Common International Classification of Ecosystem Services (CICES) V5.2
Guidance on the Application of the Revised Structure

by

Roy Haines-Young

Fabis Consulting Ltd.

The Paddocks, Chestnut Lane,

Barton in Fabis, Nottingham, NG11 0AE, UK

Contact email: Roy.Haines-Young@fabisconsulting.com

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Contents

Executive Summary

Background

i. The version of the *Common International Classification of Ecosystem Services* (CICES) in current use (V5.1) was published in 2018. On the basis of the experience gained by the user community its structure and scope has been reviewed, and a fully revised version, V5.2, has been developed. This document describes the revision and the rationale underlying it. Tables setting out the new 5.2 version and its relationship to earlier versions can be downloaded from www.cices.eu and BISE.

ii. Since V5.1 has been released it has been widely used internationally. More than 1000 papers published since 2018 cite the classification in some way, and a number have made detailed comments on its structure, scope and how it can be applied. The aim of the revision has been to build on this success and the experience gained to ensure that CICES continues to be relevant and usable by the science and policy communities.

Scope and focus of Version 5.2

iii. In CICES ecosystem services are defined as the *contributions* that ecosystems make to human well-being, and as distinct from the goods and benefits that people subsequently derive from them. These contributions are framed in terms of 'what ecosystems do' for people. Thus, in the revised version the definition of each service identifies both the purposes or uses that people have for the different kinds of ecosystem service *and* the particular ecosystem attributes or behaviours that support them.

iv. CICES aims to classify the contributions that ecosystems make to human well-being that arise from living processes. Although ecosystem outputs derived from living structures and processes remain the focus of CICES, feedback from the user community to broaden the classification to cover abiotic outputs has been addressed. The new version allows users to select only those ecosystem services that depend on living systems (i.e., biophysical ecosystem outputs) or to include the non-living (abiotic) parts of ecosystems that can also contribute to human well-being (geophysical ecosystem outputs).

v. The importance of providing detailed guidance to help people apply the classification was one of the key points to arise from the consultation on the earlier version of CICES. The formal and systematic definitions provided in V5.2 will help people identify more easily what the different services categories cover. The structure closely follows that of V5.1 and provides examples of the services themselves and types of associated benefit. In order to help users to work in more informal settings, suggestions for simpler non-technical names for services continue to be provided in the revised classification structure.

Compatibility with earlier versions of CICES

vi. The hierarchal structure that was the basis of CICES V5.1 has been retained in the biophysical and geophysical parts of the revised classification. At the highest level in each part services are grouped accordingly into three Sections that relate to whether the contributions to human well-being support a) the provisioning of material and energy needs, b) regulation and maintenance of the environment for humans, or c) the non-material characteristics of ecosystems that affect physical and mental states of people.

vii. Although the majority of the classes included in V5.1 carry over to V5.2, their ordering and coding has been modified slightly in the new version to enable users to more easily aggregate classes for reporting purposes, especially in relation to cultural ecosystem services. A full set of equivalences at Class level have been provided to enable users to make the transition to V5.2.

CICES as a reference classification

viii. In addition to providing a way to classify ecosystem services, CICES was also intended as a reference classification that would allow translation between different ecosystem service classification systems, such as those used by the Millennium Ecosystem Assessment (MA), and The Economics of Ecosystems and Biodiversity (TEEB). This feature has been retained in V5.2, and equivalence tables are provided. Tables for equivalences between CICES V5.1 and the UN SEEA Reference List, and the US EPA NESCS classification are also now available for V5.2.

1. Introduction

1.1. The Common International Classification of Ecosystem Services (CICES) has been designed to help measure, account for and assess ecosystem services. Although it was developed in the context of work on the System of Environmental and Economic Accounting (SEEA) led by the United Nations Statistical Division (UNSD), it has been used widely in ecosystem services research for designing indicators, mapping and for valuation[1].

1.2. The EEA is the custodian agency of the Common International Classification of Ecosystem Services in the United Nations' inventory of international classifications. CICES has been developed by Fabis Consulting since 2011, with support from EEA.

1.3. In 2020 and 2021, the EEA worked with the CICES developers and UNEP-WCMC to carry out a consultation on potential improvements of CICES with a view to aligning it with the UN SEEA EA ecosystem accounting standard. The aim was also to take account of recent insights from academic research on ecosystem services. The two reports by WCMC (2020 and 2021) and the subsequent study by Haines-Young (2023) have formed the basis of this revision.

1.4. The team commissioned by the EEA undertook a rapid literature review seeking to identify any issues highlighted in the published literature that might suggest that a revision of CICES 5.1 or its guidance documents might be necessary. The work in 2021 also drew on feedback from two meetings with the scientific community, namely: a workshop held at the 3rd ESP Europe Conference in Tartu, Estonia, June 2021; and, a webinar discussion in July 2021, which included selected contributors to the ESP meeting. A key output from these discussions was the idea of thematic application of CICES and how this could inform any future review of its structure or associated guidance. The particular thematic areas considered were soils, the marine environment and cultural ecosystem services.

1.5. The three thematic areas considered partly reflected the topics covered in recent publications involving CICES. It was clear, however, that the discussion points were also relevant to a number of the wider issues that had been identified in the earlier work (WCMC, 2020). Thus, while the revision drew on experience in these three application areas more general concerns have been addressed. This has been done by extending the literature review of papers published up to the end of February 2023, to include papers since the WCMC work was completed, and by correspondence with the authors of key papers to elicit their current views on any potential revision (see Haines-Young, 2023).

[1] For a history of the development of CICES see Potschin and Haines-Young (2016), and Hains-Young and Potschin (2018) and the documents on the CICES website (www.cices.eu).

1.6. The initial version of CICES (V4.3) was published at the beginning of 2013. This version developed from work started in 2009, which took as a starting point the approach of the Millennium Ecosystem Assessment (MA, 2005) for describing ecosystem services. The development work refined the classification to reflect some of the key issues identified in the wider research literature. As a result of the considerable body of work that built up around its initial publication, a review of its structure was undertaken and a major revision (V5.1) was released in 2018. The current revision builds on that and takes account both of the large number of successful applications and comments on how it might be strengthened.

2. The contribution of CICES V5.1

2.1. Although the focus of this document is on how CICES V5.1 has been modified it is important to emphasise that that there are a number of significant and successful existing applications that demonstrate the value and contribution of V5.1. The applications of CICES that we describe below illustrate that while CICES has been developed and used widely in Europe, it is now being used for wider international and global scale studies. It is vital to identify these contributions here to preserve the utility of the classification in any revision.

Comprehensive, hierarchical structure of CICES

2.2. The merits of the wide-ranging, hierarchical structure of Version 5.1 was a feature highlighted in the WCMC Review (WCMC, 2021) which looked in detail at studies dealing with soils, the marine environment and cultural ecosystem services (e.g., Ahtiainen et al., 2019; Bartkowski et al., 2020; Christianson et al. 2022; Inácio et al., 2018; Kuhn et al., 2021; MacPherson et al., 2020; Paul et al., 2021; Pavan & Ometto, 2018; Schwilch et al., 2018; von Thenen et al., 2020). The ability to standardise analysis studies has been further stressed in the more recent review of published literature. For example, von Thenen et al. (2021), along with Garcia-Onetti et al. (2021), note that the tiered structure of the classification allows addition of new ecosystem service classes that are relevant for specific studies. This has proved especially valuable in helping people to undertake thematic literature reviews or to develop customised analytical frameworks.

2.3. A key feature of much recent scientific work involving CICES has been to review the published literature in particular thematic areas. These systematic reviews seek to identify the scope and focus of current research and more importantly, the key lessons that may be learned from past work. While much of the work covered in a systematic review may not have used CICES as a reference point, the comprehensive, flexible nature of the classification has enabled authors to position the target references work in a common framework so that comparison and analysis is possible. Coverage of both biotic and abiotic ecosystem outputs has also been stressed as an important feature of the classification (Kubalíková, 2020; Von Thenen et al., 2020).

2.4. Recent examples of CICES being used as a framework for undertaking systematic reviews confirm the earlier findings of WCMC (WCMC, 2021). Such work includes that of Zieritz et al. (2022) on freshwater bivalve molluscs, and Merida et al. (2022) on the ecosystem services associated with meat and dairy production. Kuhn et al. (2021) found, for example, that over two thirds of the marine studies they reviewed did not apply any standard ecosystem service classification, they therefore also used CICES 5.1 so that effective comparisons could be made. Elsewhere, Ruiz-Agudelo et al. (2022) have made an assessment of the economic values for ecosystem services in Colombia from 154 published studies; 502 values were coded and classified according to CICES V5.1. Sheehy et al. (2022) used a somewhat similar approach to make a review of evaluation and valuation methods regulation and maintenance ecosystem services delivered by cetaceans.

2.5. The advantages of CICES as a common reference framework have recently been exploited in the design of the Ecosystem Services Valuation Database (ESVD)[2], which uses the classification as one of the search tools. The database aims to provide robust and easily accessible information on the economic benefits of ecosystems and biodiversity, and the costs of their loss, to support decision making regarding nature conservation, ecosystem restoration and sustainable land management. CICES is used to reference the studies included in the classification so that information can be extracted in a systematic way.

Knowledge elicitation

2.6. A further complementary, but distinctive type of application of CICES that exploits its comprehensive and tiered structure has been the elicitation and organisation of expert and stakeholder views. Thus, as the WCMC review (2021) noted, Ryfield et al. (2019) used the CICES to codify survey responses for coastal ecosystem services for their study for Dublin Bay. They selected CICES because of its detail in relation to cultural ecosystem services and the links it provided to the ways people derived benefits from their interaction with ecosystems. Our subsequent review has found that Christianson et al. (2022) also used CICES to codify material obtained from participant interviews within communities enrolled in an ecosystem-based adaptation project in Uganda, while Saeed et al. (2022) used a similar approach to work on perceptions of climate change with indigenous communities in the Western Himalayan Gurez Valley. Konstantinova et al. (2021) used CICES to better understand perceived benefits of animal ownership in an urban context. Zepp et al. (2021) employed the classification as a framework for knowledge elicitation in scenario modelling for Shanghai. CICES has also been used by Ruskule et al. (2023) as a framework for the elicitation of expert views in testing the concept of green infrastructure to support an ecosystem-based approach to management of marine areas in the Baltic sea.

[2] https://www.esvd.net

Supporting different analytical and indicator frameworks

2.7. The development of analytical and indicator frameworks has emerged as a key feature in the new literature reviewed by this study. Such work illustrates how CICES goes beyond a simple classification approach. In part, this is related to the conceptual framework of the cascade model, on which the classification is based. However, the work also builds on the flexible, yet comprehensive structure of the existing version.

2.8. For example, Faber et al. (2021) use the classification and the cascade framework to identify ecological production functions for use in ecosystem services-based Environmental Risk Assessment (ERA) of chemicals. In their methodological statement they note that one of the advantages of CICES was that it was consistent and transferrable (i.e., linked to other classifications) which made it ideal for systematic review where the papers needed to be categorised. The paper also demonstrated how the underpinning cascade model helped contextualise the services covered by CICES in a causal pathway. In terms of providing evidence on the coverage of CICES, the paper showed that ecological production functions could be constructed for all CICES V5.1 biotic provisioning and regulating classes. Suitability for application in chemical ERA varied considerably due to evidence gaps which meant that only part of the production function could be quantified. Nevertheless, it is apparent that CICES enabled such gaps to be identified, and the insights gained from existing literature to be applied in specific thematic context. Other examples of the classification being used as an analytical framework include: VanderWilde & Newell (2021) who have used CICES as the basis of a systematic review of ecosystem services in Life Cycle Assessment, as a way to develop consistent approaches to quantify ecosystem service supply and demand; and Gärtner et al. (2022) who used the classification and the cascade model to integrate ecosystem services into risk assessments for drinking water protection in Sweden.

2.9. For the marine environment, von Thenen et al. (2020) applied CICES and the underpinning cascade model to create a structured indicator pool to operationalize expert-based ecosystem service assessments for marine spatial planning. Subsequently, these authors used the classification to develop a site selection method for mussel farming in the Baltic sea (von Thenen et al., 2021). Visintin et al. (2022) adapted the indicators approach of von Thenen et al. (2020) to assess the benefits of Marine Protected Areas in Italy. Harris and Defeo (2022) used the classification to identify the ecosystem services associated with sandy shore ecosystems in Australia.

2.10. Other examples of work using the classification to create analytical frameworks include Tiemann et al. (2022), who combined the concept of forest function mapping with CICES V5.1, to identify relevant ecosystem services and develop indicators for their biophysical quantification. In the context of soils Steinhoff-Knopp et al. (2021) use CICES to consider the impact of soil erosion on soil-related ecosystem services to develop and test a scenario-based assessment framework.

2.11. Elsewhere, Seelen et al. (2022), used CICES to propose threshold values for ecosystem services that linked a set of state indicators with services provided by quarry lakes, and Ranta et al. (2021) have used the classification for urban stream assessment. Miah et al. (2021) used CICES alongside the DPSIR framework to assess services and their drivers of change in the Meghna River estuary of Bangladesh, and Ioannidou (2022 a & b) used the classification as the basis for assessments of soil quality parameters, orchard attributes and Agricultural Management Practices in Cyprus. Weninger et al. (2021) have employed CICES to identify and systematically review ecosystem services associated with tree windbreaks in rural landscapes. Despite noting some limitations of the classification (see below), Ojaveer et al. (2023) have used a modified version of the classification to help quantifying the impacts of human pressures on ecosystem services from non-indigenous species in the Baltic Sea.

2.12. One of the most recent, comprehensive applications of CICES V5.1 to create indicator frameworks is that of Paul et al. (2022), who have created a toolbox for assessing the actual or potential supply of ecosystem services in agricultural land and soil management. The work used the classification to identify relevant literature for 37 services for which factsheets were then created. Each factsheet provides tables with available indicators for each service applicable at field to global spatial scales, information on the type of input data required, and a reference to sources.

2.13. The use of CICES V5.1 to create mapping frameworks is also evidenced in the recent literature by for example Kaziukonytė (2021) who used CICES as a framework for expert-based assessment to map the ecosystem services potential in the Nemunas Delta and Curonian Lagoon Region of Lithuania; and Kounnamas (2022) who utilised the classification to undertake a mapping assessment of ecosystem services at Troodos National Forest Park in Cyprus.

Ecosystem accounting and the SEEA

2.14. The System of Economic-Environmental Accounting Ecosystem Accounting (SEEA EA) has been developed by the United Nations as a framework for measuring the ecosystem extent and condition of the ecosystems and the ecosystem services they deliver The goal has been to develop an internationally agreed way to document the changes in ecosystem assets and how these changes link to the contributions ecosystems make to economic and other human activity.

2.15. The key part of the work on SEEA EA that is relevant here is that which concerns the definition and identification of ecosystem services. The SEEA EA text notes (Section 6.3) that while there have been advances in the classification of ecosystem services, with the development of CICES and the US EPA National Ecosystem Services Classification (NESCS) framework, an internationally agreed approach has not been finalised. As a result, the SEEA EA proposed to focus on a ‘reference list’ of selected ecosystem services that has combined the findings from CICES, NESCS and other work (e.g., MA, TEEB and

IPBES-NCP). The primary criterion for inclusion in the reference list is that the service is considered to constitute a relevant and important ecosystem service in different geographical contexts.

2.16. In terms of the recent contribution of CICES to current debates, it is important to note several features of the SEEA EA guidance. First, that the definition of ecosystem services in the SEEA EA is consistent with that proposed for CICES, where they are seen as contributions to human well-being and distinct from benefits. Second, that the SEEA EA places emphasis on the concept of final ecosystem services and uses a definition consistent with that employed by CICES. As a result, only provisioning, regulating and cultural ecosystem services are included, while 'supporting services' are excluded from consideration. Finally, the approach used to define intermediate services also corresponds to that employed in CICES, i.e. it focusses on between ecosystem flows (see para 3.10). For the SEEA EA a single ecosystem service may be final or intermediate depending on the use context.

2.17. As a result of the conceptual consistency between the SEEA EA and CICES there is a good read-across between the services in the proposed reference list and V5.1. Furthermore, as part of the work to help people take ecosystem accounting forward, the SEEA EA is accompanied by a cross-walk between the reference list, CICES and NESCS and other classifications, such as the MA, TEEB and IPBES. The cross-walk was informed by the correspondence table developed when CICES V5.1 was released. Maintenaning and enhancing this consistency was an important factor in shaping the design and update of V5.2.

2.18. The consistency between the SEEA EA framework and CICES means that the latter can be used in ecosystem accounting in the context of official statistics. Moreover, as is demonstrated above, as a reference framework CICES may also be useful in relation to integrating different sources of data in a common framework such as the SEEA EA. An example of such work is provided by the recent paper by Nedkov et al. (2022), who used CICES V5.1 to explore the most appropriate categories of models for water regulation ecosystem services that are included in the SEEA EA reference list. The work sought to address the lack of systematic information on the use of models for water-related ecosystem services, and how they could be used in flow accounts. The paper found that while the framing of some water regulation services in the SEEA EA reference list differs in some aspects from the CICES 5.1 classes, the water purification (water quality regulation) service corresponds to three CICES 5.1 classes, each with its own specifics concerning the use of models. Nedkov et al. (2022) conclude that the results of the analysis provide the basis for recommending the most appropriate categories of models for the water regulation ecosystem services included in the SEEA EA reference list.

2.19. A further example of how the use of CICES V5.1 links to the requirements of SEEA EA is provided by Cordero-Penín et al. (2023) in their work on mapping marine ecosystem services potential across the Canary Island oceanic archipelago. CICES was used as the framework for a literature review designed to meet the first stage of ecosystem accounting, namely the construction of extent accounts. The latter gave an overview of the supply capacity of each CICES service by area across biological zones of the benthic habitats in the study area. In their conclusion the authors observe that their study illustrates the utility of standardised classification systems such as EUNIS and CICES in the marine spatial planning processes.

3. Guidance

3.1. The purpose of these guidelines is primarily to help people use V5.2 effectively. Given that some readers may be familiar with V5.1, we have mainly included a discussion of those aspects that have changed. However, it should be noted that much of the former structure has been carried over. As before, the classification table provides a full cross-reference between versions, so that users can switch easily between them.

3.2. Although CICES provides a way of defining and describing ecosystem services, it is also intended as a reference classification that allows a cross-reading between different ecosystem service classification systems, for example from the MA to CICES. The current version retains the ability to support comparison between systems, and the revised version allows cross-walks to the classifications of MA, TEEB, IPBES, US EPA NESCS and the SEEA EA Reference list.

3.3. In the sections below we discuss the conceptual underpinnings of CICES V5.2 and describe the scope and rationale for the changes in structure to V5.1. The main table for V5.2 now includes a column on 'Guidance' which provides a brief commentary on the changes made and/or the relationship with CICES V5.1 or other classifications, such as the SEEA EA Reference list.

CICES: Conceptual Background

3.4. The cascade model (**Error! Reference source not found.**) provides the conceptual framework in which CICES is set. CICES seeks to classify final ecosystem services, which are defined as the contributions that ecosystems (i.e., living systems) make to human well-being. These services are final in that they are the outputs of ecosystems (whether natural, semi-natural or highly modified) that most directly affect the well-being of people.

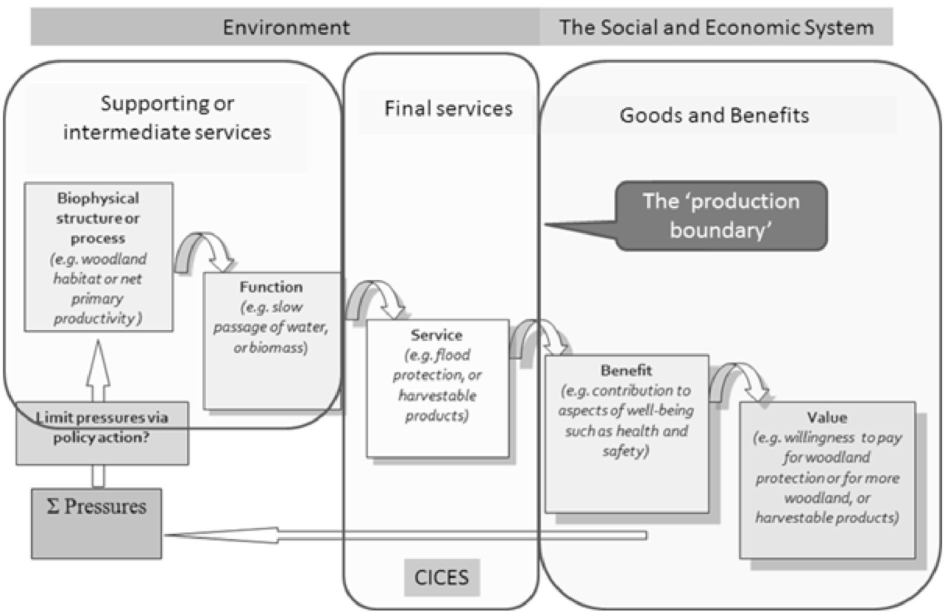

Figure 1 The cascade model (after Potschin & Haines-Young, 2016)

Final services

3.5. A fundamental characteristic of final services is that they retain a connection to the underlying ecosystem functions, processes and structures that generate them. On the 'supply side' of the cascade, the idea of 'function' is used to highlight those characteristics of the living system that come together to make something a service.

3.6. In the case of wood used for timber, for example, these would include the attributes that make the particular wood material 'workable', say, as a building material, and could include such things as the hardness, strength, and durability of the wood fibre. These attributes will all depend in turn on the underlying structural properties of the woodland, which includes tree composition, soil type, nutrient status and the growth processes that have shaped the stand being used for wood. The volume of timber ready to be cut is taken to be the service in CICES.

3.7. Services, in the cascade, give rise to goods and benefits, as in the case of timber when it is harvested and the 'production boundary' is crossed. The concepts of goods and benefits are essentially regarded as the same kind of thing in the cascade model; they are one step removed from the ecosystem and are the things that ultimately have value for people. Sometimes goods are seen as representing more tangible things, like the processed timber that can have a monetary value. In other situations, the ecosystem 'outputs' can be less tangible, and in this case are often described simply as benefits (rather than products). In the case of woodland, for example, these can include settings in a woodland, such as views or birdsongs, which facilitate recreation as a cultural service.

Final services and context

3.8. As an ecosystem service classification that aims for a global reach CICES needs to be applicable in many different contexts. Hence its approach to, and criteria for, defining individual ecosystem services need to be sufficiently general to be relevant in many different situations. This means that in applying CICES for identifying ecosystem service flows additional information on a specific setting or context is often needed for using CICES successfully in identifying final ecosystem services flows.

3.9. Although the threshold for what constitutes a final service is well defined in theory, in practice whether something is regarded as a final service depends on context. For example, if the water in a lake is used directly as a source for drinking, then it could be regarded as a final service. If, however, the focus is on the service of recreational fishing, then time spent at the lakeside would be regarded as the final service. This means that each ecosystem provides a range of ecosystem services that make contributions to human well-being in many different ways.

3.10. The problem of context dependency makes the identification of final ecosystem services quite complex. Thus, while CICES seeks to provide a classification of final services, the table developed should be regarded as providing a classification of potential (i.e., putative) final services. It is up to the user to decide whether in a particular application context, the service is to be regarded as final or not, or whether the particular ecosystem property or behaviour is regarded as having a more 'intermediate' status (and could thus better be described via an assessment of ecosystem condition).

3.11. In some of the literature on ecosystem services, flows that have an intermediate status are sometimes described as 'intermediate services', which operate alongside more basic ecological structures and processes, or 'supporting services', to underpin the output of final services. CICES does not attempt to identify or classify all the things that play this underpinning role, and indeed this guidance avoids the use of the terms 'intermediate' and 'supporting services' entirely, except in the context of service flows between ecosystems . This is where the output of one ecosystem is regarded as final even though it becomes an input to another.

3.12. This framing of the idea of an intermediate service is consistent with the terminology of SEEA EA. For a more general yet detailed discussion of this issue see, for example, Potschin-Young et al. (2017). This is not to say that these kinds of outputs are unimportant, rather that they are not regarded as services. These could likely be better documented in other ecosystem accounts in terms of the structures, processes and functions that give rise to services. These underpinning elements ultimately determine the capacity of the ecosystem to deliver particular services that can be represented by concepts other than that of a service, say in terms of measures of ecosystem condition. That is why the SEEA EA framework includes the accounts for ecosystem extent and ecosystem condition as building blocks for the compilation of ecosystem service accounts.

Abiotic or geophysical ecosystem outputs

3.13. From its initiation CICES has focused on defining final ecosystem services that depend on living systems. This was not to say that many of the physical characteristics and behaviours of physical systems that are part of nature are unimportant to people, but rather to emphasise the fundamental contribution that biodiversity makes to human well-being. In this respect, CICES followed the logic of the Millennium Ecosystem Assessment (MA, 2005) and initiatives such as The Economics of Ecosystems and Biodiversity (TEEB)[3] and the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES)[4].

3.14. When CICES V4.3 was released, a rudimentary table of abiotic ecosystem outputs was provided using the same classification logic as for those ecosystem services that depend on living systems (and water). This approach was further developed in V5.1 and V5.2.

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[3] http://www.teebweb.org/

[4] http://www.ipbes.net/

3.15. The status of 'water' was used to illustrate the issue of defining biotic and abiotic ecosystem outputs. Insofar as water is not directly produced by living systems, it is difficult to see water as an ecosystem service similar to those based on biomass (or 'biodiversity' more generally). Since the MA, TEEB and IPBES regarded water as an ecosystem service it was essential that it was included in V5.1 but defined as part of the abiotic section of the classification. This approach has been maintained in V5.2, albeit with a revised terminology for 'abiotic' ecosystem outputs.

3.16. Since the publication of V5.1, a number of authors have worked with and commented on the abiotic part of the classification. Both Fox et al. (2020) and Frisk et al. (2022), for example, have noted that while CICES lists biotic and abiotic services, the boundary between them is blurred; both papers therefore explore the dichotomy between ecosystem services (i.e., those driven by living processes) and what they call 'geodiversity services'. The latter are biophysical in nature, that is dependent on a combination of biotic and abiotic processes. These authors argue that many services that CICES, for example identifies as 'biotic', are in fact often dependent on ***biophysical*** processes rather than only on biological ones; and so, conclude that the distinction between biotic and abiotic tables in CICES is misleading. Indeed, Fox et al. (2020) argue that in CICES the definition of what counts as a service is 'artificially constructed and inconsistently applied'. Specifically, they claim that the classification omits the supporting or intermediary services that indirectly regulate ecosystem services. They note, for example, that abiotic elements of soils contribute key minerals, nutrients and water which are required to sustain living things, thus illustrating the supporting role of geodiversity in providing the physical platform for the ecological functions that produce ecosystem services.

3.17. In an attempt to bring clarity to the debate, Fox et al. (2020) offer the distinction between *theoretical biosystem services* dependent exclusively on biological structures and processes, *ecosystem services*, that are dependent on *biophysical* structures and processes (i.e. integrated biotic and abiotic structures and processes, or geodiversity) and *geosystem services* that are provided exclusively by geodiversity or the diversity of geological structures and processes (i.e. are wholly abiotic in nature). They conclude that since geodiversity and geosystem services are omitted from most ecosystem service literature and frameworks, policy and decisions often place focus on the management of living systems rather than the biophysical environment as a whole. By way of illustration, they redraw the cascade model as a logic chain for services associated with mangrove swamps, that helpfully distinguishes between biotic, biophysical and geophysical inputs (Figure 2).

3.18. The contribution by Fox et al. (2020) is useful in emphasising the difficulty in dealing with the biotic and abiotic aspects of ecosystem services in CICES. The main implication of their work is that future CICES guidance and terminology should emphasise more the biophysical as opposed to the biotic characteristics of the services identified in the main table. In designing CICES, the term 'ecosystem' has been taken to refer to living organisms and their abiotic environment. Thus, the intention has been to recognise the *biophysical* structures and processes that contribute to human well-being. **To emphasise this more clearly some revision of terminology has been made for V5.2. Biotic services are now described as *biophysical* ecosystem services, dependent on integrated biotic and abiotic processes. Moreover, the classes in the abiotic extension are relabelled *geophysical*.** The assumption is that any services that depend on the interaction between biotic and abiotic structures and processes would be covered in the main table, while only those exclusively dependent on abiotic characteristics of the natural world would be covered elsewhere.

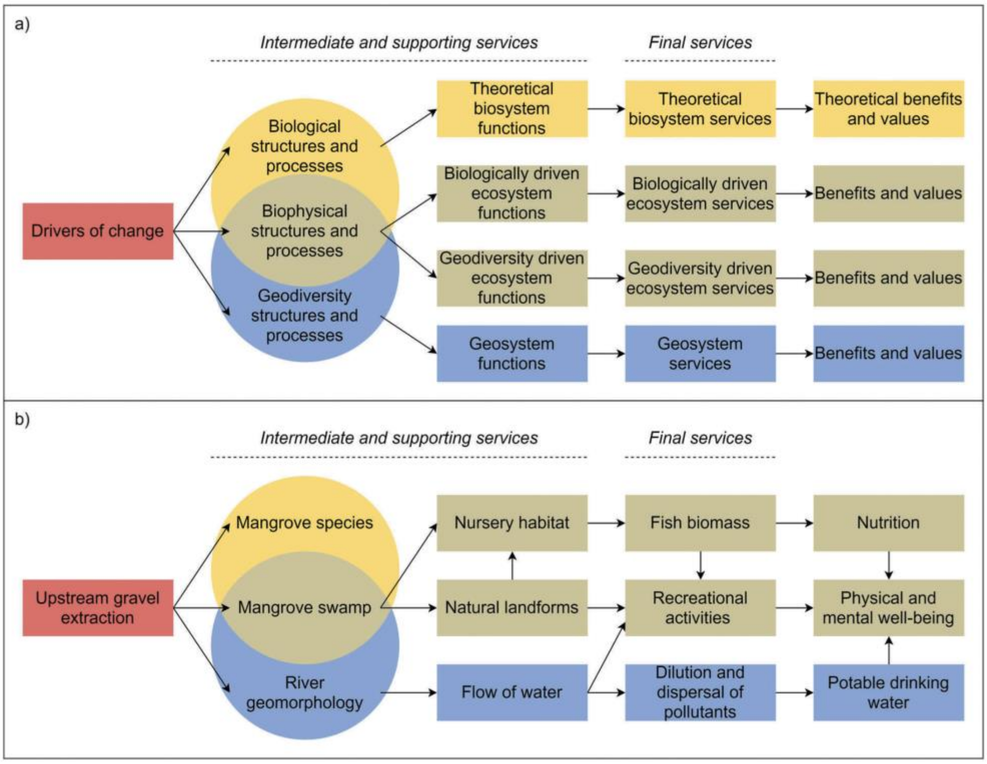

Figure 1: Application of the cascade model demonstrating the flow of Ecosystem and Geosystem Services from interactions of abiotic and biotic nature. (a) application of the framework to a real-world ecosystem – mangrove swamps (b); after Fox et al. 2020.

3.19. The strategy of updating terminology rather than of modifying the structure of the classification itself is supported by the recent work of Frisk et al. (2022) who used CICES V5.1 as a framework for a systematic review of current definitions of geosystem services and their categorisation. Their goal was to examine how the concept can support subsurface planning. They found that thirty-one out of thirty-nine services listed in the reviewed literature are included in the abiotic (geophysical) extension of CICES V5.1, which suggests that the present structure probably captures much of current thinking. Seven of the eight 'missing' services identified by Frisk et al. (2022) are described by them as supporting services, thus one might not expect to find them in the CICES tables. The remaining missing class related to geophysical support for human activities; in the revision this has been dealt with by broadening the definition of the class 'mineral substances used for material purposes, including geophysical support (foundations)' (V5.2 4.2.2.1).

Using the cascade or logic chains: ecosystem functions, goods and benefits

3.20. A corollary of the idea that context determines what constitutes a final service, is that the same logic applies to the determination of what constitutes either ecosystem functions, or the goods and benefits derived from ecosystems that people value. In all cases the issues are often best resolved in relation to an application by representing the ecosystem service in terms of the cascade model.

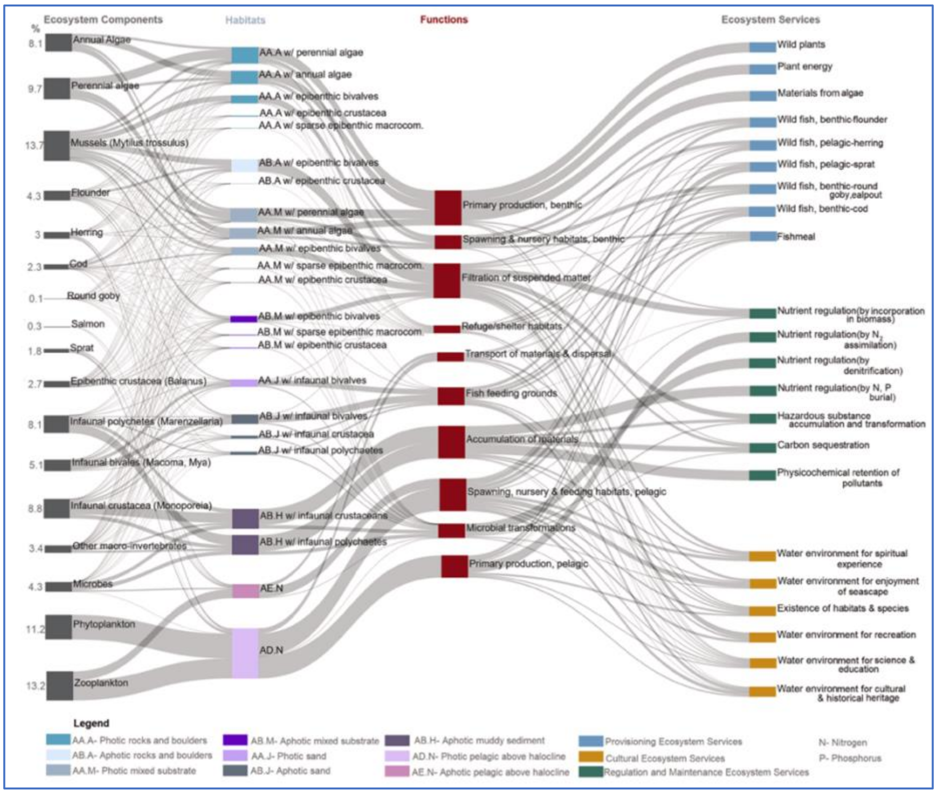

Figure 2: Linkage between species and ecosystem services This figure depicts the relative importance of species (left-hand side) in supply of ecosystem services (right-hand side) (after Armoškaitė et al. 2020)

3.21. Since the release of V5.1 in 2018 there have been several papers setting out the conceptual framework of the cascade (Potschin-Young et al., 2018) and a number of published papers where the model is used as an analytical framework alongside CICES (e.g., Fox et al. 2020; Pavan et al. 2018; von Thenen et al. 2020, 2021). The significance of this work is that it can help clarify ways in which ecosystem services can be seen to be embedded in 'logic' or 'causal' chains linking biophysical structures on the one hand and benefits and values on the other. A similar conceptual framing has been used in the SEEA EA.

3.22. An example of such work from the marine sector is provided by Armoškaitė et al. (2020) who, as part of their research on marine ecosystem components, functions and services were able to construct linkage diagrams (Figure 3). These linkage diagrams captured the richness of connections between different ecosystem components and habitats, functional characteristics and ecosystem services. The example shown here illustrates how complex the ecological processes and structures underpinning an ecosystem service can be, with single functions influencing more than one service and services dependent on more than one function.

3.23. A further example from the marine sector also illustrates the importance of distinguishing ecosystems and benefits as distinct concepts. Von Thenen et al. (2021) developed a marine planning framework for site selection based on a case study of the sea use of mussel farming in the Baltic Sea. The ecosystem services covered by CICES V5.1 were used to identify different beneficiary groups and different types of benefit. They found not only that most benefits and impacts of mussel farming can be connected to one of the ecosystem services identified as relevant to the activity, but also that there were a range of different user-environment-beneficiary interactions, from conflicts to synergies. For example, while establishing a mussel farm may be regarded as a benefit by some because the activity can reduce excess nutrients, for others the response was more negative, because it led to unwanted social effects such as an increase in tourist pressure.

3.24. The importance of setting analysis and definition of ecosystem services within the cascade framework is especially important given the development of so-called 'logic chains' within the SEEA EA methodology. These are wholly consistent with the conceptual framework underpinning CICES.

3.25. We consider that a richer understanding of both the multiple connections underpinning ecosystem services and the different types of links between these services and benefits will enable users to better frame their analysis around the CICES classes.

Carrier functions, physical support and space

3.26. A number of commentators have argued for the recognition of ecosystem properties that facilitate transportation and physical support for other human activities as ecosystem services. Others have argued that the provision of space for people might also be included.

3.27. For example, the notion of soils and other natural physical structures and surfaces (e.g., water) providing support for various human activities have been referred to more generally as 'carrier services' by, for example, Van der Meulen et al. (2016). García-Onetti et al. (2021) also explore this idea in their review of how ecosystem services can be integrated into the socio-ecological management of ports[5]. Elsewhere, the reviews of Bartkowski et al. (2020) and Paul et al. (2021) remark that CICES 5.1 does not cover the ability of soils to provide a physical base or platform for human activities (e.g., for

[5] Note that these authors, confusingly, refer to space as 'support services' in their classification.

supporting human structures, foundations for housing or livestock). They observe that the European Soil Thematic Strategy[6] also cites the importance of this property of soils.

3.28. Van der Meulen et al. (2016) acknowledge that while so-called carrier services of ecosystems are not explicitly included in the CICES classification, some aspects are covered by the abiotic extension of CICES, in the group 'physical and intellectual interactions with land-/seascapes' (6.1.1). However, they note that such things as the support for non-recreational (e.g., commercial) shipping has no explicit position in the system.

3.29. It is indeed the case that the physical space provided by ecosystems is not included in CICES; the rationale for this is that in any assessment 'space' would be covered by analysis of, and reference to, the habitats or settings in which any work was carried out. Thus Version 5.2 continues to exclude 'space'. So, for example, in terms of the ability of rivers or lakes to provide navigation and transport, this would be referenced to the physical and biological services dealing with the regulation of water flows etc., rather than the ability to support navigation or transport as a separate class. In fact, it could be argued that navigation and transport are benefits to which the regulation services provided by ecosystems contribute, since they are largely determined by the skill of people and the technology available to them.

3.30. Nevertheless, some clarification is needed in the guidance supporting CICES. Thus, in the abiotic (geophysical) extension of CICES the class *Surface water used as a material (non-drinking purposes*) (V5.2, 4.1.1.2) has been broadened to include navigation or transportation. This would also cover the use of ice or snow as a means of transport, with a suitable qualification to distinguish the use of snow for recreational purposes.

3.31. In addition, the new class under soil quality, dealing with the impacts of biological processes and agents on soil structure (V5.2, 2.3.4.3), explicitly now refers to the ability of soils to support foundations etc. Note this class covers the contribution that biological activity makes, and is distinct from the physical characteristics of soils or bedrock that might provide a supporting function.

3.32. Overall, however, we suggest that the issue of carrier services is best dealt with in other ways, such as through the classification of anthropic services, as García-Onetti et al. (2021) have done. These authors suggest that such a class can sit alongside but be distinct from the ecosystem services covered by CICES capturing those situations in which 'artificial, constructed or transformed components [of the environment], are decisive for the provision of benefits for human well-being' (García-Onetti et al. 2021, p.6). The concept of anthropic services is considered to sit outside the general concept of ecosystem services and is therefore not covered by CICES.

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0699

Defining ecosystem service bundles

3.33. Although CICES is designed to allow ecosystem service classes to be grouped into more general categories at higher levels in the hierarchy, there is nothing to prevent people grouping the classes in other ways to identify clearly what is being considered. Indeed, this is perhaps the main feature of the classification: to standardise nomenclature so that comparisons can be made more easily and accurately.

3.34. Thus, in their analysis of ecosystem services associated with windbreaks in rural landscapes, Weninger et al. (2021) were able to meaningfully group 28 CICES classes into eight bundles or 'functional ecosystem service units'. They suggested that the groupings could be used to better understand the state of current knowledge, and show the range of positive effects that windbreaks bring to landscapes. Harris & Defoe (2022) show how service bundles can be defined for Sandy shore ecosystems.

3.35. The recent contribution of Gärtner et al. (2022) demonstrates a more sophisticated approach to grouping CICES classes in novel ways. These authors explored how to integrate ecosystem services into risk assessments for drinking water protection. To define a set of groupings that have meaning in the risk assessment process, they nest the biotic and abiotic classes of CICES V5.1 into a set of water system services (WSS) that could be used operationally. Following the approach used in CICES, the proposed WSS had its own distinctive hierarchical structure, with the WSS classes defined using a similar 'two clause' structure to that of CICES.

3.36. Thus, despite the issues raised by some commentators about service groupings cutting across the hierarchical structure of CICES, no change in the structure of CICES has been made. Users are encouraged to cluster services in ways that are meaningful for their analysis.

Genetic diversity

3.37. In the consultation for V5.2 it was suggested that the importance of genetic diversity (both within and between species) should be highlighted. It is acknowledged that genetic diversity has a fundamental 'supporting role' in ecosystems. However, the benefits to people that eventually arise from this diversity are generally expressed indirectly through other ecosystem services and properties (such as the resilience of fisheries in fluctuating climates etc.). Thus, alongside functions or activities like nutrient cycling, within CICES genetic diversity would not be regarded as a service, but part of the fabric of nature that underpins them. This is not to deny that that fabric is not important and should not be protected but that 'diversity' *per se* is not a service with a direct contribution to people's well-being. To regard it so, would also pose the problem of 'double counting' in relation to the contribution that the genetic characteristics of biological entities make to human well-being.

3.38. Nevertheless, while the 'supporting' role of genetic diversity lies outside the scope of CICES, the conservation and study of genetic diversity is a legitimate aspect of the cultural relationships that people have with nature. Thus, in revising the classification reference to ‘between’ and ‘within’ genetic diversity has been added to several class descriptors. So, in the revised class: 3.2.1.1 'Elements of living systems that enable scientific investigation or the creation of traditional ecological knowledge' the definition now incorporates the phrase '.... including the importance of between and within species genetic diversity'. A similar addition has been made to class 3.2.1.2. While the conservation of genetic diversity would seem to be implicit in both 3.4.2.1 and 3.4.2.2, definition text has also been modified for clarity.

3.39. Note that class 2.3.2.3, *Maintaining or regulating nursery populations and habitats or breeding grounds* already makes reference to gene pool protection, and there is extensive reference to genetic material in the Division of Provisioning *Genetic material from all biota (including seed, spore or gamete production).*

Provisioning

Using CICES Groups to aggregate CICES Classes

3.40. The earlier revision of CICES allowed the grouping of CICES classes for assessment when no end use could be clearly identified in relation to use for nutrition, fibre and material and energy. This structure has been retained in V5.2, so that the classes in the Group ‘Cultivated terrestrial plants for nutrition, materials or energy’ (1.1.1.1, 1.1.1.2 and 1.1.1.3) can either be aggregated to align with SEEA Subtype 1.1, or be used to disaggregate the category further. This design feature of CICES was made in response to comments from the ecosystem accounting community in the 2018 revision, and is therefore retained in the structure of V5.2 for all of the Groups in the Biomass Division.

The placement of fodder and feed crops, and the problem of final services

3.41. In contrast to CICES V5.2, the SEEA EA places fodder crops under ‘crop provisioning services’ (SEEA Subtype, 1.1). Since fodder crops contribute to human nutrition only indirectly via some animal production system, CICES would place them alongside other material and fibres contributed by ecosystems which are used as an input to other processes (e.g., using class 1.1.1.2).

3.42. CICES V5.2 would only regard fodder or animal feed crops as a final service if they were ‘exported’ from the ecosystem being assessed to be used elsewhere, in another assessment unit. For CICES, for example, this would be one ecosystem contributing to the outputs of another via an ‘intermediate service’ (i.e., there would be a flow between ecosystems, see 3.10). The same logic applies whether the fodder or feed were cultivated or derived from harvested, wild material. Under CICES V5.2 the fodder or feed would be assigned to classes 1.1.1.2 and 1.1.5.2, as appropriate.

3.43. If the fodder crops were being used within the ecosystem unit assessed, then clearly, they would not be a final service. Instead, the animals that depend wholly or partly on the fodder of feed input would be given the status of a ‘final service’. Again, the same logic applies whether the fodder or feed were cultivated or derived from harvested, wild material.

3.44. Clearly the decision to include reared animals as a final ecosystem service in any assessment would depend on context. If the animals were entirely housed and all feed input was brought in, then it may not be appropriate conceptually to regard the animal production as an ecosystem service. The reared animals depend entirely on conditions created and maintained by people. In this situation, the final service would be the fodder or feed production. In other circumstances, however, animals may be partly or wholly grazed outside within the agroecosystem, in which case the weight gain associated with outside grazing could be regarded as a final service. The contribution of the ecosystem to the final output could be calculated on the basis of the proportion of the biomass provided by vegetation in the assessment unit.

Provisioning services from aquatic and nonaquatic wild animals and plants:

3.45. The SEEA EA makes a distinction between provisioning services from wild fish and other natural aquatic products (SEEA EA sub-category 1.6) and wild animals and plant (excluding fish and aquatic products) (SEEA EA sub-category 1.7). However, while 1.6 emphasises nutrition, the descriptor for 1.7 omits explicit mention of food but includes services such as hunting, trapping and bioprospecting. CICES V5.2 splits the contributions of wild plant and animals into different groups (1.1.5 & 1.1.6) and further subdivides the groups into contributions relating to nutritional, material and energetic uses. Thus, in terms of the cross walk, the CICES V5.2 classes have been assigned to SEEA sub-categories 1.6 and 1.7, but clearly could be used to make finer-scale distinctions within these broad SEEA types, since collectively the two SEEA sub-categories encompass the CICES groups dealing with wild animals and plants both aquatic and non-aquatic.

The placement of wood provisioning services

3.46. While the SEEA EA includes a sub-category for wood provisioning services (sub-category 1.5), CICES V5.2 does not, because it seeks to avoid including explicit reference to ecosystem type in the service definition. Woody material for fibre or energy from plantations would, according to CICES, be placed in classes 1.1.1.2 and 1.1.1.3, while the equivalent services from natural woodland would be placed in classes 1.1.5.2 or 1.1.5.3. Non-wood forest products are excluded from the SEEA EA sub-category 1.5 and are dealt with elsewhere in the SEEA reference list. This approach for non-wood forest products should also be followed when using CICES V5.2.

3.47. In making this distinction between the formulation in CICES and the SEEA EA, it is recognised, that for the latter a wood provisioning service could arise in any context where the associated benefit was timber or similar. This could arise from harvesting forests, but also from trees in urban areas, farmland, roadsides. Thus, the intention may not be to limit the SEEA sub-type 1.5. In working with CICES and the SEEA EA users should seek to specify how the classes and sub-types are applied and whether the wood is being used for material or energetic uses, for example.

3.48. Despite the differences between CICES V5.2 and the SEEA EA identified here, it is apparent that while some of the conceptual boundaries may differ at broad scales, the CICES classes can be assigned appropriately to each of the SEEA sub-categories and used to clarify what is being measured. For example, the CICES V5.2 class *Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)* is assigned to the SEEA EA sub-categories 1.2, 1.5, 1.6 & 1.7. The relationship to four SEEA EA subtypes does not reflect any misalignment between the two systems because depending on context the class types within CICES could be nested within the SEEA EA sub-categories. Thus, (semi-)natural vegetation used for grazing would be assigned to SEEA EA 1.2; wood biomass for materials or energy would be assigned to SEEA EA 1.5; and aquatic and non-aquatic plants and animals used for materials assigned to SEEA EA 1.6 and 1.7 respectively.

Regulation and Maintenance

Reduction of nutrient loads and mediation of wastes

3.49. Within CICES the Regulation and Maintenance Section deals with biophysical structures and processes that mediate environmental conditions that impact people's health, safety or comfort etc.

3.50. In the context of nutrient cycling in situations where anthropogenic pollution is important, the intention in V5.2 is to cover this in the classes dealing with,

Either:

- the mediation of wastes and toxic substances, namely: *Bio-remediation by micro-organisms, algae, plants, and animals* (2.1.1.1), and filtration/ sequestration/ storage/ *accumulation by micro-organisms, algae, plants, and animals* (2.1.1.2).

Or

- the condition of water bodies, namely: *Regulation of the chemical condition of freshwaters by living processes* (2.3.5.1) *Regulation of the chemical condition of salt waters by living processes* (2.3.5.2).

3.51. The intention with these classes is that they should also cover all the ways in which living systems can mediate nutrient loads, waste or pollution. To clarify the situation the Group for *mediation of wastes* was modified to read: *Reduction of nutrient loads and mediation of wastes or toxic substances of anthropogenic origin by living processes*. Of the class definitions relating to the Group on condition of water bodies, none include explicit reference to macro-nutrients.

3.52. As Czúcz et al. (2018) have shown, assessments often struggle with differentiating the CICES classes dealing with wastes, from those under the Group on condition of water bodies. This partly arises because many of the same biophysical processes underpinning 2.1.1.1 and 2.1.1.2 may be involved in the Group on condition of water bodies, making it potentially difficult for users to determine which set of classes should be used. We therefore suggest that services in the Group on condition of water bodies specifically cover aquatic macronutrients (e.g., carbon, nitrogen or phosphorus). All other wastes and pollutants would be covered by 2.1.1.1 and 2.1.1.2. In both cases, however, a specific nutrient load and its damage threshold can be identified, and a reduction in the load due to ecosystem structures and processes can be detected. See for example the discussion by Watson et al. (2016) of macronutrients in the marine environment.

3.53. The SEEA EA reference list makes a distinction between solid wastes (SEEA EA Subtype 2.8) and liquid wastes (2.9 and 2.10). The distinction seems problematic operationally, since nutrients and pollutants may change their state as they pass through an ecosystem. In that context, we suggest that services in the Group on condition of water bodies are best measured in terms of water quality parameters for macronutrients and their changes and can be assigned to SEEA EA subtype 2.9 or 2.10 as appropriate For the waste processing classes (2.1.1.1 & 2.1.1.2), however, the measurement basis would be activities or abundance of specific organisms or the volumes of nutrient or pollutant removed, and the service assigned to SEEA EA Subtype 2.8 (irrespective of whether the nutrient or pollutant were in a solid, liquid or gaseous form).

Control of erosion rates

3.54. In V5.2, the CICES V5.1 Class *Control of erosion rates* has been split into two Classes: 'Control of water erosion rates' (2.2.1.1) and 'Control of wind erosion rates' (2.2.1.2). In V5.2, they are nested together into the Group *Erosion control* (2.2.1) which is now equivalent to the V5.1 Class 2.1.1.1. These revised classes dealing with erosion specifically cover the loss of material from soils or sediments.

3.55. Note that alongside the new classes for water and wind erosion, V5.2 renames the V5.1 class *wind protection* as *surge and flood wave mitigation* (V5.2, Class 2.2.3.2). The change conceptually broadens the class which now deals with the protection offered by living structures to extreme weather events. The inclusion of surges in the new class definition arises from changes made to the scope of the V5.1 Class *Hydrological cycle and water flow regulation,* see below.

Hydrological cycle and water flow regulation

3.56. Consultation has suggested that the CICES V5.1 Class *Hydrological cycle and water flow regulation* (Including 'flood control', and 'coastal protection') appears to be a very broad one. This is especially the case in relation to the SEEA EA which has sub-categories 'Baseline flow maintenance services' and 'Peak flow mitigation services'. Recent evidence suggests that it is useful to differentiate between base and peak flow regulation (Vári et al., 2022). While they could be nested under Hydrological cycle and water flow regulation as class types, two new classes have been introduced into V5.2:

Regulation runoff and base flows (2.2.2.1) and *Regulation of peak flows* (2.2.2.2). To retain consistency with V5.1, however, the Group structure has been changed in case the two cannot be differentiated, they can be reported at the group level (as 'Hydrological cycle' and 'water flow regulation', which is broadly equivalent to the CICES V5.1 class 2.2.1.3).

3.57. Note, however, that the aspects of the hydrological cycle related to rainfall patterns are covered explicitly in V5.2 Class 2.3.6.1. This Class deals, more generally, with the influence of living systems on climate and therefore relates to broad scale and longer-term relationships. Local, shorter-term influences on weather are covered by V5.2 Class 2.3.6.2, *Regulation of temperature and humidity, including ventilation and transpiration at local scale*.

Surge and flood wave mitigation

3.58. As a consequence of including the new Class *Control of wind erosion rates*, the 'Wind Protection Class' in V5.1 has been modified in order avoid overlap. In V5.2 the Class *Surge and flood wave mitigation* (2.2.3.2) has been designed to cover protection offered by living structures to extreme weather events. It thus captures the protection offered by ecological structures to the wider human environment. Examples might include the way mangroves protect areas from tsunamis. This Class is distinct from the new classes dealing with wind and water erosion (2.2.1.1 and 2.2.1.2), which specifically cover the regulation of the loss of material from soils or sediments.

Life cycle maintenance

3.59. The CICES V5.1 Class *Maintaining nursery populations and habitats* (2.2.2.3) has been split into three new Classes in V5.2, in order to address concerns expressed in relation to the marine environment. With appropriate change in terminology, however, the new Classes also cover analogous situations in the terrestrial environment. The three new Classes in V5.2 are: *Maintaining or regulating nursery populations and habitats or breeding grounds* (includes *Gene pool protection)* (2.3.2.3); *Maintaining or regulating refuge habitats* (2.3.2.4); and *Maintaining or regulating feeding grounds* (2.3.2.5). If consistency with V5.1 is required, these new Classes can be aggregated since their scope is nested within the V5.1 Class.

3.60. The changes made are based on the recommendations of Armoškaitė et al. (2020) in relation to the CICES V5.1 Group *Lifecycle maintenance, habitat and gene pool protection*. In the marine context, they argued the Group should be split to differentiate 'Spawning and nursery habitats', 'Refuge and shelter habitats', and 'Fish feeding grounds'. This recommendation would require modification of the V5.1 class (2.2.2.3) that only dealt with 'nursery habitats'.

3.61. The status of nursery habitats has, in the past, been the focus of some debate, with some arguing that it is an ecological function rather than a service. The recommendation of Armoškaitė et al. (2020) was helpful, however, in clarifying what is intended in this class. Namely, the protection of habitats or components that are essential for the maintenance or regulation of the life cycles of organisms that contribute to people's well-being. Often, the contribution they make represents the flow of such services from one ecosystem to another (See para 3.10). Thus, the suggestions for a split of the V5.1 Class were followed, but the terminology used for V5.2 differs from that suggested by Armoškaitė et al. (2020) to be relevant in both marine and terrestrial contexts.

Soil quality

3.62. In framing the V5.2 Group dealing with 'Regulation of Soil Quality', we took soil quality to be *the condition of soil based on its capacity to perform ecosystem services that meet the needs of human and non-human life*[7]. Having reviewed the definition it was felt that the two existing Classes within the Group, dealing with weathering processes (V5.1 Class 2.2.4.1) as well as the decomposition and fixing process (V5.1 Class 2.2.4.1) needed to be augmented with a new class dealing with soil structure.

3.63. Thus, CICES V5.2 includes a new Class relating to soil quality, namely: *Maintenance of soil structure by biological agents and ecological processes* (V5.2 Class 2.3.4.3). This Class covers the role that plants and animals have in modifying the spatial arrangement of mineral particles, organic material and pore spaces in soil, as well as their role in modifying the spatial arrangement of mineral particles, organic material and pore spaces. Resistance of soils to compaction is also covered in this class.

3.64. In revising the soil quality Classes, we also considered the handling of 'salinisation'. We suggest that the service dealing with controlling salinisation processes should be assigned to one of the classes in the 'regulation of soil quality' Group (e.g., *impacts of biological processes and agents on soil structure* (2.3.4.3), by virtue of the impact of soil structure on evaporation rates, etc.), or to the Soil Quality Group as a whole, if it is considered that the service is mainly controlled by processes and structures within the soil body. Alternatively, if salinisation is mainly controlled by external factors such as changing vegetation cover and its effect on the hydrological cycle (e.g., via evapotranspiration and changes in water table) then it should be associated with V5.2 Class 2.3.6.2, *Regulation of temperature and humidity, including ventilation and transpiration*.

3.65. CICES seeks to identify putative final ecosystem services. That is, ecosystem outputs that in a given analytical situation are deemed to directly contribute to human well-being. In the context of regulation and maintenance services, they cover the ways living organisms mediate or moderate the ambient environment affecting human health, safety, comfort and its utility for people. While nutrient regulation, nitrogen fixing and biomass decomposition are all important in the overall context of human well-being, in designing CICES it seemed logical to regard them as functions contributing to soil quality.

[7] https://esdac.jrc.ec.europa.eu/ESDB_Archive/eusoils_docs/other/EUR22721.pdf

The latter then being framed as a more aggregated or integrative property of soils, capturing their ability to meet the needs of human and non-human life. When using CICES, the determination of soil quality would therefore allow an assessment of the extent to which a given body of soil contributes to human well-being via cultivation, trafficability and resilience to other potential impacts. This is consistent with our reframing of biophysical ecosystem services as being a combination of biotic and abiotic processes (See para 3.18, above). This position seems consistent with the views of Fossey et al. (2020) who stress the advantages of framing soils as providers of ecosystem services and thus an explicit subject for assessment. It is also consistent with the reworking for soils of the cascade diagram that underpins CICES by Pavan & Ometto (2018).

3.66. The suggestion that soil functions contribute to nutrient regulation, nitrogen fixing and biomass decomposition does not, of course, eliminate the potential problem of overlapping classes also identified by Paul et al. (2021) (and also cited more generally by Bartkowski et al., 2020, and Pavan & Ometto, 2018). Paul et al. (2021) specifically mention the classes dealing with the ability of soils to filter and transform organic wastes and protect water bodies. They argue that this could be allocated to three V5.1 services: *Biotic remediation of waste* (2.1.1.1)*, Biotic filtration, sequestration and storage of waste* (2.1.1.2) and *Mediation of wastes by other chemical or physical means (*e.g., *via Filtration, sequestration, storage or accumulation,* 5.1.1.3).

3.67. Soils can indeed transform organic wastes. However, the class *Biotic remediation of waste* (2.1.1.1) covers wastes of anthropogenic origin, and not general decomposition processes, which are best regarded as part of ecosystem functioning that may contribute, to soil quality. Similarly, *Biotic filtration, sequestration and storage of waste* (2.1.1.2) also deals with anthropogenic wastes, and again the general ability of soils, to filter and sequester various substances would not be dealt with here.

3.68. If, in a particular context, the quality of soil is regarded as the final ecosystem service, then the ability of soils to filter, decompose or sequester are best regarded as soil functions that determine soil quality. In contrast, if the ability of soils to process wastes is the focus of interest outside any discussion of soil quality, then in this situation it would be regarded as the final service. In devising the classes 2.1.1.1 and 2.1.1.2 it should be noted that the intention was that they could cover services *additional* to those provided by soils. So, for example, class 2.1.1.2 (*Biotic filtration, sequestration and storage of waste*) could cover dust filtration by urban trees.

Cultural Ecosystem Services

3.69. All of the Classes defined in V5.1 have been retained (albeit with some modification to definitions) but their position in the CICES hierarchy has been modified in V5.2 to provide a structure that better reflects the experience reported in the literature. The key change to note is in the coding of the Classes.

3.70. At Division level of the classification a split is made between: a) Physical and experiential interactions with the environment; b) Intellectual and representative interactions with the natural environment; and, c) Spiritual, symbolic and other interactions with the natural environment. This replaces the two-fold distinction in V5.1 between services that are either directly or indirectly experienced. It also better reflects the general ways in which the studies covered in the systematic review were grouped.

3.71. The notion of 'directly' and 'indirectly' experienced services has been moved to the Group level in V5.2. Within, the intellectual and representational Division the change is used to distinguish elements of living systems used for entertainment or representation outside the setting concerned (3.3.1.1) from those dealing with traditional knowledge, education, cultural heritage and aesthetic qualities (3.2.1.1 through to 3.2.1.4).

3.72. Characteristics of 'living systems that are indirectly appreciated and have significance for people without their presence in the environmental setting' are split at Group level from the 'Other biophysical characteristics of species or ecosystems that are appreciated in their own right by people'. This split enables classes dealing with symbolic or religious significance to be separated from those referencing existence and bequest. This allows all of the spiritual classes to be grouped at the Division level, more clearly reflecting the general types of linkage between cultural services identified by Czúcz et al. (2018).

Symbolic meaning and sense of place

3.73. The CICES V5.1 class dealing with symbolic meanings (V5.1 3.2.1.1) has in V5.2 been defined more broadly to include aspects of settings that capture the distinctiveness of settings or their sense of place. Thus, the V5.2 Class, which is now referred to as 'Elements of living systems that have symbolic meaning, capture the distinctiveness of settings or their sense of place' (V5.2 Class 3.4.1.1) is now nested into the Division *spiritual, symbolic and other cultural interactions with natural environment*. It also falls in the Group that deals with the characteristics of living systems that are indirectly appreciated and have significance for people without their presence in the environmental setting.

3.74. The inclusion of sense of place is based on the review by Ryfield et al. (2019) who argued that while the idea of 'environmental settings' has a conceptual role in CICES, sense of place is not identified as a final ecosystem service, despite reference to this aspect of ecosystems in both the MA and TEEB (where it was regarded as a benefit). They argue that the omission is serious because sense of place is 'one of the most neglected cultural services' which is especially important in conservation decision-making.

3.75. Reference to sense of place was omitted from V5.1 because it was felt that it was more of an aggregated construct, dependent on the combination of many of the services identified elsewhere in the classification. However, given the conclusion of Ryfield et al. (2019), there appeared to be a case for more explicit reference to sense of place in the revised classification. They namely found that in their study stakeholders could distinguish sense of place from other cultural services such as opportunities for recreation, amenity and aesthetic quality,.

Existence and bequest

3.76. The cultural service classes dealing with existence and bequest have been retained but the term 'value' has been dropped from the class description. The classes are now referred to as either the characteristics or features of living systems whose contemporary existence or conservation is important to people (3.4.2.1), or characteristics or features of living systems whose inter-generational existence or conservation is important to people (3.4.2.2). The assumption is that 'importance to people' can be identified in different ways, including inter alia by the assignment of monetary values.

Overlaps with provisioning services

3.77. Several commentators identified class overlap as a problem when applying CICES, especially in the area of cultural ecosystem services. For example, Bukvareva et al. (2019) highlight that hunting in Russia is a combination of provisioning and cultural ecosystem services. As these are in two different sections of the hierarchy, it is hard to apply CICES.

3.78. In the case of hunting, either a hybrid class could be constructed by users based on a combination of CICES classes, or an alternative perspective might be taken on what constitutes the most important final service (e.g. hunting for food – a provisioning service). The difficulty of taking the hunted animal as the final service is that the multiple uses of the animal could to be conflated. If meat from the animal is regarded as a final service, alongside other outputs such as ornamental materials, and/or cultural practices, then the suite of services provided by hunting can be identified (see para 3.32-3.35).

Information exchange

3.79. Bukvareva et al. (2019) and La Notte et al. (2017) identify that cultural ecosystem services involve an exchange of information between ecosystem and the user. In fact, La Notte et al. (2017) view the concept of information in ecosystems as a more fundamental concept They argue that organisms interact with their environment not just by exchanging material and energy as traditionally viewed in ecology, but also by exchanging information, and that this should somehow be covered explicitly, especially in the context of human interactions.

3.80. In relation to the conceptualisation of La Notte et al. (2017) and its implications for the structure of CICES, it was concluded that the information embedded in ecological networks is analogous to other functional characteristics that underpin ecosystem services. Thus information could be analysed using the ecosystem service cascade model or similar a logical or causal chains. In relation to human interactions, we believe the issues surrounding information are already covered in the way cultural ecosystem services are grouped and named in V5.2. The definitions at Group level for cultural ecosystem services all speak of interactions; namely: intellectual and representative interactions and spiritual, symbolic and other cultural interactions with the natural environment. Thus, no modification to the structure of CICES was made, although users should consider the information aspects when reporting cultural ecosystem services or defining class types for more detailed analysis.

4. SEEA Crosswalk and creating thematic subsets with CICES

SEEA Crosswalk

4.1. Given all changes proposed above the SEEA Crosswalk for CICES V5.1 has been updated, and the revised structure for V5.2 is provided as a spreadsheet in Appendix A. The appendix also provides the equivalent categories for IPBES, MA and TEEB.

4.2. In terms of the relationship between CICES V5.2 and the SEEA EA Refence categories, several points should be noted in order to understand how the classifications can be used alongside each other:

4.3. Where more than one CICES V5.2 class nests within a single SEEA EA subtype, the CICES classes can be treated as more detailed subcategories for the purposes of the SEEA. For example, the three CICES V5.2 classes relating to plants cultivated by in-situ aquaculture (1.1.2.1, 1.1.2.2, and 1.1.2.3) can be regarded as subcategories of the SEEA 1.4 *Aquaculture provisioning services*.

4.4. Where more than one SEEA EA subtype is assigned to a single CICES V5.2 class, the latter can be split into appropriate, more detailed CICES Class-types, reflecting the focus of each SEEA category. For example, the CICES Class 1.1.1.2, *Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials*) is assigned to SEEA categories 1.1, 1.2 and 1.5. Under SEEA EA 1.1 the CICES Class would cover harvested crops for used for fibre, whereas under SEEA EA 1.2, it would denote cultivated crops grown for fodder or animal feed. Under SEEA 1.5 the class would specifically cover woody fibres.

Thematic Subsets

4.5. Several contributors to the discussions stimulated by the WCMC (2021) review suggested that the creation of thematic subsets for services are relevant to different application areas, especially for soils and for the marine environment.

4.6. While it has been valuable to look at specific topic areas during the V5.2 review, the analysis suggests that it is difficult to be definitive as to what might be included in these thematic versions of CICES, largely because the different papers look at the subject areas with sometimes different perspectives and purposes.

4.7. For example, in our analysis of papers relating to soils (Appendix B) the paper used in column D (Paul et al., 2021) defines two subsets: services that are directly influenced by soils and their properties and services that are influenced by agricultural soil management. Bartkowski et al. (2020) also refer to agricultural soil management, while McPherson et al. (2020) refer to agricultural management so that additional services related to animal husbandry are mixed in. Although the papers match quite well, there are still some differences as to what needs to be included, compared to, say, the analysis of Pavan and Ometto (2018) who considered soils in the context of life cycle assessment.

4.8. Appendix C shows a similar crosswalk for the marine environment using V5.1. Again, it is clear that there are significant differences between authors in terms of what they recognise, although none deal with the abiotic extension. While Ruskule et al. (2023), for example, feel that only seven ecosystem services are relevant to their study, Graveland et al. (2017) identify twenty-three. The largest set (42) of marine services referenced to CICES is provided by Culhane et al. (2019). While the fit is generally a good one, this work preceded the release of V5.1, and so used V4.3. For analysis we have therefore used the relevant cross-walk to summarise their findings in terms of the V5.1 classes. Since some V4.3 classes were more general than those V5.1, more classes are shown than in Table 2.2 of Culhane et al. (2019).

4.9. Thus, while no definitive recommendations are made here as to the scope of different thematic applications, it should be noted that the main CICES Table, V5.2 now includes columns noting the terminology used in relation to the CICES ecosystem service classes by the Marine Protected Areas community, alongside some example services from the marine sector. The former was informed by the work of Culhane et al. (2019, 2020) but adapted for later applications within the UK.

5. Appendices

Three appendices are available in the associated spreadsheet for V5.2 (dated 23/11/2023), namely:

Appendix A: SEEA EA CICES V5.2 Crosswalk

Appendix B: Thematic applications of CICES - Soils Crosswalk

Appendix C: Thematic applications of CICES - Marine Crosswalk

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