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Review Article

A review of ecosystem condition accounts: lessons learned and options for further development

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Abstract

Ecosystem condition accounts are part of the System of Environmental-Economic Accounting – Experimental Ecosystem Accounting (SEEA EEA). An ecosystem condition account contains aggregated statistical information about the overall abiotic and biotic quality of an ecosystem at a policy relevant spatial scale. This article reviews 23 publicly-accessible reports undertaken or commissioned by government agencies, academic and non-government organisations that discuss or present an ecosystem condition account. This analysis revealed that ecosystem condition is usually reported for one or more ecosystem types, but there is little consistency in the terminology used to define ecosystem types. All case studies report variables or indicators that measure specific ecosystem characteristics in order to make inferences about the overall condition of ecosystems. All studies included biotic indicators and almost all studies included species-based indicators in the condition account. The thematic aggregation of indicators into a single composite index (or in a few composite sub-indices) is not a standard practice, but applied in about half of the studies. The definition and use of a reference condition or reference levels for specific indicators against which the reported condition can be evaluated is not a standard practice, but was applied in about half of the studies. Based on this analysis, we suggest the revision of the SEEA EEA to propose a globally-consistent typology of ecosystem types; to recommend a list of ecosystem condition indicators according to an agreed classification; to provide further guidance on aggregation methods and on the development of an ecosystem condition index that can be used to compare ecosystem condition across ecosystem types and across different accounting areas; to provide further guidance on how best to set reference levels and reference conditions against which the past, current and future ecosystem condition can be assessed; and to propose a standard set of statistical tables for reporting the condition account.

Keywords

ecosystem condition, ecosystem condition account, System of Environmental-Economic Accounting, experimental ecosystem accounting, review, indicators, reference condition, aggregation

Introduction

Ecosystem accounts measure how ecosystems contribute to human well-being and the economy and how this evolves over time. If recorded in a consistent manner at different points in time, ecosystem accounts allow tracking the changes in ecosystems, including ecosystem extent and condition and ecosystem services (Obst et al. 2016).

Consistent and regular production of ecosystem accounts requires the development of best practice guidelines and testing these guidelines with pilot ecosystem accounts (Obst et al. 2013, Polasky et al. 2015). This is the objective of the System of Environmental Economic-Accounting – Experimental Ecosystem Accounting (SEEA EEA, United Nations et al. 2014). The SEEA EEA defines an integrated statistical framework for organising biophysical data, tracking changes in ecosystem assets, measuring ecosystem services and linking this information to economic and other human activity. The SEEA EEA framework consists of four core accounts. The ecosystem extent account organises information on the extent (total area) of different ecosystem types within an accounting area. The ecosystem condition account measures the overall quality of an ecosystem. Ecosystem service accounts measure the supply of ecosystem services, as well as their use by beneficiaries. The monetary asset account records the monetary value of ecosystem assets. Next to these core accounts, thematic accounts provide more detailed, quantitative data on, for example, land, water, carbon or biodiversity.

This framework for ecosystem accounts was formally adopted by the United Nations in March 2013 (United Nations et al. 2014) and technical recommendations are available to help set up and present accounts in a standardised way (United Nations 2019). The SEEA EEA and its technical recommendations are presently under revision, with the aim of adopting a revised standard for ecosystem accounting in 2021. This paper was developed as part of this revision process and contributes, in particular, to an updated set of recommendations for reporting ecosystem condition accounts.

Ecosystem condition has been defined in the technical recommendations (United Nations 2019) as the overall quality of an ecosystem asset in terms of its characteristics. The measurement of ecosystem condition has advanced since the SEEA EEA was adopted (see, for instance, Jakobsson et al. 2020 and Rowland et al. 2020) . However, there remains a lack of clarity on (1) precisely which characteristics are relevant in the monitoring of condition, (2) what indicators are most relevant to quantify ecosystem characteristics, (3) if and how indicators can be measured relative to a reference condition and (4) how ecosystem condition indicators can be aggregated across ecosystem types or across accounting areas.

The objective of this paper is therefore to collect and review existing ecosystem condition accounts that included information on the condition of various ecosystem types reported in a structured way, at a scale relevant for policy- and decision-makers and with explicit reference to SEEA EEA. When analysing these accounts, we addressed the following questions:

1. For which ecosystem types and realms is ecosystem condition reported?
2. What indicators or variables were used to develop an ecosystem condition account, what were the criteria to select particular indicators and were the indicators classified according to any typology?
3. Were indicators aggregated to single (or few) high-level indices or composite indicators to report an overall measure of ecosystem condition?
4. Was the information in the accounting table on ecosystem condition compared to reference levels for condition indicators or against a reference condition and, if so, what sort of information was used to determine a reference?
5. How was the account reported or structured: for example, was the account reported as area of ecosystem (ha or %) under a certain condition or were the condition indicators and/or aggregated index reported as opening and closing values?

These questions are addressed in this paper by reviewing, summarising and synthesising the information that is presented in a set of case studies included in this review. The final goal of this review is to better understand the current practices of countries, regions or organisations with respect to the development of ecosystem condition accounts. This understanding is needed to further guide the revision of the SEEA EEA and, in particular, to help prepare globally-accepted recommendations for standardised and consistent ecosystem accounts.

Methods

Selection of case studies

Case studies for this review were selected in August 2018, based on an initial list of 58 studies that report accounts of ecosystem assets (extent, condition and ecosystem services) at national and/or sub-national scale. These case studies were taken from a list, which is compiled and updated by the office of the SEEA programme of the United Nations Statistics Division (UNSD). All accounts reported in this document were written in English and are publicly accessible on the internet. The list provided a reasonably comprehensive list of compiled and published ecosystem asset accounts at the time of selection. From this list, only studies that discuss the development of an ecosystem condition account with specific reference to the SEEA EEA or that report an ecosystem condition account including an accounting table that is constructed in line with technical accounting recommendations (United Nations 2019) were further considered. An ecosystem condition accounting table can take several forms. It can report for a specific accounting area (e.g. a country) the opening and closing values of ecosystem condition indicators for one or more ecosystem types and for one or more years; it can report for one or more years the area or stock of an ecosystem type in different ecosystem condition classes (e.g. good, fair, poor) so that the sum of the reported areas equals the total area of the ecosystem type for the accounting area; it can report an aggregated ecosystem condition index or sub-indices per year and per ecosystem type. This initial set of 58 studies on ecosystem accounting contained 17 reports with explicit information about ecosystem condition. Six additional studies were added by the authors, based on personal knowledge resulting in a total of 23 case studies.

This review does not consider articles, reports and studies that define ecosystem condition or related concepts, such as ecosystem health or ecosystem integrity or that propose indicators to measure condition if the accounting context is absent (for a review on ecosystem condition indicators, see Rendon et al. (2019)).

Since there has been more than one year between the time of data collection and the time of writing this article, we replaced one case study that reported an ecosystem condition account for Limburg, a province in the Netherlands, with a case study developed subsequently that reports a condition account for the entire area of the Netherlands.

The selected case studies were divided in two groups: type A case studies that include an ecosystem condition accounting table and type B case studies that do not include an accounting table, but that include the scoping of a condition account or that provide a discussion of ecosystem condition in the context of ecosystem asset accounts, including indicators of ecological condition.

Finally, the list of case studies was reviewed by the SEEA EEA working group on ecosystem condition[*2] and a few more case studies that had been overlooked in the first round were added, notably type B case studies that scope condition accounts for specific ecosystem types. The final list of reviewed case studies is presented in Table 1.

Table 1.

List of case studies included in this review.

Number	Country	Account (short title)	Reference
Type A case studies ("Strict" condition accounts)			
1	Australia	Port Phillip Bay	Eigenraam et al. (2016)
2	Australia	Great Barrier Reef	Australian Bureau of Statistics (2016)
3	Australia	State of Victoria	Eigenraam et al. (2013)
4	Australia	Victoria Central Highlands	Keith et al. (2017a), Keith et al. (2017b)
5	Australia	Accounting for Nature Trials	Wentworth Group (2016)
6	Australia	Victoria's Parks	Varcoe et al. (2015)
7	Canada	Measuring ecosystem goods and services in Canada	Statistics Canada Environment Accounts and Statistics Division (2013)
8	Netherlands	Ecosystem condition account for the Netherlands	Lof et al. (2019)
9	South Africa	National river accounts	Nel and Driver (2015)
10	UK	Woodlands	EFTEC (2015)
11	UK	Freshwater ecosystems	Khan and Din (2015)
12	UK	Protected areas in England and Scotland	White et al. (2015)
13	UK	Forest Enterprise England (public forests and woodlands)	Forest Enterprise England (2017)
14	UK	Green space in urban areas	Office for National Statistics (2018a)
Type B case studies: Accounts that discuss aspects of condition, but did not include condition account tables			
15	Australia	Vegetation Assets, States and Transitions (VAST)	Thackway and Lesslie (2005)
16	Australia	Australian Capital Territory - proof of concept	Smith et al. (2017)
17	EU	Ecosystem condition accounts for EU and member states	UNEP-WCMC 2017
18	South Africa	KZN province – land and ecosystem accounts	Driver et al. (2015)
19	Uganda	Experimental ecosystem accounts	UNEP-WCMC and IDEEA (2017)
20	UK	Developing UK mountain, moorland and heathland ecosystem accounts	Office for National Statistics (2017)
21	UK	Developing semi-natural grassland ecosystem accounts	Office for National Statistics (2018b)
22	UK	Scoping UK coastal margin ecosystem accounts	Office for National Statistics (2016)
23	UK	Scoping peatlands	Dickie et al. (2015)

Collection of data from the case studies

With reference to the five research questions that have been raised above, we collected the following data from the case studies.

Research question 1 on ecosystem types and realms was addressed by recording for each case study: (1) for which realm (terrestrial, inland water or marine ecosystems) the account was developed, (2) for which ecosystem type or types the account was developed and (3) if total extent per ecosystem type or types is presented in the accounting table.

Research question 2 on indicators, indicator selection criteria and indicator typology was addressed by recording: (4) the indicators used to describe ecosystem condition and (5) the classification or typology used to group ecosystem condition indicators (if available).

Research question 3 on aggregation was addressed by checking if the case studies reported: (6) a composite index of ecosystem condition or sub-indices that aggregate indicator values within a class or category of indicators.

Research question 4 on the use of a reference was addressed by: (7) controlling if the case studies compared indicator values to reference levels or if ecosystem condition was evaluated against a baseline or reference condition (for instance, a historical baseline or a pristine ecosystem condition).

Research question 5 on the structure of the account was addressed by recording: (8) the spatial unit for analysis, (9) the spatial unit of reporting or the ecosystem accounting area and (10) the structure of the accounting table and the reported values (e.g. opening and closing values or the extent of the ecosystem type in different ecosystem condition classes)

The supplement contains the list of case studies with their references (Table S1). The supplement also contains a table that summarises the 10 information types collected for the type A case studies (Table S2), as well as a more complete description of each case study (Suppl. material 1).

Results

Almost all case studies come from Australia and the United Kingdom and from countries where English is an official language (Uganda, Canada and South Africa) or for a region where English is an official working language (EU). The Netherlands undertook an effort to translate the findings into English. Clearly, this review would have benefited from the inclusion of studies in other languages as well, if they had been available. All of the 23 studies reviewed are reports. Any studies that were published as scientific articles do not include account tables, presumably because they are considered too detailed and lengthy for academic journals. Most studies are undertaken or commissioned by governmental bodies and agencies. With one exception, all of the studies were published within the last six years (2013-2019), reflecting the fact that ecosystem condition accounting is a relatively-new field of practice. Of the 23 studies included in this review, 14 contained a structured condition table (also referred to as type A case studies, Table 1). These 14 studies came from five countries: Australia, Canada, Netherlands, South Africa and the United Kingdom.

The next sections analyse in more depth the results of the review following the structure outlined by the five research questions.

Realms, ecosystem types and assets, extent reporting

The majority of the case studies dealt with the terrestrial and/or inland water realms, with the marine realm considered in five of them (Table S2, Suppl. material 1). Most case studies report a condition account for an ecosystem type, whereas two studies specifically refer to assets (land, water, carbon, timber, biodiversity, tourism, atmosphere). Reported ecosystem types include forests and/or woodland, farmland and agroecosystems, including grasslands, sparsely-vegetated areas including mountains, heathlands, rivers and open waters, inland and coastal wetlands including transitional waters, urban areas, coastal areas including dunes and beaches, marine ecosystems including coral reefs, shelfs and ocean. There is little consistency in the terminology used to define ecosystem types and usually a lack of clear definitions. The extent of the ecosystem types or assets is, in most cases, included in the condition account.

Ecosystem condition indicators, selection criteria and typology

Ecosystem condition indicators

A wide variety of indicators is used across the case studies to assess ecosystem condition. Table 2 provides a synthesis of the indicators that have been used in the various type A and type B case studies. Table 2 provides broad groups of indicators with some examples.

Table 2.

Summary of the indicators used in the case studies, grouped into main classes of indicators with some examples. + means that for these ecosystem types specific indicators on top of the generic indicators are used in the ecosystem condition accounts.

Realm	Ecosystem type	Main groups of indicators and examples
Terrestrial	Generic indicators – can be applied to all terrestrial ecosystem and vegetation types	Indicators on the structure and composition of the vegetation such as tree canopy cover, understorey strata, leaf area Outright loss or conversion of natural vegetation cover to intensive uses (linked to ecosystem extent, but is also used as an indicator of condition) Landscape indicators including landscape type, natural land parcel size and spatial configuration Air, water and soil quality indicators such as nitrogen content, heavy metal content, concentrations of different air, water and soil pollutants

Realm	Ecosystem type	Main groups of indicators and examples
		Species-based indicators such as "naturalness" of biota, species richness, red-listed species, conservation status of species Biomass/carbon indicators Other characteristics amongst which annual rainfall, annual number of growing days Pressure indicators such as lack of weeds, depth to groundwater table, degree of fragmentation Indicators on the access to ecosystems, such as distance to ecosystems, population density Indicators related to protection measures, such as sites of special interest
	+ for forests and woodlands	Specific forest indicators, such as extent of tree species type and volume, age, biomass of the timber stock Spatial configuration of the forest
	+ for urban areas	Specific urban indicators such as access and proximity of green space, as well as indicators related to protection measures (special designation of sites of interest)
	+ for mountains, moorlands and heathlands	Specific indicators include the particular management of these ecosystem types such as managed burning, length of trails, volume of sheep grazing
	+ for grassland	Specific indicators include the particular management of these ecosystem types such as cutting and grazing intensity
Inland water	Rivers, open waters, lakes, reservoirs	Physical indicators about the hydrology, such as physical form, flow, reservoir stock Indicators on the instream and riparian habitats Indicators of chemical and ecological water quality including single indicators, such as concentrations or composite indicators, such as surface water status Species-based indicators, such as macro-invertebrate diversity Access to ecosystems by people
	Wetlands	Physical indicators on the size and shape of wetlands Carbon and nitrogen stock indicators (including wetland soils) Species-based indicators, such as wetland birds Chemical water quality indicators Access to ecosystems by people
Marine	Marine inlets, transitional waters and coastal ecosystems Shelf and ocean ecosystems	Loadings of nutrients, sediment or pollutants to sea Chemical water quality indicators, such as dissolved oxygen, Chlorophyll-a, turbidity, nutrient concentrations Bathing water quality indicators Extent of specific habitats such as seagrass habitats or coral reefs Species-based indicators, such as fish diversity and abundance or conservation status Access to coastal zones and margins

The different terrestrial ecosystems share a number of generic, "cross-cutting" indicators that can be used to assess the condition of various ecosystem types. Examples are structure and composition of vegetation, conversion to intensive land uses, fragmentation, the chemical quality of the water and soil, biomass or carbon indicators and species-based indicators. In addition, indicators related to accessibility and protection of ecosystems are included in the condition account, particularly in the UK accounts. The indicators of access to ecosystems warrant some discussion.

Firstly, measures of access to ecosystems by people are frequently used as indicators in the UK condition accounts. Other studies do not use this indicator to assess ecosystem condition. The rationale is that accessibility influences the capacity of ecosystems to provide recreation services and hence links ecosystem condition to ecosystem services. Accessibility could thus be used as a metric in ecosystem service accounts rather than ecosystem condition accounts. However, measures of accessibility can also relate to management interventions or to increased pressure on ecosystems and may thus be useful in ecosystem condition accounts. The specific indicator(s) to be used (e.g. length of trails, number of visitors, population density near ecosystems) and their relationship to ecosystem condition (which could be positive or negative) is likely to be highly context specific.

A second point to note is the use of the term “species-based indicators” rather than “biodiversity indicators”. The term “biodiversity indicators” is often used in case studies to mean species-based indicators, but in principle, “biodiversity indicators” could relate to genes, species or ecosystems. To avoid confusion, we avoid the term “biodiversity indicators” in this paper when referring specifically to species-based indicators.

Besides the generic indicators for terrestrial ecosystems, specific indicators are used to assess particular aspects of condition for forests and woodlands, grasslands, urban areas or heathlands. For forest ecosystems, the size and properties of the timber stock are important, as well as the spatial configuration. Interestingly, accounts for semi-natural ecosystems that require a specific management to maintain them in a particular state include indicators in the condition account that can quantify management practices, such as grazing or burning.

The condition of inland water ecosystems is frequently measured with indicators that relate to the physical structure (e.g. quantity and flow of water) and the chemical water quality of rivers, lakes and wetlands, as well as the condition of instream and riparian habitats. There is a long history of assessing water quality using composite chemical or ecological indicators (based on specific species) which is reflected in the accounts.

The condition of marine ecosystems is measured by the same group of physico-chemical water quality indicators as for inland waters, but also uses the loads of nutrients, sediments and pollutants to sea. There is less emphasis on ecological status of marine ecosystems (perhaps due to lack of data) and this seems to be replaced with the extent of particular habitats, such as seagrass.

Table 2 shows that there is some convergence towards using a similar set of indicators for the different realms (terrestrial, inland waters and marine) and for different ecosystem types.

We draw three general observations from the review of indicators used to quantify ecosystem condition accounts at sub-national and national scales.

A first generalisation is that biotic indicators are universally used in the accounts; species-based indicators (as a sub-class of biotic indicators) are widely used to assess condition of ecosystems across different ecosystem types.

Secondly, in addition to species-based indicators that are used across the different realms, the following indicators are used within the different realms: terrestrial ecosystem condition measurements are currently based on indicators about pressures, structure (from vegetation level to landscape scale), loss or conversion of natural vegetation, the chemical quality of water and soil, the quantity of biomass and carbon. Accessibility is used in all the UK accounts for terrestrial ecosystems, but not in the other countries. Inland water ecosystem condition measurements are based on physical (such as hydrological), habitat-related, chemical and ecological status indicators. Marine ecosystem condition measurements are based on physical and chemical status indicators, as well as on an assessment of loads of nutrients, sediment or pollutants entering seas.

Thirdly, specific indicators are available per ecosystem type, which can be related to the management of that ecosystem or to specific pressures, characteristics or species.

Selection criteria for indicators

Not all studies included in this review justify the choice of particular indicators to measure condition, for instance, using a set of selection criteria. Mostly, a rationale for the selection of indicators is lacking and there is no discussion on how adequately indicators describe the condition of an ecosystem. However, in several cases, justification for selection of condition indicators is not directly found in the case studies that report the actual accounts, but in preceding articles or reports that are then cited by the case studies. A good example are studies that scope a condition account and include a rationale as to why certain indicators have been selected (case studies 20-23, Table 1). Case study 5 (Table 1), the report by Wentworth Group 2016, includes a useful section on the selection criteria for indicators.

Typology or classification of indicators

None of the studies developed a formal typology or classification of ecosystem condition indicators. Indicators are rather assorted or grouped ad hoc into classes that describe the relationships amongst indicators. For instance, the Canadian account (case study 7, Table 1) distinguishes two groups of indicators according to spatial scales: site conditions and landscape context. The Dutch case study (case study 8, Table 1) groups indicators according to major ecosystem compartments, including vegetation, biodiversity, water, air and soil. Several UK accounts have higher-level categories for indicators, but there is no consistent use of a typology or a classification across the different accounts.

The UK scoping paper on mountains, moorland and heathland (case study 20, Table 1) comes closest to proposing a classification that could be generally applied across different ecosystem types. The paper refers to the principles of natural capital accounting (Office for National Statistics 2017) which recognises seven dimensions of quality for which condition can be indicated. The dimensions are as follows: relevant volume estimates (for example, timber biomass, water quantity or flow, length of linear features), biodiversity indicators (for example, abundance indicators, mean species richness), soil indicators (for example, carbon content, water content), ecological condition indicators[*1] (for example, water quality, plant health, invasive species), spatial configuration (for example, fragmentation, connectivity), access (for example, proximity to areas of population) and management practices (for example, organic farming, degree of protection).

Several case studies do not group indicators per se but they report an implicitly-adopted hierarchy through the use of composite indicators, which in themselves, are constituted of separate metrics. The case study for Victoria (case study 3, Table 1) reports the condition of wetlands based on an index. This index is based on six sub-indices, which are derived from 13 metrics. The sub-indices represent six dimensions of ecosystem condition indicators: wetland catchment, physical form, hydrology, water properties, soil and biota. The condition of rivers is reported, based on a similarly-derived index. Case study 5 (Table 1) aggregates different indicators into three composite indicators which reflect habitat and, to a lesser extent, ecological processes, biological health and the physical/chemical quality of wetlands and streams. The South African river accounts (case study 9, Table 1) report values for an aggregated ecological condition index, based on four sub-indices that characterise river condition: flow, water quality, riparian habitat and instream habitat.

Spatial and thematic aggregation of condition indicators

All type A case studies essentially aggregate at least some information as they report the condition of ecosystems at sub-national or national level. Often indicators are spatially explicit, for instance, bird counts or water quality data and are thus spatially aggregated by summing (in case of counts) or by averaging (in case of water quality) values across space.

Eight of the 14 type A case studies and several type B case studies (Table 1) also perform thematic aggregation. They combine different indicators into a single basket or composite indicator, for instance, by normalising the indicators and summing them. Aggregation occurs in one step or in two steps. A common practice is to aggregate individual indicators or metrics into a single index of ecosystem condition (one-step thematic aggregation) or sub-sets of indicators are aggregated into several sub-indices which, in turn, are aggregated into a single condition index (two-step thematic aggregation).

Aggregation can be to a single index or score (e.g. 0 – 1 or 0 – 100) or to an ecological condition category (such as good, fair, poor) or both.

Indicators are usually aggregated (and reported) within an ecosystem type rather than across different ecosystem types.

Reference levels and reference conditions

For the purposes of this review, we considered a reference condition as a condition, against which the past, present or future condition can be evaluated. A reference level refers to the value of an indicator measured at the reference condition.

Only half of the type A studies clarified the reference levels of the indicators, referring to a reference condition or a baseline situation. Australian studies typically use the pre-European reference of the 18th century. The South African case (case study 9, Table 1) uses the natural state (prior to major human modification) as reference condition. The UK accounts commissioned by the Office for National Statistics (case studies 10, 11, 14, Table 1) do not use a reference condition as a matter of principle, measuring change only as the difference between opening and closing indicator values. However, other UK accounts report indicators for which reference levels or targets have been established, in particular under EU law such as the Water Framework Directive (WFD) or the Habitats Directive (HD). For instance, EU member states monitor the ecological status of surface water bodies under the WFD and the conservation status of threatened habitats and species under the HD. Both ecological status and conservation status have target levels (good ecological status and favourable conservation status, respectively) and are each determined using a number of indicators or assessments. These target or reference levels could possibly be used to help define a reference condition.

Reporting of the account

The way the condition account is reported is closely related to whether or not the account contains or is based on an aggregated index. There are two main ways used in the case studies to report the condition account (see Fig. 1 for a hypothetical example of both reporting systems). One method reports values of ecosystem condition indicators as opening and closing values per year, sometimes against a baseline year or a reference condition (case studies 1, 3, 5 and 6, Table 1). The second method divides indicators first into broad condition categories or classes on an ordinal scale, for example, from low to high condition (case studies 9 and 12, Table 1). This approach then breaks down the total ecosystem extent over these different categories either in absolute numbers, expressed in ha or km^2 or km length or as a percentage of the total area.

Both reporting formats can be used to report on indicators, sub-indices or a single aggregated index or a combination of these.

Those ecosystem condition tables that included a measure of extent reported ecosystem extent in ha or km^2 or km length. This confirms that ecosystems are seen by the case studies as assets that can be measured by both extent and condition.

Good practice reporting was particularly observed in the South African river accounts (case study 9, Table 1) in the sense that they provide a complete set of accounts for sub-indices, condition category and condition index that allow tracking the different thematic aggregation steps. Sometimes, studies report only values and change of the aggregated indicators which results in a loss of information.

Reporting system 1: Opening and closing values of indicators and	Ecosystem type (extent: 250 ha)	
Indicators	Opening value (Year 1)	Closing value (Year 2)
Indicator 1 (scaled between 0 and 1)	0.45	0.38
Indicator 2 (scaled between 0 and 1)	0.65	0.58
Ecosystem condition index (average)	0.55	0.48

Reporting system 2: Opening and closing stock of ecosystem extent in different condition categories	Ecosystem type (extent: 250 ha)	
Condition category	Opening stock (Year 1)	Closing stock (Year 2)
>0.6 (good condition)	100 ha	80 ha
0.4 - 0.6 (fair condition)	80 ha	90 ha
<0.4 (poor condition)	70 ha	80 ha

Figure 1.

Two frequently-used reporting systems for the ecosystem condition account: reporting the opening and closing values of an indicator or index or reporting the total area or ecosystem extent under a specific ecosystem condition category. The data are hypothetical and only presented to illustrate both approaches to reporting the condition account.

Discussion

This review analysed 23 studies that report or discuss an ecosystem condition account at subnational and/or national scales. Fourteen studies published an ecosystem condition accounting table. The analysis of these 14 condition accounts produced a number of generalisations, which can provide information for the revision of the current set of technical recommendations to quantify and account for ecosystem condition at aggregated scales:

1. Most accounts report ecosystem condition for one or more ecosystem types, but there is little consistency in the terminology used to define ecosystem types;
2. All accounts report variables or indicators that measure specific ecosystem characteristics in order to make inferences about the overall condition of ecosystems;
3. All studies included biotic indicators and almost all studies included species-based indicators in the condition account;
4. The thematic aggregation of indicators into a single composite index (or into a few composite sub-indices) is not a standard practice, but applied in about half of the studies;

5. The definition and use of a reference condition or reference levels for specific indicators, against which the reported condition can be evaluated, is not a standard practice but was applied in about half of the studies.

Following points (4) and (5), countries using single composites were not more or less likely to also use reference levels or vice versa.

While there is no “one-size-fits-all” set of condition indicators that will work for all realms and all ecosystem types, there may be common indicators or common groups of indicators that can be used to assess ecosystem condition and reported in ecosystem condition accounts in a consistent way. This is particularly evident for species-based indicators which are used in almost all accounts. It demonstrates the importance of mainly locally-collected data about the diversity, occurrence and abundance of species in the understanding on ecosystem condition (Andreasen et al. 2001, Hatziiordanou et al. 2019, Kokkoris et al. 2018, Rendon et al. 2019). Besides using species as indicators for ecosystem condition, we note that the condition of marine and inland waters is frequently assessed using indicators that measure the physical or chemical state of water. In terrestrial ecosystems, ecosystem structure and function indicators, as well as landscape metrics, complement the species-based indicators to assess ecosystem condition. These general observations on how ecosystem condition is reported in an account could be useful to provide information for a common typology or classification for ecosystem condition indicators, which allows comparison of the condition of ecosystems across ecosystem types and across different spatial contexts.

The selection of indicators, used in the accounts that were analysed in this review, appears to be largely data-driven. Accounts are thus, in the first instance, compiled using the best available information and data. Such a data-driven approach likely explains the diverging typologies to classify indicators and the relatively-poor rationale found in the studies to explain use of particular condition indicators. It appears likely that the different ecosystem condition indicators have been grouped after they have been selected rather than the indicator selection being based on a predefined typology. A good practice is therefore to always provide a clear and explicit rationale for the selection of specific condition indicators and to identify any gaps explicitly. Clear selection criteria and justification of use of particular indicators also ensure that accounts are transparent, consistent and repeatable, particularly through time (for example, with different assessors). Therefore, it may prove to be useful to develop a common, hierarchically-structured typology of indicators, including abiotic and biotic indicators, to better guide the selection of a set of indicators that provide a comprehensive representation of condition.

As already mentioned above, only half the accounts considered in this review used a baseline or reference condition against which condition indicators were evaluated. A similar observation is made for aggregation, where only half the accounts included some sort of thematic aggregation, whereby different indicators are summarised in a sub-index or a composite indicator. Not all accounts that report a reference condition have aggregated condition indicators and vice versa, not all accounts that report a composite indicator have set a reference. We thus suggest that more guidance is needed on consistent levels of reporting, in particular if ecosystem condition needs to be compared across different accounting areas or across different ecosystem types. We also suggest that a tiered or stepwise approach to compiling the account with increasing levels of information (or complexity) is a practical way forward where outputs at each step are relevant for policy- and decision-making. For example, a three-tier approach could include the following: a tier 1 condition account that reports values for the key abiotic and biotic characteristics of ecosystems for each ecosystem type across an ecosystem accounting area for a particular year; a tier 2 condition account that includes a reference condition and allows users evaluating the current values of condition indicators against reference levels; and a tier 3 condition account that aggregates individual indicators into one or more composite indicators, facilitating communication about the overall condition of different ecosystem types and allowing relative comparisons amongst different ecosystems and different accounting areas.

An evident shortcoming of this review is its bias towards English-speaking countries. Furthermore, at least a few more studies have been published since the collection of the accounts considered in this paper. We particularly refer the ongoing work in Cyprus (Vogiatzakis et al. 2020), Bulgaria (Nedkov et al. 2018), Czechia (Vačkářů and Grammatikopoulou 2019) and Greece (Dimopoulos et al. 2017) as country case studies that base the development of condition accounts on a nation-wide mapping of the extent and state of ecosystems using a common methodology for the European Union (Burkhard et al. 2018).

Conclusions

Despite ongoing progress in ecosystem condition accounting, the limited number of studies that were available at the time of collection is evidence that the development of ecosystem condition accounts is still lagging behind, relative to the ecosystem extent accounts or ecosystem services accounts (e.g. Vallecillo et al. 2019). Clearly, a better understanding of ecosystem condition and more guidance to support its consistent measurement and reporting is needed to further boost the development and application of ecosystem condition accounts.

With respect to the five research questions addressed in this review, we suggest for revision of the SEEA EEA to (1) propose a globally consistent typology of ecosystem types, (2) provide guidance on selection of ecosystem condition indicators according to an agreed classification, (3) provide further guidance on aggregation methods and on the development of an ecosystem condition index that can be used to compare ecosystem condition across ecosystem types and across different accounting areas, (4) provide further guidance on how best to set reference levels for ecosystem condition indicators and reference conditions, against which the past, current and future ecosystem condition can be assessed and (5) propose a standard set of statistical tables for reporting the condition account.

Disclaimer

The System of Environmental Economic-Accounting – Experimental Ecosystem Accounting (SEEA EEA) is going through a revision process between 2018 and 2021. The revised SEEA EEA is expected to be adopted by the United Nations Statistical Commission in March 2021. This article is based on a discussion paper that contributed to the revision process. The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official position of the SEEA EEA. The views expressed in this article do not reflect an official position of the European Commission.

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Supplementary material

Suppl. material 1: Supplementary information doi

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Data type: text
Brief description: This supplement contains the following supplementary information: Table S1: A list of case studies and their references; Table S2: Key characteristics of the 14 type A case studies (Strict ecosystem condition accounts); A description of every case study.
Download file (613.34 kb)

Endnotes

*1 It might be confusing to include “ecological condition indicators” as one of the classes of a typology for ecosystem conditon indicators.

*2 For more information on the SEEA EEA revision process, see https://seea.un.org/content/seea-experimental-ecosystem-accounting-revision