# From Moonlight Jewels to Common Browns: Butterfly accounts for the ACT

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## Abstract

We present a set of novel SEEA butterfly accounts for the Australian Capital Territory (ACT), Australia. These accounts identify the theoretical and practical issues in producing biodiversity accounts and assess the implications of such biodiversity accounts for public policy and the management of species and public areas in the ACT and beyond. The accounts are to be used in ACT State of Environment reporting and considered for broader national biodiversity application. The butterfly accounts span from 1978 to 2018, and the data sources and methods underpinning the accounts are detailed in the paper. The accounts aim to eventually include butterfly species presence and abundance by habitat type and season for each survey year and between two points in time, butterfly species area of distribution by habitat and a land cover account. These types of biodiversity accounts will support the development of the SEEA-EEA framework and the UN ambition to elevate the system to an international standard. They demonstrate the flexibility of SEEA for presenting a range of ecosystem and environmental information.

## 1. Introduction

The best method for including biodiversity in the System of Environmental Economic Accounting (SEEA) has been a vexing question for more than a decade. The specific call for including biodiversity values in national accounts in Target 2 of the Biodiversity Strategy Plan (2011-2020) for the Convention on Biological Diversity provided an impetus for this work and also coincided with the processes for elevating the SEEA Experimental Ecosystem Accounting (EEA) to an international statistical standard.

A number of activities and papers have addressed the issue from theoretical and practical points of view. This includes meetings convened as part of the SEEA EEA development, London Group Meetings and then the subsequent efforts to raise ecosystem accounting to the level of international standard.

Key questions for biodiversity accounting identified near the beginning of these processes (e.g. Harris 2011) were:

- What are the units of account? Genes, species or ecosystems?
- Can indices of biodiversity be used as an input to ecosystem accounts?
- In what types of accounts would biodiversity be included? i.e. biodiversity as an:
    - Environmental (or ecosystem) asset
    - Input to economic production
    - Input into the ecosystem which generates ecosystem services
    - Indicator of ecosystem condition
    - Ecosystem service
- When assessing ecosystem condition, what reference points can be used?

The production of the SEEA EEA provided the first response to these key questions. In the SEEA EEA, there are asset accounts for biodiversity which are one of the four thematic accounts described (the others being land, water and carbon) as well as biodiversity as an indicator of ecosystem condition. The Technical Recommendations in Support of the SEEA EEA add some additional discussion on biodiversity accounting and sources of data but augmented or additional tables are not presented. That said, a range of work has shed light on both theoretical and practical issues of accounting for biodiversity and a summary of this is presented in Table A1 in the Appendix.

A key on-going issue is the suitability of primary data for regular systematic biodiversity accounts. Improving primary data sources is a vital part of the work and the challenge is to use what is available now to help create accounts, including biodiversity, that are meaningful to managers and policy.

In the remainder of this paper, we report on the development of biodiversity accounting for the Australian Capital Territory (ACT).

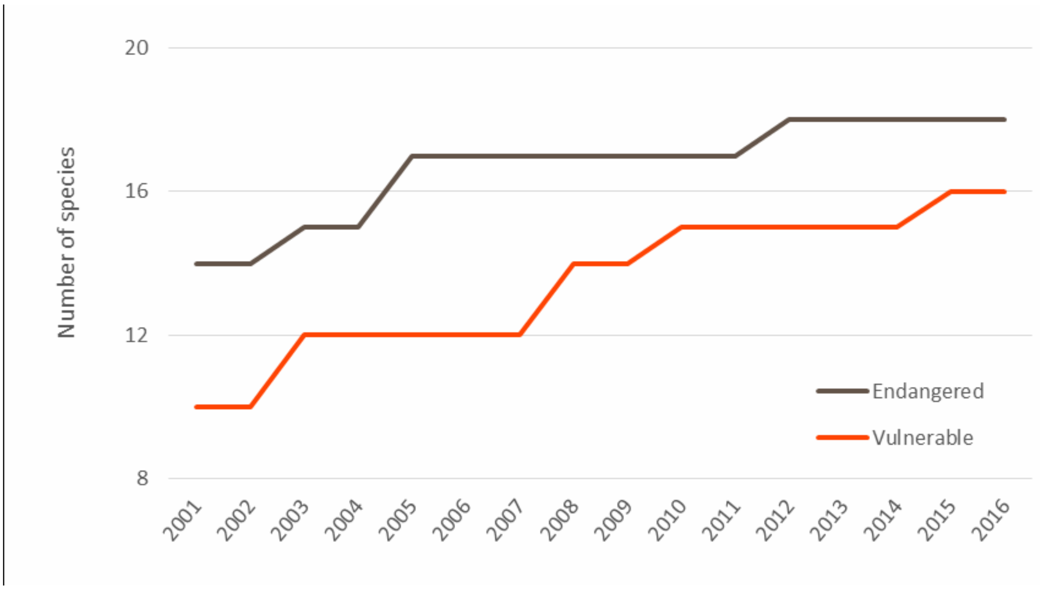
*1.1 Background to ACT*

The ACT is a small landlocked jurisdiction in Australia dominated by an extensive system of national parks and other reserves juxtaposed against the city of Canberra, which is Australia's national capital. Local residents place a high value on environmental health and natural capital, and the ACT Government has set ambitious policy and sustainability goals to guide future development (ACT Government, 2009; OCSE, 2017b). These goals focus on economically, socially and environmentally sustainable policy outcomes that align well with the United Nations Sustainable Development Goals (SDGs).

The ACT Office of the Commissioner for Sustainability and the Environment (OCSE) has undertaken the preparation of a suite of environmental accounts as part of the 4-yearly State of the Environment (SoE) reporting (Smith et al 2017). This was done with the assistance of the Australian Bureau of Statistics (ABS) and the Australian National University (ANU). Biodiversity and environmental condition accounts were prepared as part of this. The environmental condition accounts did not include a measure of biodiversity *per se* but did include tree cover, vegetation leaf area and vegetation carbon uptake.

Biodiversity assets account of threatened species were prepared for 2001 to 2016 and Fig 1. summarises the accounts for each of the years. While the table shows an increase in the number of endangered and vulnerable species, by itself it is of limited value to decision makers.

**Fig 1**. ACT Nature Conservation Act Endangered and Vulnerable Listed Species 2001 to 2016




Source: Smith et al 2017. Data at:
http://www.environmentcommissioner.act.gov.au/__data/assets/excel_doc/0020/1106408/listed_species_account_2001-16.xlsx

Several things may limit the usefulness of the accounts of species status in general. Firstly, listing is an administrative process that takes time, so the change in status will lag the physical change in distribution and abundance. This leads to the next point: the status of species is based on patterns in distribution and abundance that are naturally variable from year-to-year. In addition, the likelihood of extinction risk for most species groups (i.e. birds, mammals, plants, fish, etc.) does not change appreciably from year-to-year.

*1.2 Butterflies as indicators of biodiversity condition*

Butterflies are useful indicators of biodiversity condition as they react quickly to environmental changes (Warren et al. 2001) and changes in distribution due to climate change have been noted (Parmesan et al. 1999, Devictor et al. 2012). This is due to short life spans, limited dispersal ability, larval food plant specialization and close-reliance on the weather and climate[1]. In addition, unlike most other groups of insects, butterflies are well-documented, their taxonomy is understood, they are easy to recognize and there is much information on their ecology and life-histories. In the UK, the United Kingdom Butterfly Monitoring Scheme (UKBMS), launched in 2006, is part of the official statistics. Butterfly abundance data are produced annually[2], but are not yet integrated into biodiversity or ecosystem accounts for the UK.

For the ACT we have the butterfly guidebook (Bond 2018) and for the last 4 years (2014 to 2018) there have been regular butterfly surveys.

## 2. Materials and methods for Butterfly accounts for the ACT

*Data sources and methods for accounts*

To produce a species account for butterflies of the ACT, firstly we had to construct a butterfly species list for the ACT. Kitching et al (1978) were the first to publish an initial species list of 79 butterflies; personal observations, Australian National Insect Collection (ANIC) specimens, published papers and Braby (2016) helped confirm the final list of 87 species recorded for the ACT. For the purposes of this paper, butterfly species have been grouped according to taxonomy under the main Linnean groupings, with nomenclature following Braby (2016).

Secondly, we had to determine the presence and abundance for these 87 species across space and time in the ACT. For this, systematic butterfly surveys were conducted in the field.

Data was strictly limited to butterfly species with ACT records only; moths were out of scope and neighbouring New South Wales (NSW) records were also out of scope. Sometimes diurnal moths (such as the Sun Moths, family Castniidae) are included in butterfly surveys, and sometimes due to an overlap of bioregional zones, parts of NSW to the east of the ACT (such as the Braidwood - Tallaganda region) are often considered when discussing 'ACT' Lepidoptera. Records of butterflies in the data set were of adults.

*Butterfly survey method*

The butterfly survey method used in the ACT field work was an adaptation of the Pollard Walk (Pollard 1977), a transect count designed specifically for recording adult butterflies in a scientifically robust way. The adapted transect surveys were fixed to ten minutes survey time, with fixed survey boundaries of 100 metres long by 10 metres wide and unlimited height. The observer recorded the

[1] United Kingdom Butterfly Monitoring Scheme http://www.ukbms.org/Default.aspx

[2] UK Summary of changes to butterfly abundance 2017
http://www.ukbms.org/docs/reports/2017/UK%20Summary%20of%20changes%20Table%202017.pdf

time, date, weather conditions and any disturbance factors to the site at the survey, before setting out at a slow walking pace and recording every identifiable adult butterfly species and their abundance. The observer walked as close as possible to the centre of the transect at about the 5 m mark, and completed the 100 metre transect length within the ten minute timeframe; any butterflies observed outside of this fixed area or time were recorded as incidental records. Stopping along the transect in order to identify butterflies was permitted, but counting also stopped when the observer stopped, as otherwise this increases sampling effort, and it can also make it harder to complete the transect in the ten minute timeframe. All identified butterfly species were recorded, and an abundance per species recorded; null results were recorded as such. Individuals too hard to confidently identify were left off the survey, and photos were taken of problematic individuals for identification post survey.

This survey was conducted three times at each site during the butterfly season, once during spring, once during summer and once during autumn; each survey site was fixed so that the same area was surveyed over time. Surveys were conducted from September through to May, as this is when adult butterflies are on the wing for the temperate butterfly season in the southern hemisphere; no winter surveys were conducted despite the ability of a handful of species to fly during this period.

Because surveys were aimed at detecting adult butterflies on the wing, weather was an important factor in determining survey effort. Where possible, surveys were only conducted in the following weather conditions: when the forecast daily maximum was at or above 21°C but below 35°C, no strong winds, and no rain. These parameters were established based on previous experience in the field, where it was found that there was too little butterfly activity if these conditions were not met. It is important to note that ideal surveying conditions for the temperate zone can be different in different parts of the world, for instance in the UK it is recommended that surveys be carried out in temperatures beginning at 13°C (van Swaay et al 2015). The first snowfall or heavy frost in the mountains during autumn usually signifies the end of the flight season for most ACT butterflies, and therefore the end of the surveys for that season.

Each survey site was located within one habitat type only, with all sites together providing a good representation of different habitats with the ACT. Grassland, lowland woodland, dry forest, montane forest, wet forest, montane and subalpine woodland, wetlands, urban parks/gardens and riparian habitats were all sampled across the ACT. Habitats not surveyed were *Pinus radiata* plantations, heath shrublands and private suburban gardens; this was because pine plantations are essentially ecological deserts for ACT butterflies, many of the heath shrublands were too problematic to easily access, and gardens had privacy issues for conducting surveys; however there may be scope in future surveys to include these habitats. In addition to different habitat types, survey sites were also varied according to their topographic position in the landscape and altitude.

Site locations were also chosen based on several factors. Because most of the previous records of ACT butterflies were restricted to a few areas, this project initially aimed for improved geographic coverage across the ACT. Potential sites with ease of frequent access were identified, and these were selected so that a cluster of sites could be surveyed in one visit. Sites were then selected to fit the variables identified as important, with some sites included specifically to target rare and restricted species.

The ongoing ACT butterfly surveys were set up in 2014 as Australia's first long-term butterfly monitoring project. Survey sites consist of core sites which are surveyed every year, and supplementary sites which may not be surveyed every year. For the 2014-2018 seasons, a total of 176 sites were surveyed, with an average of 72 sites surveyed each season. In the short term, improved knowledge of butterfly presence and distribution will be gained, and in the long term, trends may be ascertained and better understood.

## 3. Butterfly accounts for the ACT

Table 1 presents a summary of butterfly species at different scales at one point in time (2018). These species are grouped by state (ACT), federal and international levels of endemism, and number of introduced species. This provides an overview of the numbers of species the accounts are dealing with, and provides context. It should be noted that there are currently no butterflies listed as threatened under the ACT Nature Conservation Act (2014), however one member of the Lepidoptera is represented with the Golden Sun Moth (*Synemon plana*) listed as endangered in the ACT.

**Table 1**: Summary table of butterfly species (2018)

| | Number of species | Endemic to Australia | Introduced to Australia |
|---|---|---|---|
| Global | ~18 000 | NA | NA |
| Australia | 408* | 200 (49% of Aust) | 3 |
| ACT | 87 | 61 (70% of ACT) | 2 |

* Represents continental Australia only; there are 435 species including islands, and 396 confirmed resident butterfly fauna permanently established in Australia

Table 2 presents a butterfly species asset account for the ACT in 2018, arranged by family, how many species from each family are endemic, and how many species are introduced. The Papilionidae are also known as the swallowtails, and are predominantly a group of tropical and subtropical butterflies; the Hesperiidae are known as skippers and are usually small, often overlooked dull butterflies; the Pieridae are known as a group of highly mobile species, many of which are long distance migrants; the Nymphalidae in the ACT are comprised of the Satyrinae (display a preference for shaded, grassy habitats), Nymphalinae (preference for sunnier habitat) and the Danainae (often are toxic to predators); and the Lycaenidae are known as blues and often have an ant association with the butterflies. Endemism is when a species is restricted to a defined geographic location or area, here defined as Australia, and an introduced species is when a species does not originate in Australia but has been either deliberately or accidentally brought to Australia.

**Table 2**: Snapshot 1 of ACT butterfly species, 2018

| | Native species | | | | Introduced species | |
|---|---|---|---|---|---|---|
| | Endemic ACT | Endemic Australia | Non-endemic Australia | Listed as threatened | Introduced Australia | Total species |
| Papilionidae | 0 | 1 | 5 | 0 | 0 | 6 |
| Hesperiidae | 0 | 17 | 0 | 0 | 0 | 17 |
| Pieridae | 0 | 4 | 6 | 0 | 1 | 11 |
| Nymphalidae | 0 | 15 | 8 | 0 | 1 | 24 |
| Lycaenidae | 0 | 25 | 4 | 0* | 0 | 29 |
| Total | 0 | 62 | 23 | 0 | 2 | 87 |

* It is anticipated that the Small Ant-blue (*Acrodipsas myrmecophila*) will soon be formally listed as a threatened species in the ACT

Table 3 presents a second snapshot of ACT butterflies for 2018, this time with a focus on classifying butterflies in such a way as to enable a link between butterfly species and ecosystem condition. This is by identifying the butterfly species which rely on habitats in the ACT to breed, and the identification of species considered specialists. It must be remembered that the categories presented are in the context of ACT only. Breeding species were defined as butterflies that regularly breed and have established a self-sustaining population in the ACT; this typically includes residents and regular migrants. Non-breeding species includes all species which do not breed in the ACT, and species which may breed opportunistically but are unable to establish a population; this typically includes migrants and vagrants. Species for which their breeding status is unclear have been added to this category, such as the Copper Pencil-blue (*Candalides cyprotus*).

Generalists are usually common and widespread species able to survive in a range of environmental conditions; specialists are usually less common and localised species with specific environmental conditions which need to be met for them to survive. In this paper, generalists are defined as species which must have at least two of the three following characteristics:

- A widespread distribution in the ACT
- Three or more breeding and foraging habitats in the ACT
- Four or more plant species, or more than one plant family, for their larval food plant preference in the ACT

Specialists on the other hand must have at least two of the three following characteristics:

- A localised, very localised or restricted distribution in the ACT
- One or two breeding and foraging habitats in the ACT
- One, two or three plant species within the same plant family, or a preference for ant larvae, for their larval food preference in the ACT

**Table 3**: Snapshot 2 of ACT butterfly species, 2018

| | Breeding category | | Specialisation | | |
|---|---|---|---|---|---|
| | Breeding species* | Non-breeding species^ | Generalists | Specialists | Total species |
| Papilionidae | 3 | 3 | 3 | 0 | 6 |
| Hesperiidae | 17 | 0 | 7 | 10 | 17 |
| Pieridae | 3 | 8 | 3 | 0 | 11 |
| Nymphalidae | 18 | 6 | 9 | 9 | 24 |
| Lycaenidae | 26 | 3 | 9 | 17 | 29 |
| Total | 67 | 20 | 31 | 36 | 87 |

* Resident and regular migrant species

^ Migrants and vagrants; not included in classification of generalist/specialist breakdown

Table 4 presents a butterfly species account linking two periods in time, 1978 for the opening point in time and 2018 for the closing point in time. This table brings together information presented in Tables 2 and 3, with the addition of data from 1978 to pinpoint where the change over time has occurred.

**Table 4**: Butterfly species account for the ACT, 1978 – 2018

| | | Native species | | | | Introduced species | Specialisation | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Endemic ACT | Endemic Australia | Non-endemic Australia | Listed as threatened | Introduced Australia | Generalists~ | Specialists~ | Total species |
| Opening stock 1978 | | 0 | 56 | 19 | 0 | 2 | NA | NA | 78 |
| Additions | | | | | | | | | |
| | Discovery of new species | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| | Rediscovery of extinct species | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| | Addition of species | 0 | 5 | 3 | 0 | 0 | NA | NA | 8 |
| | Taxonomic reclassification | 0 | 1 | 0 | 0 | 0 | NA | NA | 1 |
| | Total | 0 | 6 | 3 | 0 | 0 | NA | NA | 9 |
| | | | | | | | | | |
| Reductions | | | | | | | | | |
| | Extinction of species (Aust) | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| | Loss of species (distribution) | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| | Taxonomic reclassification | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| | Re-evaluation of records | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| | Total | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| | | | | | | | | | |
| Closing stock 2018 | | 0 | 62 | 23 | 0 | 2 | 31 | 36 | 87 |
| | | | | | | | | | |
| Net change | | 0 | 6 | 4 | 0 | 0 | NA | NA | 9 |

~ Cannot assign specialisation categories to 1978 data, no comprehensive measure of distribution available

## 4. Discussion

Between 1978 and 2018 nine species were added to the list of butterflies found in the ACT. The species added since 1978 fall into two broad categories:

1. Range extensions
    - for vagrants and migrants, this includes the Pale Triangle (*Graphium eurpylus*), Lemon Migrant (*Catopsilia pomona*), Yellow Albatross (*Appias paulina*), Copper Pencil-blue (*Candalides cyprotus*);
    - for residents, this includes the Amethyst Hairstreak (*Jalmenus icilius*), Fiery Copper (*Paralucia pyrodiscus*), Flame Sedge-skipper (*Hesperilla idothea*);
2. Taxonomic change - the Golden Ant-blue (*Acrodipsas aurata*) is a new species split from Copper Ant-blue (*Acrodipsas cuprea*), so the Copper Ant-blue is subsequently absent from the ACT list.

Most species added were from range extensions, and some of these new species (as well as species rare in 1978) have also become more common and widespread over time. Much of the change in the species recorded reflects the changing landscape of Canberra. The creation of the Canberra Nature Park reserve system has increased floristic diversity in what were formerly cleared sheep paddocks, with species such as the Bronze Flat (*Netrocoryne repanda*) doing so well on their larval food plant of Kurrajongs that they have gone from only known 'from a few specimens' in 1978 to 'fairly common' across lowland ACT in 2018.

Another change to the landscape is urban expansion, with suburban gardens and botanical gardens now offering exotic larval food plants, enabling butterflies otherwise unlikely to be present, such as the Flame Sedge-skipper (*Hesperilla idothea*) to colonise the ACT and breed in the botanical gardens. Some of the change in this species distribution and abundance may also be driven by climate change. For example, some species formerly considered vagrant and migrant have, because of changed weather conditions and specifically milder winters, allowed species like the Tailed Emperor (*Charaxes sempronius*) to persist over winter for the first time and thereby establish resident populations.

*Theoretical and practical issues in producing biodiversity accounts*

The ACT has 87 butterfly species with 70% of these species endemic to Australia. The introductory summary of butterfly data places the accounts into global and regional contexts (Table 1).

Unusually for a faunal group in Australia, there are only three introduced species of butterfly in the ACT, with none posing ecological threat:

- the Monarch (*Danaus plexippus*), which is thought to have arrived in the 1870s, possibly from New Caledonia, and is well-known for their spectacular migrations between Central and North America - in the ACT they are an occasional migrant;
- the Cabbage White (*Pieris rapae*), arrived in Australia in the 1930s and has since become a pest on brassicas and canola, very common and widespread in the ACT and one of the few species which can be seen flying throughout the frosty winter months; and
- the Tawny Coster (*Acraea terpsicore*), which arrived in northern Australia in 2012 and has quickly spread east to far north Queensland and as far south as central Queensland.

An asset account for one point in time (2018, Table 2) enables a break-down of summary data by family group. Table 2 shows the Hesperiidae, Nymphalidae and Lycaenidae are important groups with several endemic species; unsurprisingly, the tropical and subtropical Papilionidae and the mobile Pieridae do not feature strongly in the ACT.

A second asset account for one point in time (again 2018, Table 3) then draws out species groupings based on classifications designed to be able to link butterfly species with ecosystem condition and climate change/change over time. Overwhelmingly, most of the butterflies use ACT ecosystems for breeding purposes; therefore the ability to track species data and link them to the management of ecosystems is crucial. Species deemed specialists were from the Hesperiidae, Nymphalidae and Lycaenidae only.

Bringing together the asset account data and examining such data at two points in time to produce a species account can not only depict change in the dataset, but, valuably for policy and management identifies the reasons underpinning and driving change. For the ACT butterflies species account, looking at two points in time forty years apart has certainly shown change, with nine species added.

This exercise has revealed an unexpectedly complex area of change over decades relevant for species accounting, namely taxonomic revisions. This has proven most noticeable in the updated scientific names for some species since 1978, such as the Meadow Argus (*Junonia villida*, formerly

*Precis villida*). In the case of the Golden Ant-blue, it was described as a new species by Sands (1997), but in 1978 this species was still considered to be the Copper Ant-blue (*Acrodipsas cuprea*, formerly *Pseudodipsas cuprea*). Another taxonomic oddity involves an occasional vagrant to the ACT, the Cycad Blue, considered *Theclinesthes miskini* in 1978, but since revised to *Theclinesthes onycha* – except to confuse matters, the fairly common ACT resident, the Wattle Blue, was considered *Theclinesthes onycha* in 1978 and is now *Theclinesthes miskini*; only *Theclinesthes miskini* was recorded for the ACT in 1978 but it is likely this was the Wattle Blue rather than the Cycad Blue – the two species look very similar and are difficult to separate.

One drawback of comparing two points in time so far apart is that significant events in between are hidden. Significantly, in 2003 extensive and intense bushfires in the ACT had a devastating impact on butterfly fauna, with the following effects:

- Suspected reduced diversity at former hotspots in Brindabella Ranges based on anecdotes and ANIC specimens
- Some of the specialists suspected to have gone extinct from the ACT post 2003; these species included:
    - Banks' Brown – rediscovered 2017, now only two known locations
    - Silky Hairstreak – rediscovered 2017, now only two known locations
- And suspected severely impacted upon the following species:
    - Montane Grass-skipper – absent from surveys until 2018, only one prior known record since 2003 and 2018
    - Satin Azure – anecdotally slow recolonisation of river Casuarina mistletoe

However, by only looking at 1978 and 2018, this significant ecosystem disturbance and recovery afterwards is lost. More comprehensive and annual and even season-by-season sets of species accounts would pick-up such changes. They would also help to address the variability in presence and abundance of butterflies and other invertebrates which fluctuate season-to-season and year-to-year according to climatic conditions. This is where the ACT butterfly surveys come into play.

The provision of primary data as presented and discussed here has allowed for an assessment of the suitability of such data for regular systematic biodiversity accounts. It also has implications for public policy and management of biodiversity and public areas in ACT and beyond.

*Management of ecosystems*

Butterflies can be used as indicators of environmental condition and change, and indeed are already used by the UK as part of the Butterfly Monitoring Scheme which is part of the government's Official Statistics (UKBMS, 2018). Accounting for butterflies provides a metric of ecosystem condition that can be used by government or other to identify problems and guide management of ecosystems. The ACT butterfly species accounts will be used in the forthcoming (2019) ACT State of Environment Report.

By categorising species into generalists and specialists for biodiversity accounting surrogates for environmental condition can be developed. For instance, nominated generalists will be sufficiently widespread and abundant as to track climate change, while nominated specialists can be used as indicators for environmental condition of particular habitats and thus be used for targeted management strategies. We present a generalist butterfly species and a specialist butterfly species as case studies here.

A good example of an ACT generalist butterfly species is the familiar Common Brown (*Heteronympha merope*). This species occurs in every habitat type in the ACT, has cosmopolitan tastes in their larval food plant preferences, including the ability to eat introduced grasses as well native grasses; adult butterflies have the ability to go into a summer dormancy known as aestivation to survive periods of hot weather, they are able to move with great mobility through the landscape if required, have a long flight period of several months, and the females can delay laying their fertilised eggs until autumn rains trigger fresh growth in grasses for improved larval development.


Left to right: Common Brown and Alpine Sedge-skipper.

Conversely, a good example of a specialist butterfly in the ACT is the Alpine Sedge-skipper (*Oreisplanus munionga*). Alpine Sedge-skippers only occur in boggy patches of subalpine eucalypt woodland and grassland and are restricted to the higher elevations; they have a localised distribution within their range and only have a flight period of one to two months. Their presence indicates that the ecosystem is in excellent condition. Alpine Sedge-skippers are thought to be highly vulnerable to climate change and inappropriate fire regimes drying out their moist habitat. Their reliance on this specific habitat is also due to the availability of their single larval food plant, the Tall Sedge (*Carex appressa*); this food plant can easily be lost through trampling and overgrazing by feral horses and cattle. This species is already listed as Endangered in the state of Tasmania.

While not butterflies, two moth species deserve special consideration here in discussion around accounting for the Lepidoptera of the ACT. The first is the iconic Bogong Moth (*Agrotis infusa*). This is a well-known species to many Canberrans due to the moth's attraction to building lights as they migrate into the ACT. Bogong Moths arrive in Canberra from late September onwards from their breeding grounds in northwest New South Wales and southeast Queensland; their target is the Snowy Mountains, and as spring progresses into summer and the temperatures increase, the moths move gradually from lower to higher elevations. Once they reach the subalpine and alpine zones, they form aestivation sites in rock crevices until February when they set out to complete their return migration to their breeding grounds. Bogong Moths are an integral part of the alpine ecosystem, and are particularly important as a food resource during the breeding season for the Endangered Mountain Pygmy-Possum. Bogong Moths were also hugely significant to local Aboriginal groups, who would congregate in the high country to feast on the moths and conduct important cultural exchanges (Zborowski and Edwards, 2017).

The second is the only currently listed member of the Lepidoptera on the ACT's Nature Conservation Act (2014), the Golden Sun Moth (*Synemon plana*). This moth inhabits lowland grasslands dominated by Wallaby Grass (*Rytidosperma carphoides*) and is a flagship species for the conservation of these ecosystems within the ACT. Unusually for a moth, it flies during the day and has clubbed antennae, features more often assigned to butterflies. It flies from mid-November to early January, and the larvae feed underground for about two years before pupating into adult moths.

## 5. Final thoughts

The development of butterfly accounts for the ACT has highlighted the problems with primary information on biodiversity. There are few regular, systematic surveys of species meaning that the base data needed for biodiversity accounts often has to be compiled from a variety of ad hoc data sources.

It is fortunate that systematic surveys of butterflies have been conducted over the past 4 years by a team of dedicated volunteers. This has enabled high quality data to be produced and used in accounts. The compilation of the accounts has also shown the importance of expert knowledge of the species and their habitats. Without such knowledge the systematic surveys could not be run and the information collected could not be verified. It also enables ad hoc information to be more readily incorporated and for the survey areas to be modified to maximise the number of species that may be found.

A key feature to emerge is the need to classify species in a number of ways. While conservation status is important, a number of other classifications are useful for understanding the management needs of species, or strategies for conservation of species. In particular, classifications of species as specialists or generalists in terms of habitat needs as well as by area of distribution and movement (e.g. resident, breeding migrant, non-breeding migrant, vagrant, etc.) is important. Having these classifications, and importantly having them standardised (and various IUCN and CBD documents have a range of definitions that should prove useful), will enable a range of useful tables to be presented.

Going forward the species accounts will need to be integrated with ecosystem accounts, both accounts of condition and well as ecosystem services. A draft set of ecosystem condition accounts for the ACT were compiled based on remotely sensed data. Comparing the measures of condition obtained from the remotely sensed with those obtained from the butterfly accounts will be an important area of work. The cultural and recreation services obtained from species will also be important and an indication of this is seen in the cultural significance of the Bogong Moth to Aboriginal people.

*Questions for discussion*

i) What does the audience think of our table presentation? Is there a way to improve or change data presentation for greater clarity or impact?
ii) Have there been similar species accounts constructed for biodiversity following the SEEA EEA we haven't covered here that would be useful?
iii) How could we best approach the future integration of this style of biodiversity species accounts with ecosystem accounts?

## 6. Acknowledgement

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## 8. Appendix

**Table A1**. List of biodiversity papers presented at accounting meetings (excluding London Group at present)

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| Expert Meeting on Ecosystem Accounts, 5-7 December 2011, London UK. | | | |
| Charles Perrings | Biodiversity, Ecosystem Services and Wealth Accounting | https://unstats.un.org/unsd/envaccounting/seearev/meetingMay2011/bg7_C_Perrings.pdf | |
| Didier Babin | CBD and National Accounting Systems: Opportunities and Challenges | https://unstats.un.org/unsd/envaccounting/seearev/meetingMay2011/s13_D_Babin.ppt | |
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| Expert Meeting on Ecosystem Accounts, 5-7 December 2011, London UK. | | | |
| J. McDonald | Key Concepts for Accounting for Biodiversity | https://unstats.un.org/unsd/envaccounting/seeaLES/egm/Issue6_Aus.pdf | |
| E. Ivanov, R. Haines-Young, J.L. Weber | Developing a Diagnostic Species and Biotope Index for Europe | https://unstats.un.org/unsd/envaccounting/seeaLES/egm/Issue6_Ivanov.pdf | |
| P.A. Garnåsjordet | Issue Paper on Biodiversity Accounts and Indices: Some Comments on the Difference between the Australian and Norwegian Approaches | https://unstats.un.org/unsd/envaccounting/seeaLES/egm/issue6_pag.ppt | |
| R. Harris | Presentation of Discussant on biodiversity accounts and indexes | https://unstats.un.org/unsd/envaccounting/seeaLES/egm/Disc_issue6.ppt | |
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| Expert Meeting on Ecosystem Accounts, 16-18 May 2012, Melbourne Australia | | | |
| P.A. Garnåsjordet, J. McDonald, P. Cosier, B. ten Brink, A. Saltelli, B. Magnusson, S. Nybø, O. Skarpaas, and I. Aslaksen | Biodiversity Accounts and Indices | https://unstats.un.org/unsd/envaccounting/seeaLES/egm2/BiodiversityOP.pdf | |
| J. McDonald, P. Gibbons, S. Bond, A. Cadogan-Cowper, J. Ovington and M. Vardon | Proposed Biodiversity Accounting in Australia | https://unstats.un.org/unsd/envaccounting/seeaLES/egm2/Biodiveristy_Aus.pdf | |
| B. Schweppe-Kraft | Natural Capital in Germany: State and Valuation with special reference to Biodiversity | https://unstats.un.org/unsd/envaccounting/seeaLES/egm2/Biodiveristy_BSK.pdf | |
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| London Group, 12-14 November 2014, London, UK | | | |
| S. Bond, J. McDonald, M. Vardon | Experimental Biodiversity Accounting in Australia | https://unstats.un.org/unsd/envaccounting/londongroup/meeting19/LG19_16_1.pdf | |
| M. Eigenraam, J. Chua, J. Hasker | Victorian Experimental Ecosystem Accounts | https://unstats.un.org/unsd/envaccounting/londongroup/meeting19/LG19_16_5.pdf | |
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| London Group, 17-20 October 2014, New Delhi, India | | | |
| N. Steinbach, V. Palm | Land Accounts for Biodiversity - A Methodological Study for the Allocation of Land with High Nature Values to Owners and Industries | https://unstats.un.org/unsd/envaccounting/londongroup/meeting20/LG20_3_4.pdf | |
| C. Sbrocchi | Multiscale Environmental Asset Condition Accounts for Australia | https://unstats.un.org/unsd/envaccounting/londongroup/meeting20/LG20_3_12.pdf | |
| Australian Bureau of Statistics | Towards Experimental Ecosystem Accounts for the Great Barrier Reef | https://unstats.un.org/unsd/envaccounting/londongroup/meeting20/LG20_3_1.pdf | |
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| London Group, 17-20 October 2015, The Hague, Netherlands | | | |
| M. Vardon, D. Lindemayer, H. Keith, S. Ferrier, P. Gibbons | Progress, Challenges and Opportunities for Biodiversity Accounting | https://unstats.un.org/unsd/envaccounting/londongroup/meeting21/Vardon%20et%20al_Biodiveristy%20Accounting%20for%20LG%20(reduced).pdf | |
| | | | |
| Biodiversity Accounting based on the SEEA-Experimental Ecosystem Accounting framework, Cambridge, UK, 15th – 17th February 2016 | | | |
| UNEP-WCMC<br>(S. King, L. Wilson lead authors) | Guidance on experimental biodiversity accounting using the SEEA-EEA framework | http://wcmc.io/SEEA_EEA_Bio_Accounting | |
| S. King, C. Brown, M. Harfoot, L. Wilson | Exploring approaches for constructing species accounts in the context of the SEEA-EEA | http://wcmc.io/Species_Accounting | |
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| London Group, 17-20 October 2016, Olso, Norway | | | |
| S. King | Biodiversity Accounting | https://unstats.un.org/unsd/envaccounting/londongroup/meeting22/F_30.pdf | |
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| 1st Policy Forum on Natural Capital Accounting for Better Decision Making, 22-23 November 2017, The Hague, The Netherlands | | | |
| M. Vardon, S. King, D. Juhn, S. Bass, P. Burnett, C. Manuel Rodriguez, S. Johansson | The Aichi Targets and Biodiversity Conservation – The Role of Natural Capital Accounting | https://www.wavespartnership.org/sites/waves/files/kc/WAVES%20report%20final%20version%20%20%281%29.pdf | |
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| London Group, 17-20 October 2017, San Jose, Cost Rica | | | |
| S. King, M. Eigenraam | Accounting for ecosystem and biodiversity related themes in Uganda | https://seea.un.org/sites/seea.un.org/files/lg23_accounting_for_ecosystem_and_biodiversity_related_themes_in_uganda.pdf | |
| M. Vardon, R. Harris | Review of ecosystem condition indicators | https://seea.un.org/sites/seea.un.org/files/lg23_review_of_ecosystem_condition_indicators_vardon-harris.pdf | |
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| 2nd Policy Forum on Natural Capital Accounting for Better Decision Making, 22-23 November 2017, The Hague, The Netherlands | | | |
| R. Portela, M. Alam, C. Schneider, D. Juhn | Ecosystem accounting for water and biodiversity policies: Experience from a pilot project in Peru | https://www.wavespartnership.org/sites/waves/files/images/10.%20Ecosystem%20accounting%20for%20water%20and%20biodiversity%20policies.pdf | |
| S. King, M. Eigenraam, C. Obst, M. Vardon, D. Juhn | Revisiting the role of natural capital accounting for biodiversity conservation - Discussion and a case study from Uganda | https://www.wavespartnership.org/sites/waves/files/images/11.%20Revisiting%20the%20role%20of%20natural%20capital%20accounting%20for.pdf | |
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| Forum of Experts in SEEA Experimental Ecosystem Accounting, 18 – 20 June 2018, Long Island, USA | | | |
| S. Ferrier | The Role of Biodiversity Indicators in Condition Measurement | https://seea.un.org/sites/seea.un.org/files/documents/Forum_2018/s12_area_2_ferrier_-_seea-eea_expert_forum.pdf | |
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