 2011 for the Burdekin NRM, one of the regions, which drain into the Great Barrier Reef lagoon. The data presented are provided by the Department of Environment and Resource Management (DERM Queensland) and presents information for species according to the Linnaean binomial system. The data on species abundance are categorised by the classes used by the Queensland government, not according to the IUCN Red List. The Queensland system distinguishes species, which occur in particular regions according to whether they have been introduced, if they are native, if they are rare or endangered, and if they are protected. It also shows that there has been an overall increase in species in every category. Species in the table could be grouped in a number of different ways, such as subdivision of terrestrial and marine habitat.

37. In relation to Table 4, one issue is how to account for species at the regional scale that were not present in the past, but are now currently present. This does not necessarily mean that these species were previously extinct, but rather that these species previously did not occur within the boundaries of the NRM region. Obviously the converse situation of species lost from the NRM region, which were previously there, raises the same issue. This could be accounted for in the discoveries by expanding the scope but may be better dealt with via inclusion of extra rows to account for the shift in the range of species.

Table 3. Terrestrial species asset account for Australia, 2010 to 2011

	IUCN Red List categories									
	Extinct	Extinct in the wild	Critically endangered	Endangered	Vulnerable	Lower risk	Near threatened	Data deficient	Least concern	**TOTAL**
Opening stock 2010	**23**	**0**	**46**	**96**	**157**	**7**	**112**	**78**	**1302**	**1821**
Additions										
- from lower threat categories	0	0	0	0	0	0	0	0	0	**0**
- from higher categories	0	0	0	0	0	0	0	0	0	**0**
- discoveries of new species	0	0	0	0	0	0	0	0	0	**0**
- rediscoveries of extinct species	0	0	0	0	0	0	0	0	0	**0**
- reclassifications	0	0	0	0	0	0	0	0	0	**0**
- updated assessments	0	0	2	0	0	0	1	1	11	**15**
- new additions to list	0	0	0	0	0	0	0	1	178	**179**
Total additions	0	0	2	0	0	0	1	2	189	**194**
Reductions	0	0	0	0	0	0	0	0	0	**0**
- to lower threat categories	0	0	0	0	0	0	0	0	0	**0**
- to higher categories	0	0	0	0	0	0	0	0	0	**0**
- reclassifications	0	0	0	0	0	0	0	0	0	**0**
- updated assessments	0	0	0	0	0	0	0	0	0	**0**
Total reductions	0	0	0	0	0	0	0	0	0	**0**
Net change	0	0	2	0	6	0	1	2	189	**388**
Closing stock 2011	**23**	**0**	**48**	**96**	**157**	**7**	**113**	**80**	**1491**	**2015**

Table 4. Native and introduced species(a) asset account for the Burdekin NRM.

Burdekin NRM	Introduced	Native species				
		Unprotected	Protected	Rare and endangered	*Total native species*	Total species
Opening stock 2000	408	74	4280	179	4354	4762
Additions						
-from lower threat categories (ie increased risk of extinction)	NA	NA	NA	NA	NA	NA
-from higher threat categories (ie reduced risk of extinction)	NA	NA	NA	NA	NA	NA
-discoveries of new species	NA	NA	NA	NA	NA	NA
-rediscoveries of extinct species	NA	NA	NA	NA	NA	NA
-reclassifications(b)	NA	NA	NA	NA	NA	NA
Total additions	NA	NA	NA	NA	NA	NA
Reductions						
-to lower threat categories (ie reduced risk of extinction)	NA	NA	NA	NA	NA	NA
-to higher threat categories (ie increased risk of extinction)	NA	NA	NA	NA	NA	NA
-reclassifications(c)	NA	NA	NA	NA	NA	NA
Total reductions	NA	NA	NA	NA	NA	NA
Net change	*121*	*34*	*353*	*30*	*387*	*508*
Closing stock 2011	529	108	4633	209	4741	5270

(a) The species in this table includes mammals, birds, reptiles, amphibians, bony fish, cartilaginous fish, insects, plants, fungi and protista.
(b) Where one existing species is now recognised as two or more distinct species
(c) Where two or more existing species are now recognised as one species

38. Table 5 shows an account for the Australian Psittacidae (parrots), using data from the IUCN as an example of an asset account. This example perhaps provides a better illustration of the changes over time.

39. In terms of the data in the table, if a parrot species was not deemed to be in danger (i.e. Least Concern), it was not added until later editions of the Red List (i.e. from 2004 onwards). In terms of changes to particular species, the status of three species (glossy black-cockatoo, scarlet-chested

parrot and Alexandra's parrot) improved their status from vulnerable to least concern/near threatened, and four species (orange-bellied parrot, swift parrot, Baudin's black-cockatoo and Carnaby's black-cockatoo) declined in status from vulnerable/endangered to endangered/critically endangered. The only species that were of conservation concern and remained as the same status were the superb parrot (remained vulnerable from 1994-2008); golden-shouldered parrot (endangered 1994-2008); and the night parrot (critically endangered 1994-2009).

Table 5. Asset account for Australian Parrots, 1995-96 and 2008-09

	IUCN Red List categories										
	Extinct	Extinct in the wild	Critically endangered	Endangered	Vulnerable	Lower risk	Near threatened	Data deficient	Least concern	**Unlisted prior to 2004**	**TOTAL**
Opening stock 1995-96	0	0	1	2	7	0	0	0	0	42	**52**
Additions											
- from lower threat categories	0	0	1	3	0	0	0	0	0	0	**4**
- from higher categories	0	0	0	0	0	0	1	0	2	0	**3**
- discoveries of new species	0	0	0	0	0	0	0	0	0	0	**0**
- rediscoveries of extinct species	0	0	0	0	0	0	0	0	0	0	**0**
- reclassifications	0	0	0	0	0	0	0	0	0	0	**0**
- updated assessments	0	0	0	0	0	0	0	0	0	0	**0**
- new additions to list	0	0	0	0	0	0	0	0	42	0	**42**
Total additions	0	0	1	3	0	0	1	0	44	0	**49**
Reductions											
- to lower threat categories	0	0	0	0	3	0	0	0	0	0	**3**
- to higher categories	0	0	0	1	3	0	0	0	0	0	**3**
- reclassifications	0	0	0	0	0	0	0	0	0	0	**0**
- updated assessments	0	0	0	0	0	0	0	0	0	42	**42**
Total reductions	0	0	0	1	6	0	0	0	0	42	**49**
Net change	0	0	1	2	-6	0	1	0	44	-42	**0**
Closing stock 2008-09	**0**	**0**	**2**	**4**	**1**	**0**	**1**	**0**	**44**	**0**	**52**

Condition account for biodiversity

40. Due to the complexity of biodiversity, accounts will necessarily represent a portion of biodiversity or specific levels of components biodiversity. Measures for a physical account need to be carefully chosen. For example, a physical account listing all the species and their abundance is not necessary or useful. However, if a policy objective related to the protection of threatened species then an asset account detailing the threatened species and the changing status of species could be used to track increases (and decreases) in relative abundance and the number of threatened species (as described above).

41. An add-on to this account would be an asset account on the condition of native species. In its present form a physical account can compare changes in status between threatened species and between threatened taxa. It does not indicate the condition of native species as a whole. Creating a condition account would represent the proportion of non-threatened species relative to the number of native species, which can be used to compare between geographic regions and over time and will indicate the relative increase (or decrease) in the proportion of species threatened.

42. The asset account for species condition (Table 6) is an example of a condition account. As with the physical account this asset account follows the general form of assets accounts from the SEEA Central Framework, with opening stock, additions, reductions and closing stock. The rows of the account are:

    - ***Opening stock*** is the number of species under each category at the stated point in time (e.g. 2010),
    - ***Additions to non-threatened categories***, which indicates a reduction in the risk of extinction for the species;
    - ***Additions from discoveries of new species***, which includes the detection of species that were previously unknown to science;
    - ***Additions from reclassifications***, where one existing species is now recognised as two or more distinct species;
    - ***Reductions to threatened categories***, which indicates an increased risk of extinction to the species;
    - ***Reductions from reclassifications***, where two or more existing species are now recognised as one species;
    - ***Net change*** the additions less reductions
    - ***Closing stock*** is the number of species under each category at the stated point in time (e.g. 2011).

43. Categories in the columns are:

    - ***Non-threatened*** is the number of native species found in the region not listed in any of the IUCN threatened categories (i.e. excluding extinct, extinct in the wild, critically endangered, vulnerable)
    - ***Total species,*** is the total number of species recorded in the region, excluding vagrants and non-native species;
    - ***Metric of condition***, non-threatened species as a percentage of total species

44. This account is constructed for one taxonomic group (Australian birds). It records all species known to occur in a NRM region and the number of species that are not threatened between two time periods (2000 and 2010). In this period, 7 species were listed from non-threatened to some level of

threat. This corresponds to a decrease in condition of 3, from 96 to 93. A decreasing metric of condition indicates a decrease in the condition of this set of species. The account is designed to express the metric from between 0-100 where 100 would be all species un-threatened. The net decrease in condition in this account is 3.

Table 6: Native species condition asset account (Australian Native Birds) showing open and closing stock and the change in the proportion of non-threatened species for Region 1.

REGION 1	Non-threatened	Total species	Metric of condition
Opening stock 2000	224	234	96
Additions			
- to non-threatened category	0	0	
- discoveries of new species	0	0	
- reclassifications	0	0	
Total additions	0	0	0
Reductions			
- to threatened categories	7	0	
- reclassifications	0	0	
Total reductions	7	0	3
Net change	7	0	0
Closing stock 2010	217	234	93

Source: The International Union for Conservation of Nature Red List of Threatened Species, 2012, http://www.iucnredlist.org/

45. Threatened species is but one measure of biodiversity. As described above any one measure is not going to capture 'biodiversity' in its entirety. The more measures that are included in the account the greater the statistical integrity of the information available to decision makers.

46. Using this concept it is possible to bring different biodiversity surrogates together in a meaningful way to create a creating a common currency.

47. These condition accounts could be populated by other established metric such as those suggested in Biodiversity accounts and indices by P.A. Garnåsjordet.

5. Linking accounts

Biodiversity and habitat

48. Another accounting construction that will increase the utility of the accounts and link species to land units is to account for species per vegetation/habitat type or ecosystem. This would require an extra row in an asset account to include the vegetation type or habitat categories. Rows would be summed to create a total for spatial units such as regions, state or national.

Biodiversity and land cover

49. The linking of land cover to terrestrial biodiversity and in particular the occurrence of particular species in particular habitats is an obvious step in the creation of environmental and ecosystem accounts. This can be done at a relatively straightforward way. For example the terrestrial biodiversity accounts for the NRM regions of Australia (e.g. Table 4) can be presented along with data on land cover in an extended table.

50. This could be taken a step further as the link between the number of species and the area and type of habitat is well established in the ecological literature (Brooks et al. 2002). For example, forests support more species deserts and larger areas of a particular habitat support more species than smaller areas of the same habitat type. A general mathematical relationship has been established and for the loss of habitat and species number:

No. existing species = (No. original species)*((existing area of habitat)/(original area of habitat))^0.25

51. This formula can be used to predict the number of species existing in a particular place and time using current data on land cover, which is available relatively inexpensively from satellite imagery, and historical data on land cover and species occurrence. In the absence of real data on species occurrence the original number of species could be taken as an index (i.e. = 100). In some cases it may be appropriate to use this index as a measure of the condition of the biodiversity in particular areas but this needs to be tested further (some work on this is progressing at the ABS, ANU and UQ).

Linking national to regional level accounts

52. Physical and condition accounts can be linked. In this case, the physical account (number of non-threatened species) provides the data to create a condition account.

53. National biodiversity accounts can be built up from regional level accounts. The regional account can be compared directly to other regional accounts and to the national account. However, the condition scores are not additive because species are not mutually exclusive between regions.

6. Valuation of biodiversity

54. It is not the intent of this paper to cover in detail the issue of valuation, which is being primarily addressed by others in the development of SEEA Part 2. Its inclusion here is to provide a marker for those unfamiliar with the issues of valuation and to highlight that that the physical and monetary accounting for biodiversity needs to be progressed jointly.

55. The valuation of biodiversity is notoriously complex. Biodiversity provides multiple economic and non-economic benefits, often lacks property rights and is generally not traded explicitly.

56. As with ecosystem services in general, there are several types of economic value that can be attributed to biodiversity. These include: direct use value; indirect use value; option value; and non-use value. Attempts to discover these values use two main valuation methods: revealed preferences and stated preferences. Of note, both of these methods use a democratic premise that the value of biodiversity is revealed through individual values (and behaviour), irrespective of their environmental knowledge or expertise.

57. A point of caution here is to distinguish between individual behaviour as consumers (seen in revealed preferences) and as citizens. The same individual can signal quite different preferences depending on whether they are acting in their capacity as a consumer or as a citizen. For example it

is consistent for an individual to decline the option of paying more for 'greener' electricity but to vote in favour of policy that requires everyone to pay for the 'greener' electricity.

Revealed preferences

58. There are certain economic transactions that appear in the national accounts that can be analysed to reveal some degree of biodiversity value (either explicitly or implicitly). These include purchases of land (for production, conservation or residence), eco-tourism expenditures, bio-prospecting contracts and environmental protection expenditures. Methods used to disentangle a biodiversity component from these transactions include: hedonic pricing; travel costing; production function analysis; and aversion behaviour/cost analysis.

59. The general strength of revealed preference techniques is they analyse actual transactions undertaken by individuals (as opposed to stated preference techniques which look at hypothetical behaviour). However, revealed preference methods provide no assessment of non-use values.

60. While these transactions are 'economic' in the national accounting sense, care needs to be taken with the method used to reveal biodiversity values. For example, a problem with using the travel cost method is that it includes the consumer surplus of visitors and therefore breaks from the conceptual basis of the System of National Accounts (SNA) and conventional economics which use the marginal price multiplied by quantity to determine value.[3]

Stated preferences

61. An alternative technique for assessing biodiversity values (use and non-use) is to ask individuals to state their preferences (e.g. contingent valuation), usually in surveys or questionnaires. The principal advantage of this method is that it can shed some light on non-use values. However there are also some fundamental issues with this procedure, which are discussed below.

62. A major challenge is to gain meaningful answers on components of biodiversity that are not iconic (e.g. whales) and hence many respondents are unfamiliar with, including essential life supporting functions. One approach to this problem is to load the respondent with information prior to questioning. However, this can make the respondent unrepresentative in a sample that already has to deal with other demographic biases (e.g. income levels, urban/rural, cultural background etc). This leads to an interesting philosophical discussion as to whether individual (democratic) views suffering from significant information problems outweigh expert opinion (which can also host a range of biases).

63. Another fundamental issue with using surveys to elicit environmental values is revealed by Kahneman (2002) in his work on behavioural economics[4]. Kahneman argues that while we make mistakes in undertaking market transactions (particularly in regard to the non-immediate future), we make these even more when answering surveys. Because there is less riding on the answers (no money is actually exchanged), we are likely to use intuition rather than reasoning (which requires more time and effort) in framing our response. While serving us well in many circumstances, intuition, it is argued, also results in many frequent and predicable mistakes.

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[3] Of note there are a number of non-market transactions in the SNA where market values are approximated using costs as a proxy.

[4] 'Maps of Bounded Rationality: a perspective on intuitive judgment and choice', Kahneman (2002)

64. Finally, and significantly, stated preference methods capture a consumer surplus, and therefore are inconsistent with the SNA and SEEA valuation principles which require knowledge of the marginal price (i.e. the intersection of marginal cost and marginal benefit) in order to determine value.

7. Discussion

Data limitations

65. Following on from this, different methods used to collect the data that populates the tables may yield different results in terms of the species found and the measures of their abundance. Comparisons between different measurement methods must therefore be considered when combining data into summary tables or accounts.

66. No single indicator or measure will represent 'biodiversity'. As described above it is a complex and multi-layered concept. If the object of accounting is to represent to the degree possible the true scope of biodiversity, then accounting for biodiversity will need to use a biological index that combines condition information in a scientifically rigorous way. Certainly at the very least the accounts should be comprehensive enough to address policy questions relating to biodiversity, if not to measure the complexity of biodiversity as a whole.

67. The composition of the species can be measured in many ways including by species richness, rarity, functional traits and taxonomic uniqueness. Species richness and the proportion of introduced species will give a good indication of the condition of species and accounts should be developed to represent these measures. A limitation with a simple species richness measures is that all species are considered equal. A common species is not weighted more than a rare species, nor are other considerations such as endemism or function considered. This would require further work. It is not a problem faced in the asset accounts here because the measures are of relative abundance, not absolute abundance.

68. The accounts presented here are mostly for terrestrial fauna but could work for marine and plant systems. It is important to note that even within any group it is difficult to include all taxa. Insects, for example, are not included due to uncertainty regarding the number and abundance of species. Arguably insects are one of the more important aspects of biodiversity in terms of functionality and diversity. This will need to be addressed in the future development of accounts.

Reference points

69. Baselines provide a means of providing biological context for measures and provide a means of scaling measures to a common benchmark allowing for comparison between species, taxa and ecosystems. The benchmark cannot be arbitrary. In the accounting examples described in this paper and the work by Cosier and Garnåsjordet the benchmark employed is pre-disturbance benchmark.

70. Identifying a reference point provides a scale to understand the current observations, as well as to simplify, quantify, communicate and most importantly standardise information. This scale is very useful in analysing change over the gradient of human disturbance, as we try to understand the relationships between human activity and biodiversity change. It is also an appropriate measure for describing where ecosystems are approaching critical thresholds, which are common in complex ecosystems. (Chapin, Zavaleta et al. 2000; Scheffer, Carpenter et al. 2001; Walker and Meyers 2004; Raudsepp-Hearne, Peterson et al. 2010).

Frequency of accounting

71. Many changes in ecological systems are rapid, but many are also slow and observational change occurs over time frames longer than a year such as 5-10 years. This is in contrast to policy and funding cycles, which are 1-3 years.

72. While changes over a year will typically be small (compared with say a 5 or 10 year cycle) there is a need to embed the biodiversity accounting process within ongoing operational procedures and thus link to planning cycles and project funding. Consequently there is a strong need for annual environmental accounts to link to funding, monitoring, future investments.

73. There are significant lags in cause-and-effect cycles in ecological processes so there would need to be recognition of this in the interpretation of accounts. Ultimately, it might be necessary to design these accounts to have predictive powers so we are not in the position of waiting to detect significance in a trend we know is occurring. Attributing the change between natural variation, climatic change and direct human activities can be difficult and is probably beyond the scope of these accounts at this stage. If it were to be attempted the indicators of choice would have to be chosen carefully to be sensitive to a human related activity, rather than general indicators that would detect changes caused by both. A pragmatic approach at this stage is to measure change independent of the cause and then use data on natural change such as rainfall and climate to determine if the observed change is explained by natural change.

Accounting for different classifications of species or specially identified species

74. Species may be grouped in a number of ways. In the tables above we have grouped according to that originated by Linnaeus. Species may be grouped in other ways. For example, based on their: origin (native/non-native); desirability (e.g. usefulness for agricultural production or crops); undesirability (pest and weeds); functionality (carnivores, herbivores); or religious or cultural significance (e.g. sacred cows). In this the particular species may be grouped into different classes depending on the location of their occurrence.

75. Some species are important because they are endemic (only found in a particular space and nowhere else).

Scale

76. Typically environmental data are compiled at a variety of spatial levels dependant on the purpose that the data was originally compiled. Standard definitions of spatial units would allow the integration of data, including from different sources. Ideally local or accounts for smaller areas can be aggregated to regional accounts and then state or national level accounts.

77. Interpretation of data at different finer spatial level needs special consideration as species may changes classification depending on scale and context (see above accounting for different classification) and accounts will be subject to greater influence from localised events (e.g. natural disasters such as bushfires) and species may be absent in one period but reappear in later periods due to reintroduction from surrounding areas. At larger scales, these changes are not so volatile, and for example, once a species become extinct from the world it is very unlikely that it will reappear, but it may become locally extinct (or more accurately absent) but appear in later time periods.

78. Ultimately a balance of scale is needed. A small scale will provide comprehensive coverage but will be financially prohibitive. Too higher a scale, ie national, will not detect changes that are needed to manage species.

79. As such, a regionally based reporting system is necessary because every region or catchment has unique environmental characteristics which need to be managed to cater for the specific pressures on these landscapes and environmental assets. As a consequence, it might be necessary for indicators of ecosystem condition to vary from region to region, so that they can best describe the health of an environmental asset in that locality.

Questions for discussion

80. Are there any comments on the classifications and entries used in the draft accounts?

81. What spatial areas are most appropriate for biodiversity accounting?

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