Australian Government
Bureau of Meteorology

Methods for evidence-based conceptual modelling in environmental accounting

A technical note

Contributing to the Australian Government National Plan of Environmental Information initiative

Methods for evidence-based conceptual modelling in environmental accounting: a technical note

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Abbreviations

ABS ... Australian Bureau of Statistics

AG EIAG ... Australian Government Environmental Information Advisory Group

CSIRO ... Commonwealth Scientific and Industrial Research Organisation

NPEI ... National Plan for Environmental Information

SEEA ... System of Environmental-Economic Accounting

SEEA–EEA ... System of Environmental-Economic Accounting–Experimental Ecosystem Accounts

Glossary

Term	Explanation
Account framers	Those who prepare an account so it can be used over time for its intended purpose.
Account participants	Those involved in all aspects of framing and using an account.
Account perspectives	Different viewpoints with associated units of measurement (monetary and non-monetary) that can be adopted for the purpose of measuring an environmental asset good or service.
Account producers	Those who determine that an account is needed to fulfill some purpose then initiate and guide the process of creating the account.
Account purpose	The reason for producing an account, framed as an accounting question such as 'Has there been any change in the capacity of Ningaloo Reef to deliver ecosystem services?'
Account stakeholders	All those who have an interest in a particular account and how it is used.
Account subject	That which is being measured to provide numbers in an accounting table e.g. gigalitres of water in a river system, $ cost of remediation of an ecosystem.
Account users	Those who use an account once it has been framed and developed and is operational.
Accounting questions	Questions of interest to account users, designed to be answered by the data in the account tables.
Ancillary conceptual models	Conceptual models developed to provide scientific support for an environmental account.
Commodity	The term commodity is used to describe a class of goods for which the market treats all instances as equivalent or nearly so regardless of who produced them. Gold and wheat are examples of commodities.
Conceptual model	A conceptual model is an abstraction of reality expressing a general understanding of a more complex process or system. Conceptual model building consists of choosing the system parts and relationships that link these parts, specifying how the parts interact and identifying missing information (DEHP, 2012).
Credibility and legitimacy	Credibility and legitimacy are principles underlying the production of environmental accounts. The credibility of an environmental account refers to the validity of the knowledge on which it is based. Legitimacy refers to the acceptance among stakeholders that the account is well-founded and useful.
DPSIR	DPSIR stands for Driver–Pressure–State–Impact–Response. The DPSIR causal framework for conceptualising the relationship between people and the environment was adopted by the United Nations Environment Programme in 1994 and is often used in environmental monitoring and management programs.
Ecosystem asset	An ecosystem asset is an ecosystem that may provide benefits to humanity. Ecosystems are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together.

Ecosystem capacity	The capacity to supply ecosystem goods and services to humans, whether or not humans are currently consuming the goods and services. Ecosystem capacity is measured by extent and condition or quantity and quality (Bureau of Meteorology, 2013).
Ecosystem characteristics	'Ecosystem characteristics relate to the ongoing operation of the ecosystem and its location. Key characteristics of the operation of an ecosystem are (i) its structure (e.g. the food web within the ecosystem); (ii) its composition, including living (e.g. flora, and micro-organisms) and non-living (e.g. mineral soil, air, sun and water) components; (iii) its processes (e.g. photosynthesis, decomposition); and (iv) its functions (e.g., recycling of nutrients in an ecosystem, primary productivity). Key characteristics of its location are (i) its extent; (ii) its configuration (i.e. the way in which the various components are arranged and organised within the ecosystem); (iii) the landscape forms (e.g., mountain regions, coastal areas) within which the ecosystem is located; and (iv) the climate and associated seasonal patterns. Ecosystems also relate strongly to biodiversity at a number of levels. For this reason ecosystem characteristics include within and between species diversity, and the diversity of ecosystem types.' (European Commission et al, 2013).
Ecosystem operation	Key characteristics of the operation of an ecosystem are its structure, composition, processes and functions (European Commission et al, 2013; and see 'ecosystem characteristics' above for more detail).
Ecosystem services	Ecosystem services 'are the contributions of ecosystems to benefits used in economic and other human activity'.
Environmental valuation	Measuring environmental assets, goods and services, including ecosystem services, so their value can be tracked through time and space and between owners. Often the value of environmental assets goods and services can be measured or estimated in monetary units but other units such as physical units (hectares, gigalitres) or indices of condition or indicators can be used to track environmental value.
Evidence base	A carefully structured database of evidence relating to specific questions or assumptions of relevance to management. For environmental accounting purposes the evidence base represents the body of evidence which is relevant to the account topic and of sufficient quality, used to underpin the account conceptual models and provide the account with credibility and legitimacy. (R. Richards, pers. comm., 2014).
Evidence base/conceptual modelling questions	Questions of interest to account framers, relating to the validity of the account subject and measuring methods.
Evidence domain map	Results of a broad search to ascertain what evidence exists and what gaps there may be on a topic in order to inform and direct future research or evidence collation in the area.
Flows	In economic accounts, flow refers to changes in the volume, composition or value of stocks. In ecosystem accounts, flows are the intra- and inter-ecosystem flows and the goods and services contributed by the environment to human benefit (ecosystem services) and the flow of residuals (waste) to the environment.
Landscape connectivity	The degree to which the landscape facilitates or impedes movement among patches (Hansson 1991).

Landscape vegetation connectivity (LVC)	A measure of the physical connectedness of the vegetation across a landscape that influences the movement of genes, propagules, individuals and populations. It includes the landscape scale connectedness maintained within large patches of vegetation as well as that related to vegetation corridors and stepping stones. It is sometimes referred to as 'structural vegetation connectivity' to distinguish it from 'ecological connectivity'.
National Connectivity Index	A tool for assessing landscape vegetation connectivity under development by the Australian Department of the Environment's Environmental Resources Information Network (ERIN).
Stocks	In economic accounts, stock is the amount of an asset (financial and nonfinancial) held at a particular time that has the capacity to produce goods or services. In environmental accounts, stock is the amount of an environmental or ecosystem asset that at a particular time has the capacity to produce environmental or ecosystem goods or services.

Executive summary

This technical note introduces the process of gathering and presenting the body of information needed to underpin credible and legitimate ecosystem accounts. It is particularly focused on the use of conceptual models based on the best-available evidence. The methods could be readily applied to other uses besides environmental accounting; for example, they could be used for any environmental assessment purposes especially those with a mix of environmental, social and economic values.

Environmental accounting involves tracking the movement of that which we value in the environment between times and places and between owners or those responsible. Because human populations have reached numbers and stages of development approaching the limits of our planet's capacity to support us, we need to do environmental accounting to ensure that our use of the Earth's natural resources is sustainable into the future.

All accounting practice assumes that what we value can be measured. Money is one convenient yardstick of value. Other measures are available for environmental accounting, though accounting for the environment in terms of monetary units becomes necessary if cost/benefit analyses are being done. In all cases of environmental valuation, whether monetary or non-monetary, the key to arriving at a value is having as complete as possible a set of information about how an environmental asset, good or service is produced and about all the ways environmental assets, including ecosystem assets, benefit people and nature.

This technical note, *Methods for evidence-based conceptual modelling in environmental accounting*, is a first attempt to describe a process for getting as comprehensive as possible a set of high quality information about an account subject and the method of measuring that subject. This is the information on which an environmental account can be based.

The methods involve collaborative development of an evidence base and conceptual models to encapsulate and communicate the information, especially scientific information, behind an environmental account. While the technical note introduces evidence-based conceptual modelling for environmental accounting in general, it focuses on ecosystem accounting because, at the time of writing, this represents the greatest and most urgent challenge presented to environmental accounting.

It is becoming critical to a prosperous and sustainable future to take explicit account of the functioning and capacity of ecosystems. We cannot use ecosystems sustainably without being able to measure and account for ecosystem capacity and we cannot value ecosystems, for such accounting purposes, unless we know how ecosystems function and unless we have valid ways of measuring their function. This technical note introduces processes for doing so.

1 Introduction

This document, *Methods for evidence-based conceptual modelling in environmental accounting*, was one of a series produced by the Bureau of Meteorology to underpin environmental accounting practice in Australia. The primary document in the series was the *Guide to environmental accounting in Australia* (the Guide), which aimed to improve environmental outcomes in Australia and contribute to the country's long-term sustainability through the implementation of environmental accounts (Bureau of Meteorology, 2013). While the Bureau's environmental accounting role ceased in 2014, this study has been released to ensure key documents remain publically available.

In the Guide a three-step method is presented for producing an environmental account (Figure 1). In the first step—account scoping—the work that must be done to produce the account is structured into eight modules, as illustrated in Figure 2. The first four modules establish the purpose and conceptual basis for the account, while modules five to eight address practicalities in account scoping, such as data kind and access, reporting frameworks and methods and accounting standards to apply.

While the current document—*Methods for evidence-based conceptual modelling in environmental accounting*—by necessity considers all modules of the account scoping process, its primary aim is to guide the completion of module four: establishing conceptual models and an evidence base for the account subject.

Conceptual models are abstractions of reality expressing a general understanding of a more complex process or system. They tell the story of how the system works. Conceptual model building consists of choosing the system parts and relationships that link these parts, specifying how the parts interact and identifying missing information (Department of Environment and Heritage Protection, 2012). Conceptual models offer a way of summarising complex environmental account subjects, such as ecosystem operations, using the best available current knowledge. They provide a basis for measurement and for subsequent policy and activity based on [an] environmental account (Bureau of Meteorology, 2013).

The **evidence base** is a carefully structured database of evidence relating to specific questions or assumptions about the account subject and its measurement. It brings credibility and legitimacy to the account. To fulfil this function, it must be produced in a robust and transparent manner. The evidence base itself should bring the best available scientific knowledge for use in developing and maintaining the account over time. Clear links should be made between the evidence in the evidence base and how this evidence has been used to inform the account. The guiding principles used in sound systematic review of evidence can be applied to the development of an account evidence base. These principles ensure that the evidence used is comprehensively representative and that the process is transparent and scientifically robust and is undertaken in a systematic fashion. The application of these principles will contribute to the credibility and legitimacy of an account.

Figure 1. The three stepmethod for producing an environmental account.

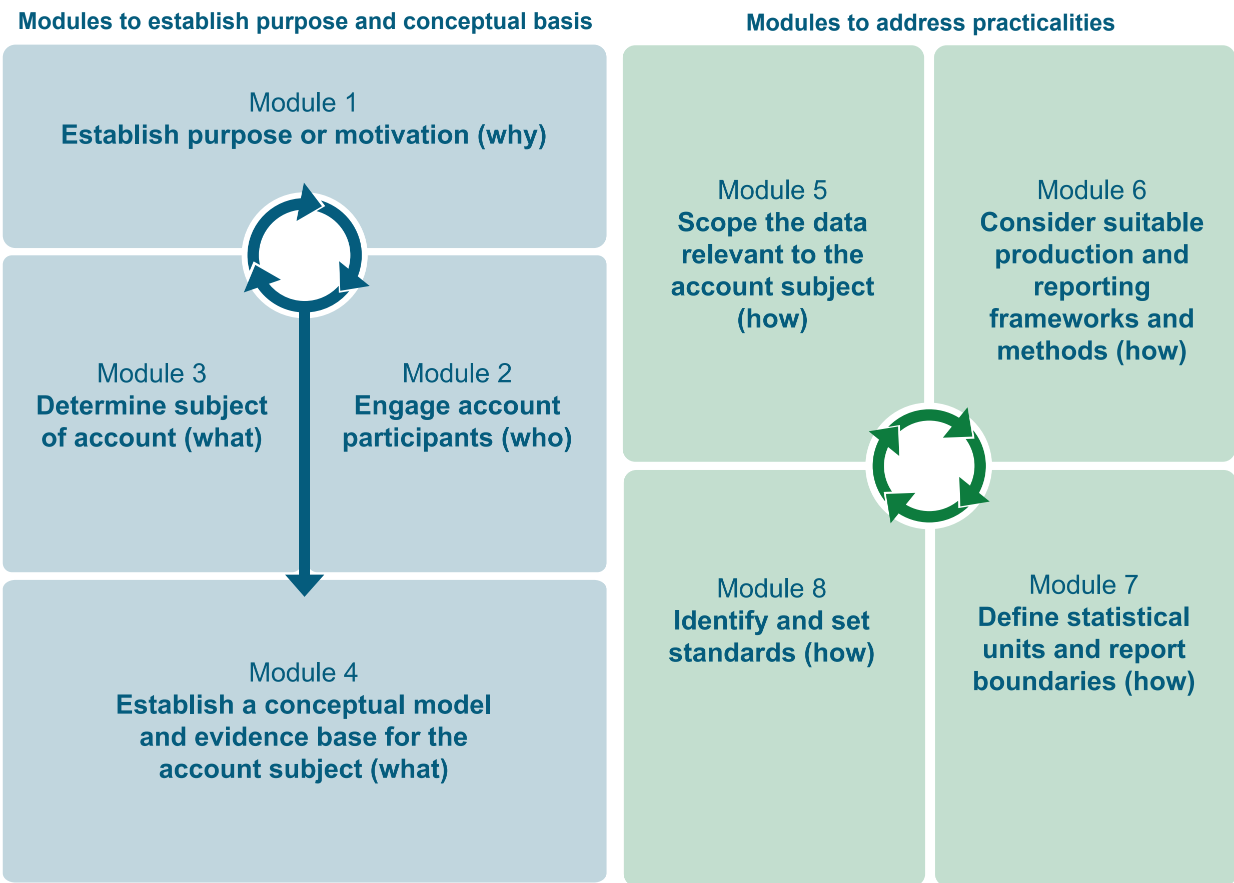


Figure 2. Eight modules for scoping an environmental account (from the Guide, p 51)

1.1 Why conceptual models for environmental accounting?

Critical to all accounting is the ability to measure value and changes in value. The standard economic approach to establishing value uses money as the unit of measure. Value is equated with price and price is determined by a market, that is, the combined activity of all the individual buyers and sellers interested in a good or service. The key to arriving at a market price is that all the players have the information they need to determine the value of the good or service, hence the value is equal to the price. When it comes to valuing assets, the price is a succinct summary of the value people place on the potential future benefits that they expect to flow from an asset, again based on the assumption that all the information needed to price the asset is available.

> Critical to all accounting is the ability to measure value and changes in value.

However, in accounting for the value or changes in value of an environmental asset, good or service, there is incomplete information available to make the determination. Historically, market prices of ecosystems and their services have underestimated the true value of ecosystems to people. This is partly due to insufficient information about the benefits of ecosystems to people—as this is a very complex matter to determine—and also due to the fact that prices (and hence values), in dollar terms, reflect benefits to individual economic units and tend not to capture collective benefits. Further, if there is an abundance of the resource, such as sunlight, there is no incentive or need to establish a price—sunlight is effectively free, though of course it is essential to all life on Earth.

1.2 Valuation in ecosystem accounting

To do ecosystem accounting (a specific type of environmental accounting—see Box 1), an approach different from market pricing is needed to gather, reveal and exchange the information for estimating value or changes in value of ecosystem assets or ecosystem services, and for getting agreement about value among stakeholders in ecosystem benefits.

The units of measurement for environmental accounting need not be money. In fact, money can be a misleading measure, particularly when evaluating ecosystems and their services to humans. The historical connection of money with the mechanisms of markets and pricing tends to imply that all the necessary information for fixing a value is known and shared among all the players. This is rarely the case when valuing environmental assets goods and services. Typically, much value is omitted due to lack of knowledge. This omitted value should not be overlooked.

Non-monetary valuation methods can incorporate formal records of the information used in the valuation, thereby drawing the attention of account participants and users to what, and how much, has been included or left out. In the method for environmental accounting set out in the Guide, and in this document, such formal records are constituted by an evidence base and conceptual models, developed using high practice standards.

Box 1 Environmental accounting vs. ecosystem accounting

Accounting tracks the transfer of value through time, between locations and between owners or those responsible. Environmental accounting focuses on what we value in the physical earth and living earth systems including those elements of the natural environment that are treated as commodities by the System of National Accounts (SNA) and the System for Environmental-Economic Accounting—Central Framework (SEEA–CF). Examples include timber, minerals and fish—that is, products of the natural environment.

Ecosystem accounting focuses on ecosystems as an integrated whole, rather than treating them as a number of separate components such as water, food or timber. For example, while the SNA and the SEEA–CF treat timber as a product of native forest ecosystems, an ecosystem account would consider the forest as an integrated, functioning ecosystem, and would account for the ecosystem services and associated benefits that flow to people from the forest, such as regulation of the water supply to streams and erosion and flood protection, as well as provisioning products such as timber. This is the approach taken by System for Environmental-Economic Accounting—Experimental Ecosystem Accounting (SEEA–EEA).

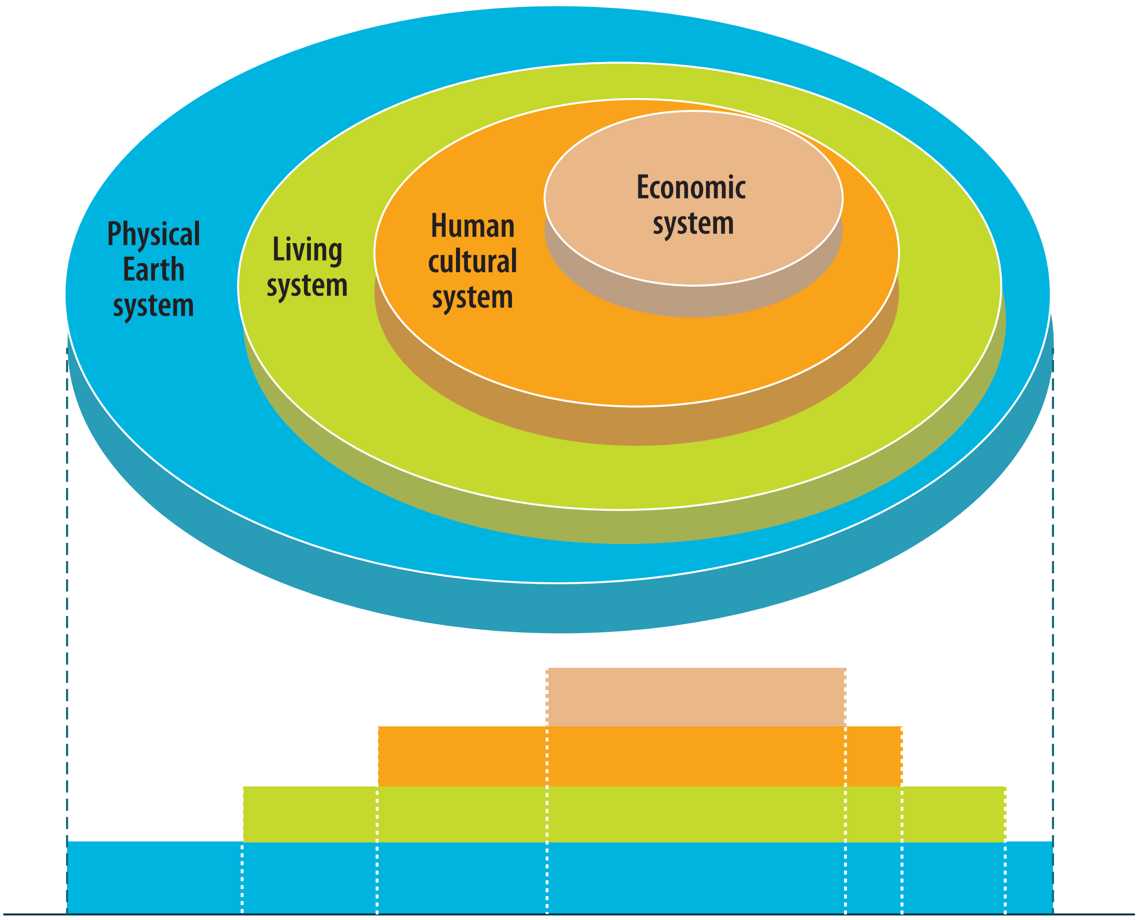


Figure 3. The Joint Perspectives Model. In cross section, the vertical dotted lines delineate systems, while the coloured horizontal slices represent the different perspectives from which the systems can be viewed.

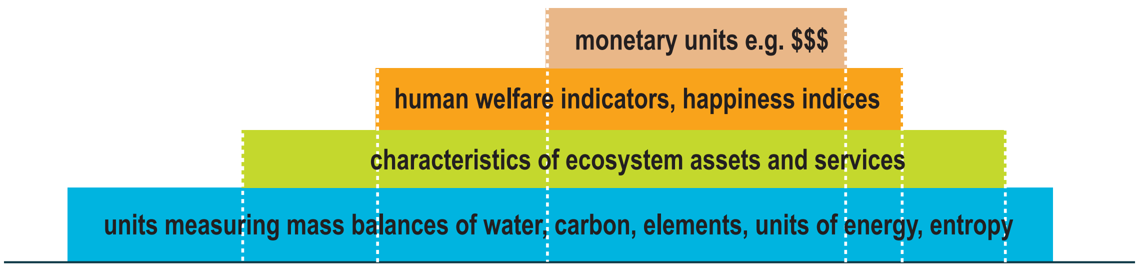


Figure 4. Examples of potential measurement units from different perspectives.

1.2.1 Environmental valuation and the Joint Perspectives Model

The *Guide to environmental accounting in Australia* introduces the Joint Perspectives Model as a context for developing environmental accounts (Figure 3). The Joint Perspectives Model consists of four nested systems: the physical Earth system, the living system, the human cultural system and the economic system. Each system has emerged from all the others listed before it and is not separate from these systems. This means that any transaction in an emergent system can also be viewed from the perspective of the systems in which it is nested. More information about the Joint Perspectives Model and its application to environmental accounting is given in chapter 5 of the Guide.

In environmental valuation, the Joint Perspectives Model helps an account framer to choose the appropriate perspectives for accounting and then to use those perspectives to choose measures of value along with conceptual models to underpin them (the Guide, p 42). Figure 4 gives examples of measurement units that could be applied from different perspectives.

1.2.2 Non-monetary valuation in ecosystem accounting

In developing non-monetary measuring units for ecosystem accounting, one key characteristic is that each unit be equivalent or interchangeable across the domain of the particular account, just as units of currency are interchangeable everywhere within a country. If accounts are to be aggregated (say regions aggregated into countries) then the unit must have equivalent value between regions as well as within them. Even when accounting within a narrow geographic domain, the unit must be equivalent from one accounting period to the next. This is important for comparability, one of the fundamental characteristics of an account.

One approach with environmental accounting has been to use absolute counts and physical measures such as hectares and gigalitres to track change and movement of environmental assets, goods and services across time and space. In ecosystem accounting, physical units are appropriate when the account subject is the extent or quantity of some ecosystem asset, such as land, water or a habitat type. Accounting for the *condition* of an ecosystem asset, an important dimension of its capacity to maintain itself and/or to deliver ecosystem services to people, requires a different approach to measurement.

In ecosystem accounting, indices of ecosystem condition, and changes in condition, can be used as measuring units for accounting. These indices may reflect variation from a benchmark of ecosystem condition, as with the Econd, an ecosystem currency unit developed by the Wentworth Group of Concerned Scientists (2008). Otherwise, accounting indices may be based on some subset of environmental variables acting as a proxy for environmental condition, as with the Ecosystem Capability Unit (ECU), an index of carbon, water and ecological integrity being trialled by the European Environment Agency (Weber, 2011). In the case study accompanying this guide, an Australian landscape vegetation connectivity index (the National Connectivity Index) is used to indicate aspects of ecosystem condition.

Figure 5 shows different kinds of measurement units appropriate for different environmental account subjects, depending on subject complexity. It also shows the process of developing accounting units for complex subjects such as ecosystem assets and services. Implied or explicit conceptual models underpin each step in developing such accounting units.

1.3 Roles of evidence-based conceptual models in accounting

Three roles for evidence-based conceptual modelling in environmental accounting are:

- summarising the scientific knowledge base for what will be measured in an account
- helping to establish the legitimacy of the account through a collaborative conceptual modelling process
- communicating the science behind the account.

1.3.1.Summarising science

Any measurement developed for ecosystem accounting is based on a conceptual model or models of how the particular ecosystem works. In turn, these models may rest on an evidence base of science, including the current scientifically-validated understanding of the links between indicators, indices and actual ecosystem operation. An important role of the conceptual models and evidence bases is to summarise the science behind what will be measured and how.

For example, if we wish to account for carbon sequestration and storage in an ecosystem and we want to value that particular ecosystem service in terms of dollars, an evidence base and conceptual models would address how carbon is processed in the ecosystem and how carbon is measured to establish the ecosystem's carbon budget. An evidence base is also needed to describe and justify the process behind converting units of sequestered carbon into dollar equivalents. For each step connecting the account subject (carbon sequestration as an ecosystem service) with the accounting units (dollars), developing an evidence base and conceptual models helps to ensure that

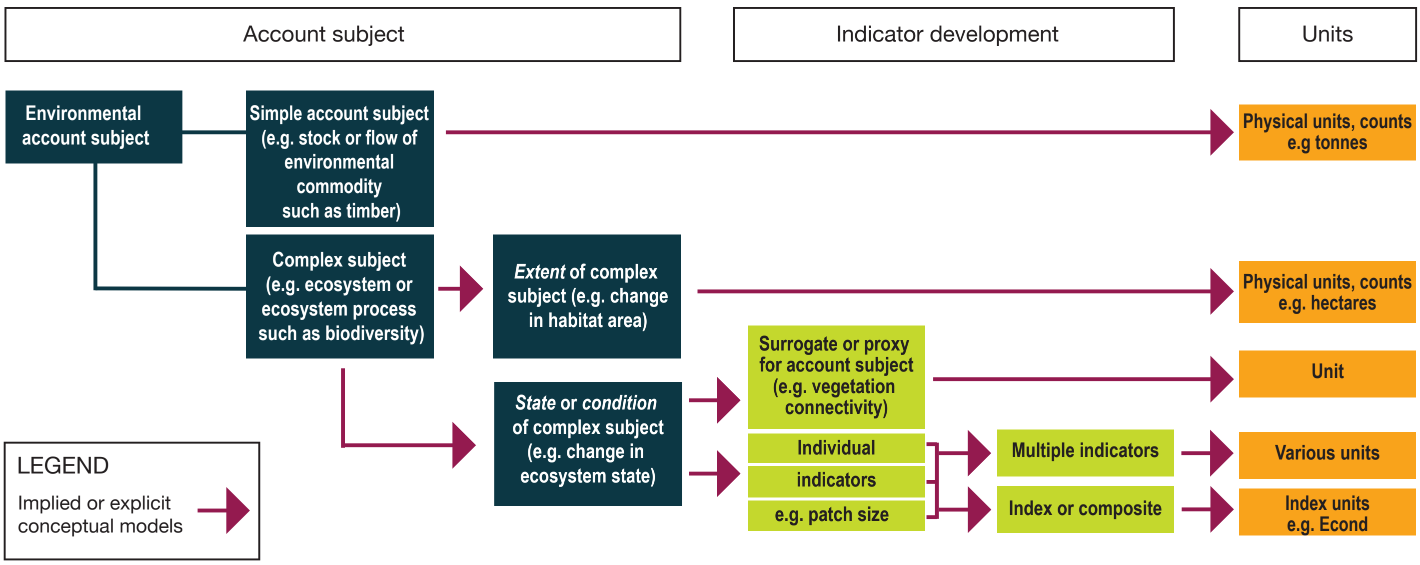


Figure 5. Measurement units for environmental accounting and their relationship to conceptual modelling

the process for obtaining the numbers in the account is transparent and repeatable. The central role of the evidence base and models is to underpin the credibility of ecosystem valuation.

Guiding questions for identifying evidence base and model content to fulfil this role are:

- What is the reasoning and perspective behind this account?
- What is the knowledge, including the scientific knowledge, that links the account subject with the numbers (data) representing measurements (observations, estimates) of it?
- What is the relationship of these measurements/numbers with the real world?
- How are the numbers (data) that represent measurements of the account subject obtained in practice?

1.3.2 Facilitating collaborative modelling

A major contribution to the legitimacy of ecosystem valuation is the process of arriving at the underpinning evidence base and conceptual models. This process involves standards and rules for developing evidence bases. It also includes a set of practices for achieving agreement among the account participants and stakeholders that any evidence-based conceptual models produced reflect an appropriate, best available, current understanding of the ecosystem and its relationship to the account subject.

As explained in the Guide, this process of developing an evidence base and conceptual models helps link the account purpose (module 1) and subject (module 3) to the account participants (module 2). While conceptual models for ecosystem accounting should be based on the best available science, there will still be knowledge gaps and hence room for differences of opinion, depending on the perspectives of those involved in the modelling exercise. These features are not an artefact of a less-than-perfect process but are intrinsic to human knowledge seeking. For this reason, the conceptual modelling must be a process of dialogue involving a range of expertise and perspectives. To be legitimate, creating a summary of our current understanding of the account subject must be a transparent collaborative process.

Guiding questions associated with the conceptual modelling process include:

- Who are the experts and stakeholders likely to have useful (including differing) ideas about the science behind the account?
- What process will be used to identify these experts and stakeholders?
- Does a relevant and reliable evidence base (e.g. compiled and synthesised peer-reviewed literature) exist or will it need to be established or supplemented?
- How will the evidence base for the account be maintained?

1.3.3 Communicating science

As well as summarising the scientific knowledge base for what will be measured in an account and helping to establish the legitimacy of the account through a collaborative conceptual modelling process, standardised evidence-based conceptual models are also useful for communicating the science behind the account among scientists involved and also with account developers, stakeholders and users, at all stages of the accounting process.

1.4 About this technical note

This technical note integrates two major processes for gathering and summarising the best available information about an account subject: (1) compiling a comprehensive and representative evidence base and (2) collaboratively developing conceptual models. These two are combined into a method for evidence-based conceptual modelling (EBCM) for environmental accounting, to fulfil the roles set out in section 1.3.

Chapter 1 (this chapter) introduces key environmental accounting concepts and discusses how and why conceptual models and evidence bases can contribute to accounting practice.

Chapter 2 is the checklist chapter outlining the entire process for developing evidence-based conceptual models for environmental accounting. As well as the stages described in chapters 4 to 6, five additional stages are adapted from a guide to collaborative conceptual modelling produced by the Queensland Wetlands Program (Department of Environmental and Heritage Protection [DEHP], 2012). Eight stages in total complete the process of making evidence-based conceptual models for environmental accounting. For experienced account framers, Chapter 2 serves as a checklist for completing module four of the environmental account scoping process, described in the *Guide to environmental accounting in Australia*, that is 'establish a conceptual model and evidence base for the account subject'.

Chapter 3 introduces the first stage of an environmental account conceptual modelling process—developing an account subject conceptual model. The account subject conceptual model helps to define the research questions about the account subject that will be needed to compile the evidence base.

Chapter 4 is about developing an evidence base and details an eight-step process for compiling a comprehensively representative evidence base to underpin an environmental account.

Chapter 5 focuses on conceptual modelling, including the development of collaborative ancillary conceptual models.

1.4.1 A guide to collaborative model building

Before continuing, it will be useful to give more information about the Queensland Wetlands Program (QWP) conceptual modelling guide, *Pictures worth a thousand words: a guide to pictorial conceptual modelling*, and its substantial contribution to this technical note.

Pictures worth a thousand words offers a collaborative process for arriving at a scientifically valid pictorial conceptual model (PCM). This process (developed through PCM practice in the wetland sciences) offers a basis for other types of conceptual modelling where collaboration of stakeholders across different sectors is required.

Central to the process is a science synthesis workshop. Participants collaborate to develop a conceptual model that is accepted as the best current understanding among the group. Other inputs to the model can be included, such as the opinion of experts outside the group and peer reviewed literature. The subsequent model is reviewed, refined and signed off by the participants. The evidence base is recorded along with the degree of certainty of each of the elements. Knowledge gaps are also recorded.

Figure 5 shows the stages in the QWP collaborative conceptual modelling process on the left of the diagram. The current document (*Methods for evidence-based conceptual modelling in environmental accounting*) builds on this process. Two new stages are added and stages that follow (output/outcome ID, information synthesis etc.) are

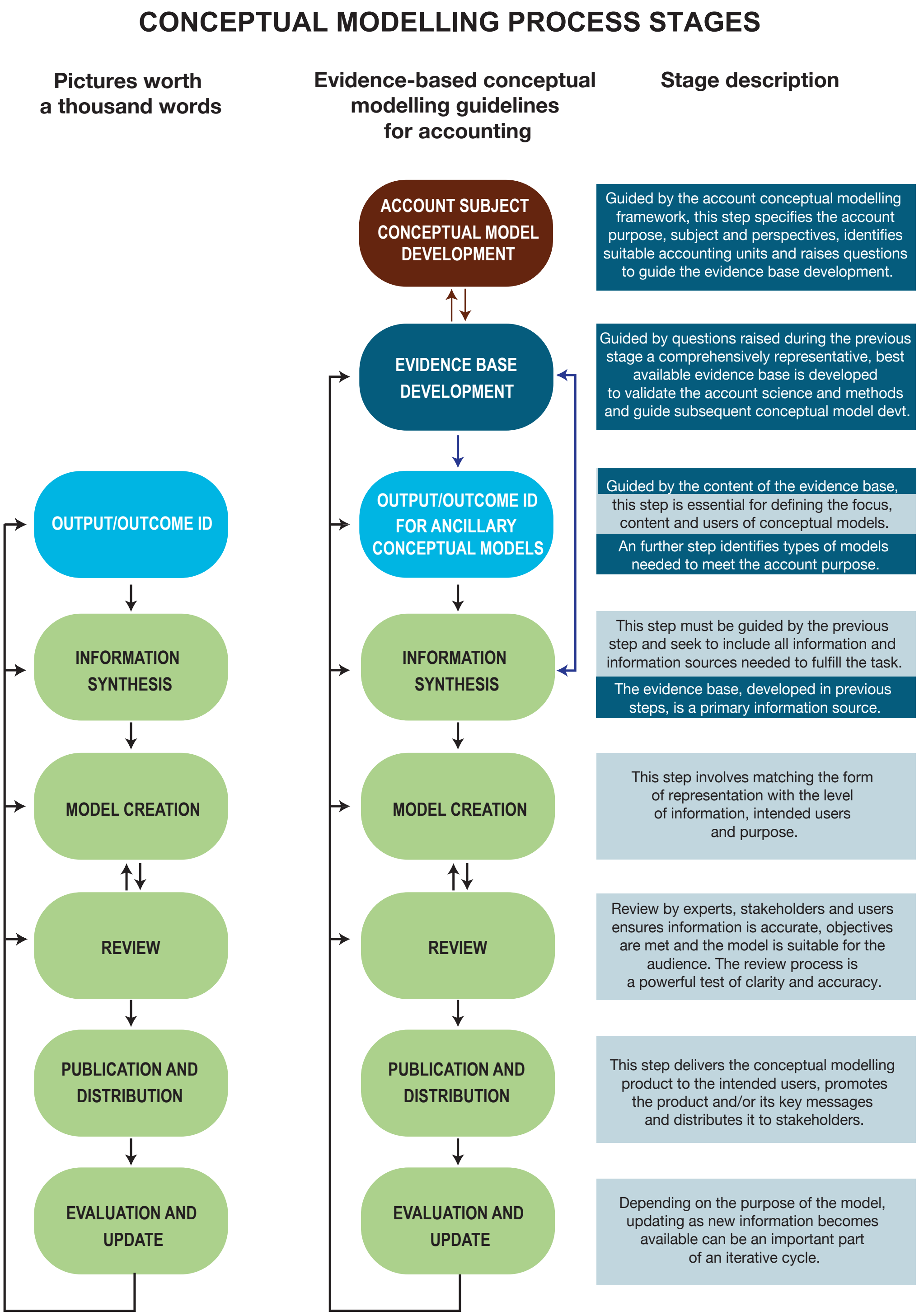


Figure 6. Comparison of the Queensland Wetlands Program process for developing collaborative conceptual models and the process outlined in this document. The dark blue sections of the stage descriptions are new to the accounts conceptual modelling process.

adapted for environmental accounting needs and to accommodate the use of more kinds of conceptual models. Boxes in the right column of this figure summarise each of the stages, with new elements introduced to meet environmental accounting needs highlighted in dark blue.

In stage 1 of the evidence-based conceptual modelling (EBCM) process, an overarching account subject concept model is developed to help clarify the purpose of the account, and to specify account subject, perspectives and measuring units.

The account subject conceptual model also helps an account framer identify a set of questions that will be used to initiate stage 2, the development of a comprehensively representative evidence base of the best available science to underpin the account.

In stage 3, the type and content of ancillary account conceptual models are chosen based on the outcome of stages 1 and 2.

From stage 4 through to stage 8, the evidence-based conceptual modelling process for accounting closely parallels the methods set out in *Pictures worth a thousand words: a guide to pictorial conceptual modelling* (DEHP, 2012).

Figure 7 is a diagrammatic summary of the complete process of producing an evidence-based conceptual model. The eight stages are arranged across the top in a horizontal line. Immediately below the sources for information about each stage are given. Arranged in a vertical line below each stage are the steps involved in completing that stage.

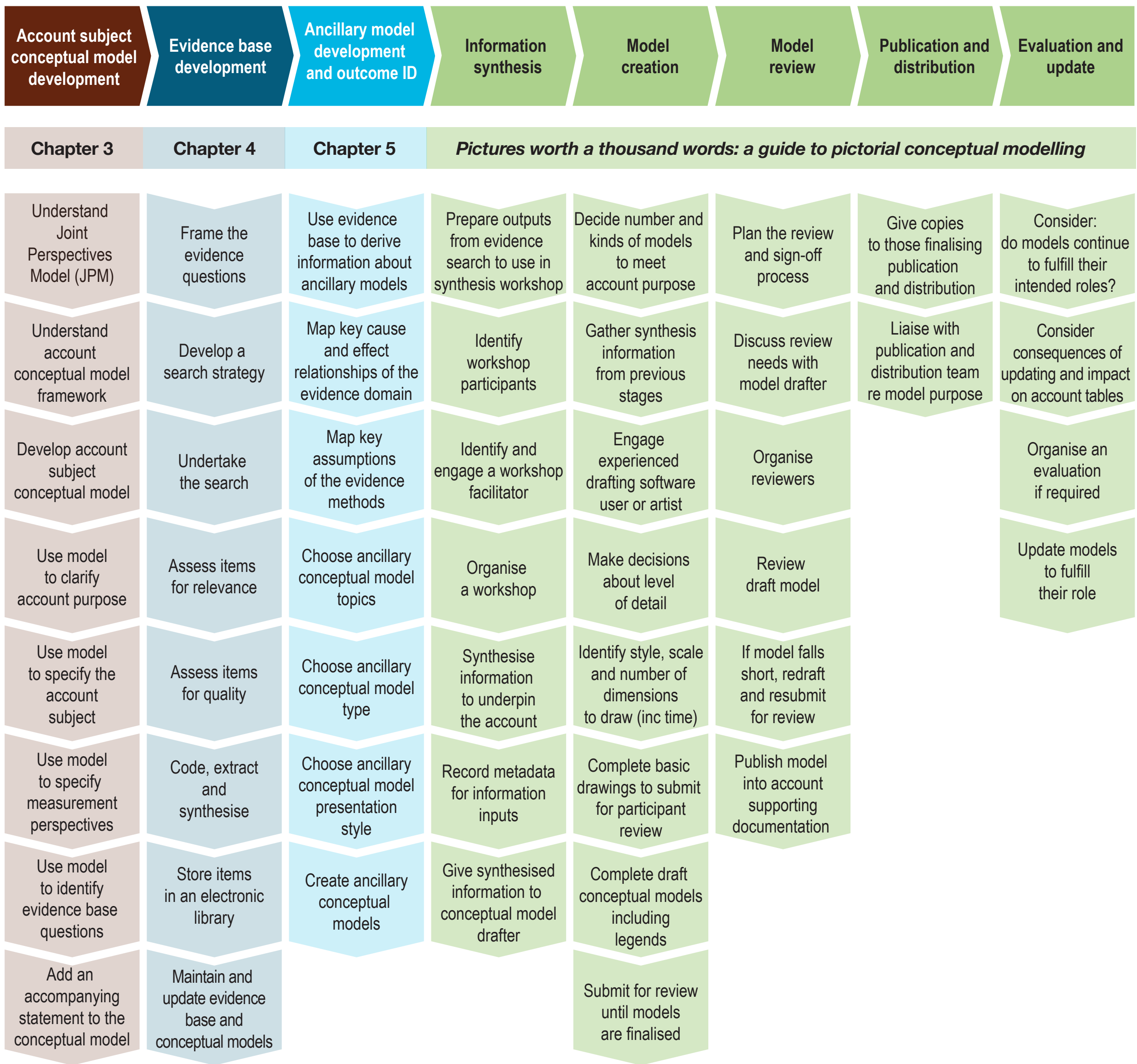
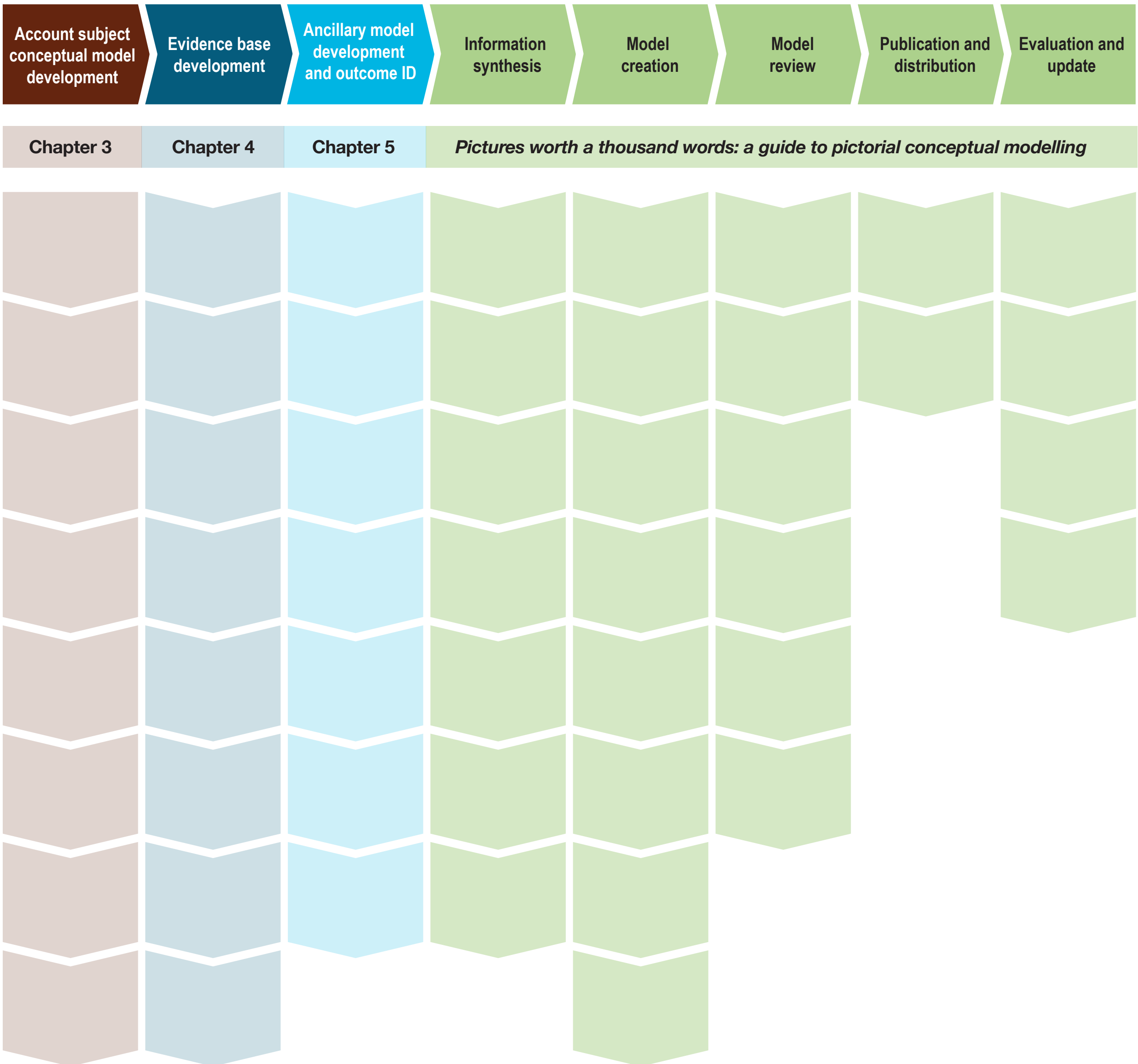


Figure 7. The evidence-based conceptual modelling (EBCM) process for environmental accounting presented in this technical note.

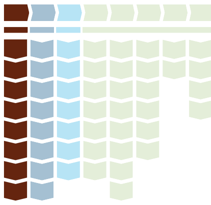

Account subject conceptual model development
Evidence base development
Ancillary model development and outcome ID
Information synthesis
Model creation
Model review
Publication and distribution
Evaluation and update
Chapter 3
Chapter 4
Chapter 5
Pictures worth a thousand words: a guide to pictorial conceptual modelling

2 Stages of evidence-based conceptual modelling: a checklist

Checklist Summary

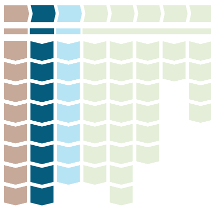
The stages for producing an evidence-based conceptual model are as follows:

1. Develop an overarching subject conceptual model



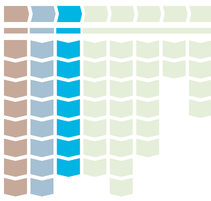
Guided by the conceptual modelling framework, specify the purpose, subject and perspectives for the model (see chapter 3)

2. Develop an evidence base



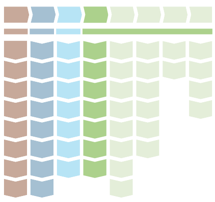
Based on stage 1, compile comprehensive, representative, best-available evidence (see chapter 4).

3. Develop ancillary conceptual models



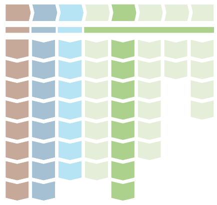
Informed by stage 2, focus on specific aspects of the subject conceptual model. Identify types of models and users (see chapter 5).

4. Information synthesis



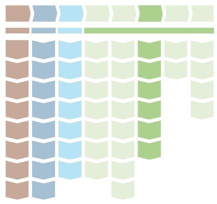
Form an information synthesis specific to each ancillary model via science synthesis workshops and expertise.

5. Conceptual model creation



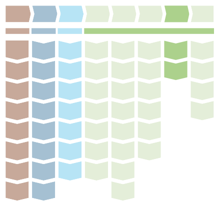
Draft the finished conceptual model.

6. Review



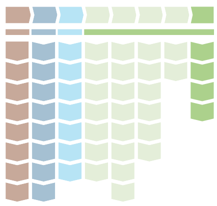
Review by experts, stakeholders and users.

7. Publication and distribution



Deliver and promote the conceptual model to the intended users.

8. Evaluation and update.



When required, update as new information becomes available.

Stage 1 Developing an account subject conceptual model

This stage is unpacked in chapter 3, which describes the rationale behind the account subject conceptual model and methods for developing such a model using an account conceptual modelling framework.

Aim

This stage aims to specify the account purpose, subject, accounting units and perspectives and to bring to light scientific assumptions underpinning the account. Typically this process will include a collaborative workshop, using the account conceptual modelling framework to help with the process.

Actions involved

(For more detail, refer to chapter 3.)

- Using the account conceptual modelling framework for guidance, develop an overarching model to help specify the purpose of the account.
- Using the account conceptual modelling framework for guidance, identify the accounting perspectives.
- Based on the foregoing steps, identify the subject of the account.
- Identify key questions for developing an evidence base of science about the current understanding of the account subject and how it links to the account purpose.
- Based on the chosen account perspectives and subject, decide what is going to be measured and what units will be used.
- Identify key questions for developing an evidence base of science about the relationship between the subject and how it will be measured (methodological evidence).
- Write an accompanying statement to give context to the account subject conceptual model and make it accessible to account users.

Key information

The following is a list of the key information requirements to complete this step:

- Read chapter 3 of this document which sets out the rationale and process for developing an account subject conceptual model.
- Be familiar with the content of the *Guide to environmental accounting in Australia* (Bureau of Meteorology, 2013a).
- Have as clear as possible a concept of the purpose of the proposed account.
- Identify the account participants, account users and other audiences for the account.
- Set up and begin to complete the *Environmental account framing workbook* (Bureau of Meteorology, 2013b).
- Understand how to use the account conceptual modelling framework to develop an account subject conceptual model and identify account purpose, subject, perspectives, units and questions needed to develop the evidence base.
- Understand the Joint Perspectives Model and its application to environmental accounting. (See chapter 1 of this document. For further

information, consult chapter 5 of the *Guide to Environmental Accounting in Australia*.)

- Have a set of questions upon which to base account evidence bases.

Guiding questions

- When the account is set up, what accounting questions will we want it to be able to answer? See section 3.2.2 for a discussion about the difference between accounting questions and conceptual modelling questions.
- What types of accounts do we want to produce?
- Is the account focussed on environmental assets, on ecosystem services and/or interactions, on drivers of system change or on some combination of the three? (See section 3.1 for explanations of these different types of accounts.)
- What are the proposed perspectives of the account?
- In accounting from the proposed perspectives, what value will we fail to capture with this account?
- What are the proposed measuring units?

Stage 2 Evidence base development

This stage is explained in detail in chapter 4, where the rationale and methods for developing an evidence base to support an environmental account are described in detail.

Aim

Developing a comprehensively representative evidence base for an account subject is a way to ensure that any credible information available to use in valuing an environmental asset, good or service has been discovered and recorded, using a collaborative, transparent and systematic process. Inevitably, relevant information will be missed but, within the resources available to the account developers, every effort will have been made to source and share information about the ecosystem characteristics of the account subject and the methods by which the account subject will be measured. Thus, developing an evidence base aims to provide legitimacy and credibility to an environmental account.

Actions involved

(For more detail under each step listed below, refer to chapter 4.)

- Use the account subject conceptual model to frame questions that will be used to develop the evidence base.
- Develop a search strategy.
- Undertake the search.
- Assess items for relevance.
- Assess items for quality.
- Code, extract and synthesise information needed to develop ancillary conceptual models.
- Repeat the preceding steps in relation to the ancillary conceptual models.
- Store all items in an electronic library.
- Maintain and update the evidence base and account conceptual models.

Key information

- Chapter 4 of this document

Guiding questions

- What is our current understanding of the account subject?
- What science links this account subject with the purpose of the account?
- What science links the account subject with the methods used to measure it?
- What are the scientific assumptions underlying the account?
- What are the key questions that will help us to search for evidence relevant to the science behind the account?
- Does a suitable evidence base already exist for the intended account?

Stage 3 Ancillary conceptual model development and outcome identification

A good conceptual model is purpose driven, so the first step in producing one is to articulate the intended purpose or purposes and a clear set of outputs and outcomes that will achieve the purpose.

Is the primary purpose of the ancillary conceptual model to support the science behind an account, to help achieve consensus among experts or is it primarily a tool for communicating with account users and stakeholders? Are there other desired outcomes apart from these primary roles of conceptual models in environmental accounting?

It should be carefully considered who needs to be involved in identifying the desired outcomes, as well as how they will be engaged and at what level. Once considered, all key stakeholders need to be consulted.

Aim

The aim of this stage is to decide what information needs to be represented in the ancillary conceptual models, the purpose of the conceptual models, the audience for the conceptual models and what type of conceptual models best fit the specified content, purpose and audience.

Actions involved

- Based on the evidence search outcomes and input from account participants, decide what information needs to be included in the ancillary conceptual models to fulfil the purpose of the account. (Guidance about this action is given in sections 5.3 and 5.4.)
- Identify the intended audience for the conceptual models.
- Decide what types of conceptual models would best represent the required information for the intended audience. (Guidance about this action is given in section 5.5.)
- Determine whether suitable models already exist.
- Identify the purpose of the conceptual models.
- Identify outcomes/outputs that would achieve the purpose/s.
- Identify who needs to be involved in deciding the outputs and outcomes of the conceptual modelling project.
- Decide whether a workshop is needed at this stage of the conceptual model development and if so, organise a workshop.
- Identify the 'stories' or key messages of the conceptual models.
- Prioritise and list the desired outputs/outcomes.

TIP

Allow sufficient time for account developers to clearly define the purpose, focus and audience/users for the conceptual models.

TIP

Be aware that the purpose of the account conceptual models is not the same as the purpose of the account itself. The models and the process used to obtain them are secondary to the account but nevertheless are vital to ensuring the account's credibility and legitimacy.

Key information

- Chapter 5 of this document
- *Pictures worth a thousand words: a guide to pictorial conceptual modelling*

Guiding questions

- What is the purpose or purposes of the conceptual models?
- What types of models are needed?
- What will they look like?
- What type of evidence will the models be required to illustrate? Will it be evidence about current understanding of the account subject or evidence about the methods linking subject to accounting units?
- What story or stories will the models be telling?
- Who needs to be involved in identifying the outputs or outcomes of the model development?
- Is a workshop needed to establish the desired outputs or outcomes or the types of models required?
- Who will be the users or audience for the models?
- How and where will the models be published?
- How will the published models reach their intended audience?
- Have the purpose and expected outputs been documented and circulated (in a project plan)?
- Has the list of outputs and outcomes been prepared for the information synthesis?
- What methods will be used for the information synthesis?
- Has the list of intended outputs and outcomes been conveyed to the person drawing or compiling the conceptual models?

Stage 4 Information synthesis

Science synthesis expands knowledge by integrating ideas, findings, data and other information in original ways. In this emergent knowledge, the whole is greater than the sum of the parts. Carpenter et al. (2009) state that synthesis is critical for progress in ecology and the environmental sciences because these sciences are inherently multidisciplinary.

An essential point is that new science emerges from the synthesis process, partly due to the interdisciplinary cross-fertilization taking place. For this reason, rigorous standards must be applied to the synthesis process to assure the scientific credibility of the models produced.

If models are being developed in a synthesis workshop, the following practices help ensure consistency and rigour:

- Inputs to the workshop include an evidence search where rigorous standards have been applied to produce a comprehensively representative body of the best available evidence to underpin the proposed conceptual model.
- The use of drawing in the workshop (on a whiteboard, flip chart etc.) helps ensure that all participants have the same mental picture. Drawings are less ambiguous than words.
- A good process of dialogue can help resolve disagreements about the information being shown in the model.
- If consensus is achieved, the likelihood of accurate science is greater. Agreement among experts from different disciplines is akin to triangulation.
- If consensus is not achieved, a knowledge gap and the need for further research can be noted.
- Confidence factors can be introduced. In conceptual models for environmental accounting a high maturity of understanding is needed for all model elements in the account. Any uncertainty about the science should be noted.
- A referenced list of information sources must be accessible to anyone interested in scientific verification of the model. Information from sources other than published literature can also be referenced. Workshop dates and attendees, working group terms of reference, members and meeting dates can be documented. Details of all contributors and reviewers should be recorded. Documenting and completing metadata is a very important step for establishing referable records.

Along with scientific input, other expert knowledge may be integrated to create a conceptual model

> TIP
>
> Involving workshop participants in rough drawing of conceptual models helps to encourage a sense of ownership and immersion in the process. Rough unfinished drawings encourage participants to change or improve the models more than drafts that look finished.

suited to its intended purpose. Other experts whose knowledge could be represented in the finished model include environmental planners, policy makers and managers, local and/or indigenous experts, industry and conservation experts. Depending on the intended outcomes of the conceptual model development, all these people might have a seat around the information synthesis table.

The science synthesis is a very important step in conceptual model making, bringing experts and stakeholders together and forging an understanding that engages the workshop participants in later stages of an account process.

Types and sources of information to integrate into a conceptual model could include the following:

- literature from a systematic evidence search
- output from other synthesis workshops, whether internal to organisations or with broader stakeholder participation
- workshop outputs such as sticky notes, rough diagrams, simple sketches and cartoons drawn with the whole group engaged
- focus groups and working groups to elicit knowledge and information and refine content
- interviews with experts of various kinds, e.g. knowledge holders, managers, scientists
- original research (if the information is not already available, for example testing hypotheses generated by early iterations of models)
- other conceptual models
- photographs and illustrations.

Whatever methods are used to complete the information synthesis, sources should be referenced and made accessible to reviewers and potential users of the model as an important underpinning of its scientific validity.

Appendix 2 gives tips on how to run a successful information synthesis workshop. More than one synthesis workshop may be needed to develop any ancillary conceptual model and it is likely that more than one ancillary model will be needed to underpin any account.

Aim

The aim of this stage is to use the account evidence base and the scientific and other expertise at a workshop to synthesise the information needed to develop ancillary conceptual models for the account.

Actions involved

- Prepare, for use in the synthesis workshop, all outputs from the evidence search, including the evidence base, evidence domain maps and drafts of the ancillary conceptual model/s to be developed in the synthesis workshop. The development of these draft ancillary models is described in chapter 5.
- Identify workshop participants.
- Identify and engage a workshop facilitator.
- Organise a workshop.
- Synthesise information to underpin the account.

> TIP
>
> The credibility and legitimacy of the account will depend to a considerable extent on identifying and inviting the right participants to the synthesis workshop.

- Record metadata for information inputs.
- Convey synthesised information to the person who will draw the conceptual models.

Key information

- Be familiar with the content of the *Pictures worth a thousand words: a guide to pictorial conceptual modelling*, especially Appendix 1 in this document.

Guiding questions

- What level of detail is required in the conceptual models?
- What kind of knowledge and information from which disciplines is needed to supplement the evidence base at a synthesis workshop?
- If consultation with experts and knowledge holders is needed, have they been identified and engaged?
- What other inputs are needed for the information synthesis?
- What range of workshop participants will be needed to satisfy the identified purposes of the modelling project?
- Who will facilitate the workshop?

> TIP
>
> Ideally, the person who will be drawing the finished conceptual models should be present at the synthesis workshop.

Stage 5 Conceptual model creation

Ideally, the science synthesis process should yield clear, unambiguous information about the following:

- the characteristics of the ecosystem and/or flows to and from the ecosystem that are to be modelled
- the relationships linking those characteristics and/or flows
- spatial and temporal scales to be illustrated
- information about assumptions and gaps in the state of knowledge
- references to substantiate the model
- metadata about the sources of information that are to be included in the model.

These elements may be presented in various forms, for example, any or all of the following:

- results of an evidence search
- rough collaborative drawings from a synthesis workshop
- 'sticky notes' and scribbles on butcher's paper
- box and arrow diagrams created with software such as Visio or Doview
- notes from interviews with relevant experts.

The next step in the conceptual model drawing process is to convert these resources into a draft ancillary conceptual model. Before starting to draw, decisions need to be made about the following:

- the drawing medium
- fitting models into their publishing context (overall shape and level of detail)
- dimensions and scale of the model drawing.

Drawing medium

The first decision in relation to drafting a conceptual model is what medium or software is best to meet the identified purpose of the model. This will partly depend upon the types of models that have been chosen. Box and arrow conceptual models can be drawn in programs such as Visio and Doview. Such programs allow a skillful user to make drawings 'on the fly' at a synthesis workshop. These drawings can later be refined into finished conceptual models to meet the accounting purposes.

If many relationships are required to be included in the drawing, instead of producing a tangled 'horrendagram', some sort of tabular model format may be more appropriate, depending on the intended audience.

On the other hand, if pictorial conceptual models are chosen, a high end drawing program and considerable skill and artistic ability are needed to get an attractive set of models. These kinds of models are more likely to be needed if a major purpose of the models is to communicate the science behind the account, especially to a non-science audience.

Publishing context

The next set of decisions to be made involves identifying:

- the level of detail needed in the models
- how that level of detail can be achieved in the context in which the drawings will be published
- the number of drawings that will be needed to model the concepts (tell the story).

Publishing decisions dictate the amount and shape of the space available for the finished drawings. In a typical report or handbook, print published in the standard A4 vertical page format, the amount of detail that can be included in a drawing is low. If greater detail is required, 'pop-outs' or magnifiers may be needed—small drawings that show important sections of the main picture at a larger scale. Alternatively, several drawings may be needed so all the necessary detail can be included without making things too cluttered or too small to see.

The time and budget for creating the models will increase if more drawing has to be done. This is why these decisions need to be made as early as possible in the process.

Drawing style, dimensions and scale

Once the medium is chosen and decisions made about trade-offs between level of detail and available space, the next things to consider are the dimensions and scale needed to illustrate the concepts.

- Do the illustrations need to show processes at more than one scale? If so, how will this be achieved?
- How many physical or conceptual dimensions are needed?
- Is it necessary to illustrate the time dimension in some way and if so how is this to be achieved?

Any illustration of a process involves illustrating time. Processes are typically shown using arrows, implying the change of something from one state to another or else movement of something into, through or away from the system being modelled. The time dimension can also be illustrated with a series of models showing how a system changes over time, say through the seasons or through cycles of wetting and drying. Another possibility for dynamically illustrating how things change over time is animation.

Aim

To draft a set of ancillary conceptual models that will fulfil the purposes identified in the outcome identification stage and support the comprehensively representative evidence base developed in Stage 2.

Actions involved

- Decide what types of models will be needed to fulfil the account purpose and how many.
- Gather the synthesis information from the previous stages.
- Engage a suitably experienced model drawing software user or artist.
- Make decisions about the level of detail.
- Identify the best style, scale and number of physical or conceptual dimensions needed (including time).
- Complete basic drawings and submit for review by workshop participants, experts and intended users of the models to see that they are scientifically accurate and suited for their intended purposes.
- Complete draft conceptual models, including legends.
- Submit for review until models are finalised.

Key information

- *Pictures worth a thousand words: a guide to pictorial conceptual modelling*
- Communication resources offered by the Integration and Application Network (http://ian.umces.edu/)

Guiding questions

- What types of models will be needed for the account ancillary conceptual models?
- Do suitable conceptual models already exist or models that can be readily adapted to be suitable?
- If not, what methods and software will be used to create the models?
- What level of detail is required?
- Who will draft the models?
- Can the model drafting process be started in the synthesis workshop and if so, using what tools and techniques?
- Can the process be streamlined to get drafts of the models to the participants as quickly as possible?
- How many models will be needed?
- What is the appropriate scale for the models?
- Do the models need to show processes at more than one scale. If so, how will this be achieved?

Stage 6 Review

To ensure that the finished drawing is fit for its intended purpose, drafts should be reviewed not only for scientific accuracy but also for their effectiveness as communication products for the intended audience and for their suitability to fulfill all the purposes identified at stage 3, ancillary conceptual model development and outcome identification.

Content review

The content review is an essential part of the scientific validation process for conceptual models. Ideally, this will be a properly conducted, formal peer review. Short of a peer review, the model could be reviewed by seeking comments from a range of relevant experts—both scientists and people with other relevant expertise.

Outcome review

At this stage, the list of intended outcomes and outputs should be consulted and models evaluated to get a sense of whether they are falling short of expectations in any way. Those who participated in the outcome identification step could be involved at this stage.

Another aspect of the outcome review is checking to make sure the draft models are technically fit for their intended purpose as this relates to the production of environmental accounts. Will they present the science behind the account in a way that meets any agreed practice guideline or standard? Will they fit the context in which they will be published?

Communication review

An overlapping but not identical issue is whether the model works as a communication product for the intended audience. Is the language pitched at the right level? Does accompanying text include jargon? Is the accompanying text framed in such a way as to make the key messages interesting and compelling? Are the models eye-catching? Are the stories (key messages) being told effectively? Is the amount of information or the number of key messages right for the audience? These are the kinds of questions that could be answered with a communication review.

User testing and focus groups are ways in which the last two types of review could be achieved.

Drafting-and-review is an iterative process, with feedback from all types of review going back to the model creator to be addressed in the draft models. A further round of review may be needed or there may be scope for negotiating over the suggested changes to arrive at a finished product that suits all parties and purposes.

For a smooth and efficient review process, it is important to have a clear sign-off procedure, to have reviewers prepared ahead of time and to allocate sufficient time for reviewers' comments to be taken into account. To speed up the review process, it is helpful to have the feedback collated and to organise for the person drafting the conceptual model to have just one point of contact with the reviewers.

Aim

The aim of the review step is to enlist the independent oversight of relevant experts to ensure that the account ancillary conceptual models are scientifically rigorous and fit for their intended purpose.

Actions involved

- Plan the review and sign off process.
- Discuss review needs with the model drafter.
- Organise reviewers.
- Review the draft model.
- If the review falls short on content, outcome or communication goals, redraft and resubmit.
- Publish the model into the documentation supporting the account.

Key information

Pictures worth a thousand words: a guide to pictorial conceptual modelling

Guiding questions

- Has a clear process for reviewing the models been planned?
- Have reviewers been identified for the scientific review, independent of those involved in model development process?
- Have reviewers been identified to see whether the models will achieve their intended outcomes and their communication goals?
- Have reviewers been contacted to make sure they are available?
- In terms of the planned publication and release process, has enough time been allowed for the reviewers to do their work and the model to be redrafted in response to any feedback?
- How will the information from the reviewers be transferred to the model drafter? Has someone organised to collate the feedback and act as a point of contact? Is there a clear signoff process and an agreed timetable for the signoff?

TIP

The review process is one of the most time-consuming stages of developing conceptual models.

Stage 7 Publication and distribution

Once the iterative drafting and review phase is complete, the models are ready for publication and distribution as part of the suite of supporting material for an account, or for other purposes such as communication about the account. The mode of publication and distribution will depend on the intended outcomes of the project and the identified audience or users, established at stage 3.

Publishing conceptual models as an element of an account, a communication plan or another publication entails attention to the following details:

- The conceptual models should ideally match the colour and style of other illustrations. To ensure this requirement is met the person drafting the models will need to liaise with the designer of the publication.
- It must be ensured that everything is visible at the size the model will be published, including any text.
- No text element should be set less than 8 pt at the published size. If this is smaller than the size at which the model was originally drawn then the text in the original model must be correspondingly larger.
- Early liaison with the designer/publisher about the required file format is important.

The mode of distribution of conceptual models will also depend on their intended use. Distribution could be just to the primary client/user or to the members of the team involved in the information synthesis. Wider distribution could involve launching a package of communication products or promotion through the media. Conceptual models can be incorporated into communication plans to maximise their potential for engaging possible users of the account.

Aim

The aim of attending to important publication and distribution details while developing the conceptual models, instead of leaving everything up to design professionals at later stages of the publication process, is to ensure that the models achieve their maximum potential as communication tools and to minimize unnecessary and expensive iteration in the model development process.

Actions

- Give copies of the finalized models to anyone who needs them to complete the publication and distribution process.
- Liaise with those responsible for the publication and distribution of the models about what is required to fulfil the intended purposes of the models.

Key information

- *Pictures worth a thousand words: a guide to pictorial conceptual modelling*

Guiding questions

- What steps can be taken by model developers to ensure that the publication process runs smoothly and the communication potential of the models is maximized?
- Are publishers of the account aware of the need to include graphic material?

- What other elements need to be put into place before the models can be distributed in the manner intended?
- Who else needs to be involved in the publication and distribution of the models?
- Have the models been distributed to everyone who needs them in order to fulfill the purposes identified in the outcome identification phase?

Stage 8 Evaluation and update

Evaluation of an account's ancillary conceptual models will determine whether they achieved their intended accounting, scientific and communication outcomes. Updating keeps the models relevant and provides a time and place where new knowledge can be captured. However, there is a dilemma with updating conceptual models underpinning environmental accounts if changes to the models entail changes to the accounts, which could compromise the accounts' comparability across time. This is one reason it is important to use rigorous evidence search and science synthesis processes in preparing the original models.

Strategies may have to be devised to preserve the comparability of important time series, for example recalculating earlier account entries based on new information or adding new tables to the accounts to show the potential impact of the new information, while retaining the original accounts.

Scientific evaluation of conceptual models

Lookingbill et al. (2007) proposed three criteria for evaluating any model to determine whether it needs to be revised and updated. Their correspondence, applicability and reliability criteria are relevant when models are used to predict outcomes. The use of any conceptual model in an account implies some ability on the part of the model to make predictions about ecosystem behaviour and some relationship between trends in the account and the predictions of the model.

The **correspondence** criterion suggests a model may need revision if long-term accounting fails to provide good correspondence between the model predictions and account data. For example, if a catchment model indicates that managing grazing pressure will reduce sediment levels in inshore waters, while trends in the account data fail to confirm this prediction, the model may need to be revisited.

The **applicability** criterion suggests revision if the account purpose requires additional information or a more detailed understanding of an ecosystem's response to changes in the environment. In the previous example, suppose the grazing pressure in the catchment increases substantially. Additional information may now be needed to determine the impact on ecosystem services. The model of current understanding will need to be revised.

Finally, the **reliability** criterion for revision and updating a conceptual model is triggered if the range of responses observed in the actual ecosystem is narrower than what the model predicts. This would indicate either that the model is unreliable and needs revision or that the available data fail to capture the true breadth of ecosystem behaviour. This might be the case, for example, if the model predicted system behaviour across seasons while data were collected only in one season.

These criteria apply specifically to the model's ability to predict ecosystem behaviour. Different kinds of models are capable of predictions at different levels of specificity. Numerical models may predict the exact values of change in some environmental variable, while conceptual models may simply specify that changing one variable leads to a change in another, or may predict the direction but not the magnitude of the change. Ancillary models used for accounting do not need to be capable of numerical prediction.

Evaluation and update of process and communication outcomes

Ideally, account ancillary conceptual models and any products into which they were incorporated should be evaluated against all the purposes, outcomes and outputs identified at stage 3, especially if they are going to be updated. Both the developers and the users of the models should be consulted in the evaluation process.

Aim

The aim of evaluating and updating an account's ancillary conceptual models is to see whether they are fulfilling their intended accounting, scientific and communication outcomes and to incorporate any new science that affects the use of the account for its intended purposes.

Actions required

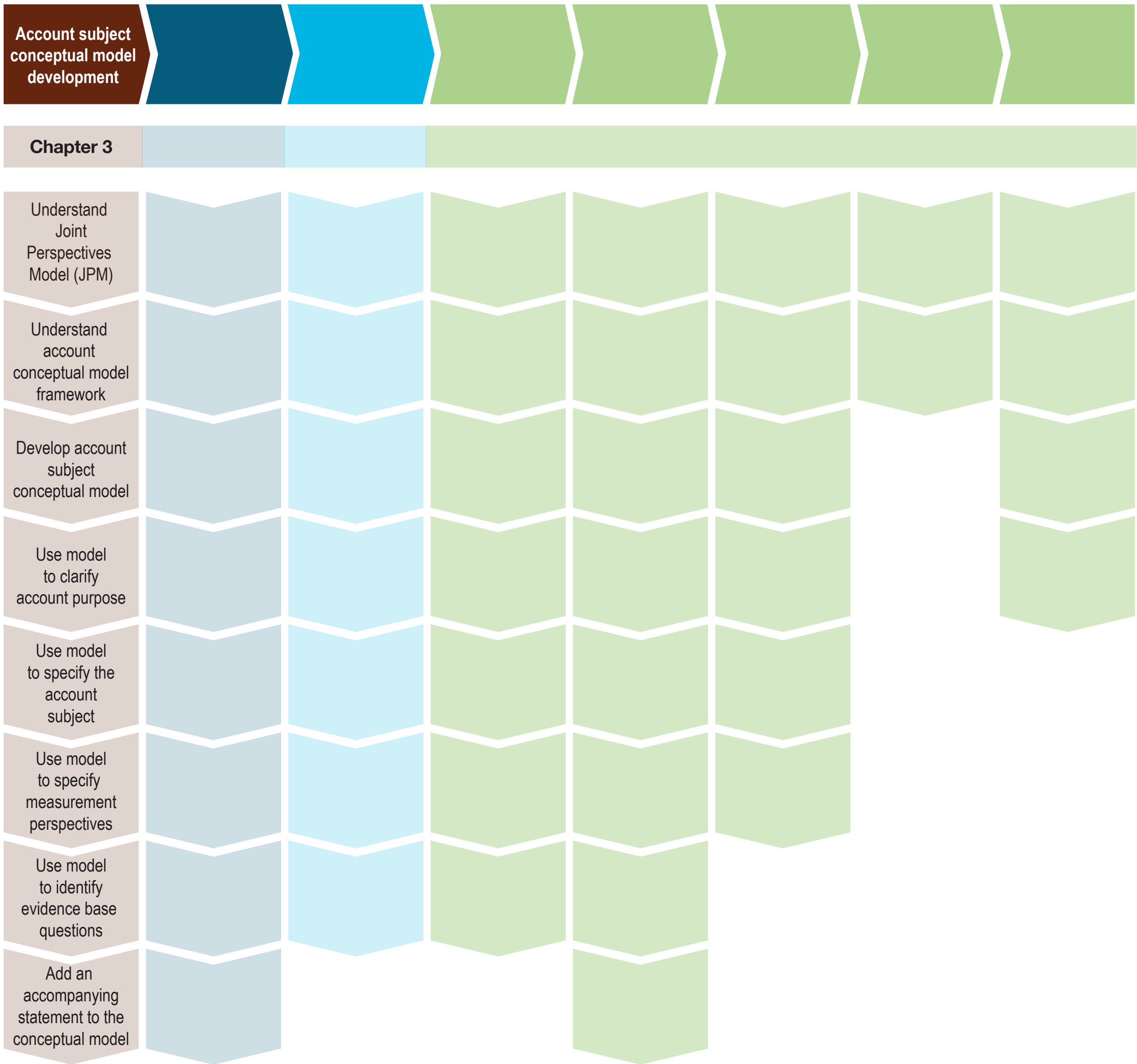
- Consider whether an evaluation of the account conceptual models is needed in order for them to continue to fulfil their roles of underpinning the science of the account, maintaining its legitimacy and communicating with stakeholders and account users.
- Consider the pros and cons of updating the models and how updated models will impact on the account tables.
- Organise an evaluation if required.
- Update models to fulfil their role.

Key information

- *Pictures worth a thousand words: a guide to pictorial conceptual modelling*

Guiding questions

- What roles in the environmental accounting process are the conceptual models designed to support?
- If the models support current understanding has there been any change in the environment that may need to be reflected in the models?
- If the models support the measurement methods used to derive the account tables, has there been any new science to suggest better measurement methods could be available?
- What is the maturity of any new science, considering new measurement methods would compromise the comparability of the accounts across time?
- Do the account data support the hypotheses implicit in the models?
- Are there any account reporting needs that require the models to be updated?
- Do the models need to be evaluated against the list of intended outcomes to ensure that they are fulfilling the desired purpose?
- Has a type of evaluation been identified that will answer the questions about the models that need to be answered?
- If an evaluation is needed are the resources available to carry one out?
- Have the people been identified who need to be involved in any evaluation?
- Once the evaluation has been carried out, how will the results be fed back into the process for creating a new iteration of the evidence base and conceptual models?


Account subject conceptual model development
Chapter 3
Understand Joint Perspectives Model (JPM)
Understand account conceptual model framework
Develop account subject conceptual model
Use model to clarify account purpose
Use model to specify the account subject
Use model to specify measurement perspectives
Use model to identify evidence base questions
Add an accompanying statement to the conceptual model

3 Developing the account subject conceptual model: a framework

Though it can be used for any environmental assessment activity, the conceptual modelling approach in this technical note is primarily intended to support ecosystem accounting. It draws on the preeminent internationally-agreed environmental accounting system, the System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting (SEEA–EEA) (European Commission et al, 2013). THE SEEA-EEA summarises the key conceptual relationships of ecosystem accounting in terms of stocks and flows:

> Stocks in ecosystem accounting are represented by spatial areas each comprising an ecosystem asset. Each ecosystem asset has a range of ecosystem characteristics—such as land cover, biodiversity, soil type, altitude and slope, climate etc—which describe the operation and location of the ecosystem…
>
> …flows in ecosystem accounting are of two types. First there are flows within and between ecosystem assets that reflect ongoing ecosystem processes … [s]econd, there are flows reflecting that people, through economic and other human activity, take advantage of the multitude of resources and processes that are generated by ecosystem assets—collectively, these flows are known as ecosystem services. (SEEA–EEA, p 19)

According to the SEEA–EEA, ecosystem accounting focuses either on stocks of ecosystem assets or on flows of ecosystem services. The stock can be conceived as the capacity to generate ecosystem services and may be tracked with measures of extent and condition (i.e. quantity and quality). Flows include both inputs from the environment to people and residuals (wastes) flowing back to the environment from economic and other human activity.

3.1 Components of the account conceptual modelling framework

Figure 8 is a simple illustration of a conceptual modelling framework for ecosystem accounting and Figure 9 expands on the same framework. Stocks of an ecosystem asset and three kinds of flows are identified.

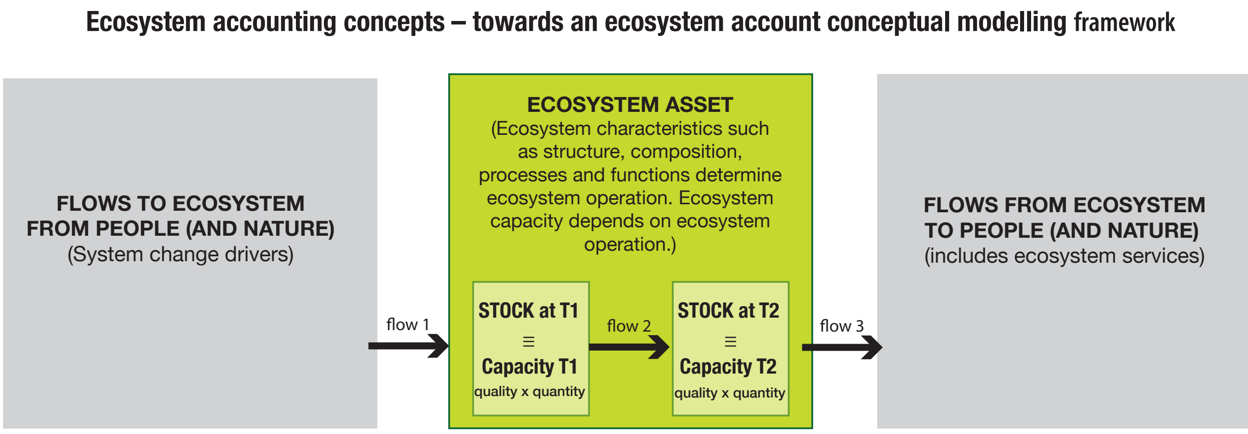


Figure 8. Some ecosystem accounting concepts from the SEEA, used to generate an ecosystem account conceptual modelling framework.

Account conceptual modelling framework for an ecosystem asset account

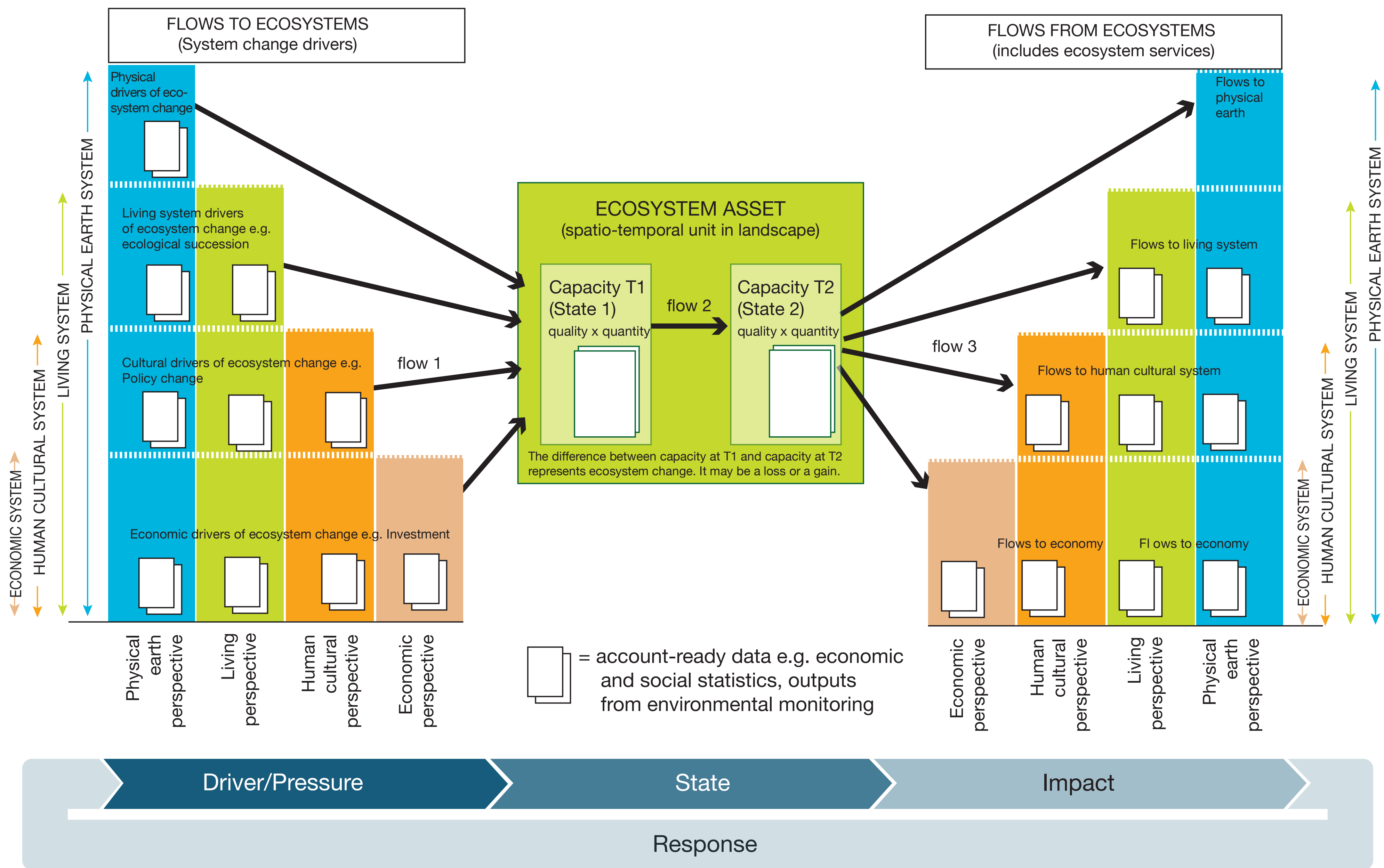


Figure 9. An account conceptual modelling framework for setting up an ecosystem account

Account conceptual modelling framework for a social asset account

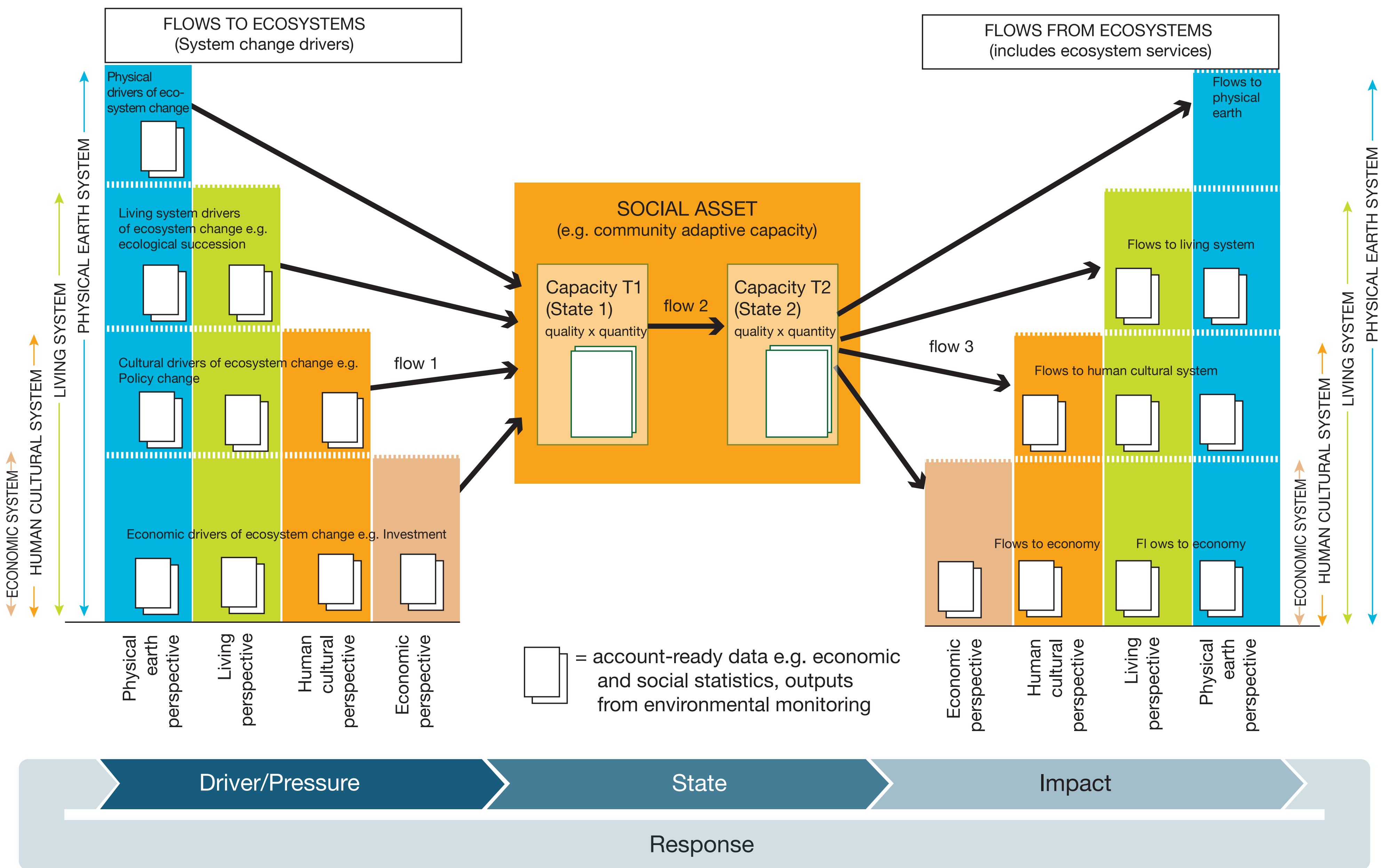


Figure 10. An account conceptual modelling framework for setting up a social asset account

While the role of people is highlighted in ecosystem accounting concepts such as 'pressure' and 'residuals', which are flows to ecosystems, and 'ecosystem services' which are flows from ecosystems, the Bureau's Joint Perspectives Model for environmental accounting emphasises that human systems (cultural, economic) are embedded in natural systems (living, physical earth).

So flows to and from ecosystems that are entirely of the natural world must also be considered (in the grey boxes in Figure 8). In Figure 9 the flows to and from the ecosystem asset are expanded using the four systems and perspectives of the Joint Perspectives Model (illustrated on page 6). The resulting conceptual modelling framework helps account framers to develop different kinds of ecosystem accounts for different purposes and from different perspectives. This framework also aligns with the Driver–Pressure–State–Impact–Response (DPSIR) framework used by the European Environment Agency (and many others) for describing causal relationships between people and ecosystems, especially for the purposes of monitoring and managing environmental assets (European Environment Agency, 1999).

Because the economic system is embedded in the human cultural system which is in turn part of the living system, this conceptual modelling framework is useful to frame any type of account. However, the methods for evidence-based conceptual modelling are particularly aligned to the challenge of *ecosystem* accounting, which will be the focus of the remainder of this document.

As in Figure 3 (on page 6), which illustrates the Joint Perspectives Model itself, accounting perspectives are illustrated in Figure 9 with coloured slices (in this case arranged vertically), while systems under consideration are delineated using dotted white lines. Thus, accounting for stocks and flows in the economy—that is those stocks and flows for which markets exist—can be from any of the four perspectives—physical earth, living earth, human cultural or economic. For example, water could be measured by monetary value and/or by volume or environmental quality. Ecosystem assets for which there are no markets, or no market-based ways of calculating value, can be accounted from other perspectives, depending on the purpose of the account. This will be clarified in later sections using examples.

In all cases, the stacked white rectangles in Figure 9 represent data that can be used in account tables. They also represent the operational units for measuring account subjects. An account subject can be measured from any account perspective and system relevant to the account purpose. For example, an account purpose could be to determine whether the demand for forest products is affecting the capacity of the ecosystem asset (forest) to deliver ecosystem services to the living system.

Living system units measuring change in species richness or change in the water cycle could be used for this accounting. On the other hand, if the purpose involved an economic cost-benefit analysis, some legitimate method would be needed to estimate capacity to deliver ecosystem services in dollars.

The following sections further explain elements of the account conceptual modelling framework, focusing in turn on each of three areas in Figure 9: the central rectangle, representing the ecosystem asset, flows to the ecosystem (drivers of change) on the left side and flows from the ecosystem, including ecosystem services, on the right.

3.1.1 Ecosystem assets

The central rectangle in Figure 9 represents an ecosystem asset, a spatio-temporal unit in the landscape, such as a hectare per year. The ecosystem asset may be as small as a pixel (in SEEA terms, a Basic Statistical Unit or BSU) or may represent some larger spatial area, such as an ecosystem accounting unit (EAU). In this case, as we are dealing with a living system asset, the central rectangle is shaded green, but the framework can also accommodate other kinds of assets, for example a community might be represented with an orange rectangle and the account subject could be some aspect of social capital, such as community adaptive capacity or community resilience (Figure 10).

The following accounting processes are represented within the ecosystem asset box:

- Indicators of change in the capacity of the ecosystem to deliver ecosystem services are measured at the start and finish of the accounting period, shown as time 1 and time 2 (T1 and T2).
- The data in accounting tables (represented by the stacked white boxes) are obtained by measuring these indicators or indices of ecosystem capacity.[1]
- In accounting terms, any changes in capacity are flows within the ecosystem asset, as represented by the arrow between capacity at time 1 and capacity at time 2.
- In this case, the account purpose is to detect any change in ecosystem capacity to deliver ecosystem flows (including ecosystem services to people) and the account subject is the indicator or index used to measure capacity.
- The capacity of the ecosystem aligns with the concept of State in the DPSIR framework.

3.1.2 Flows to ecosystems (system change drivers)

To the left of the ecosystem asset box are 'system change drivers'. In DPSIR terms, these are drivers and pressures. For present purposes, both are forces for system change so they are combined under one heading. Use of the neutral term 'flows' reflects the fact that drivers of change, whether economic, social or natural can have negative or positive effects on ecosystems. In fact the valence of ecosystem impacts can change from negative to positive (or vice versa) depending on the ecosystem characteristic or time-scale being considered (e.g. the short term impacts of bushfires can be devastating for nature as well as people, but, taking a longer view, some natural systems, adapted to intermittent intense burning, benefit from bushfires).

In accounting terms, the effects of system change drivers, whether positive or negative, are flows to the ecosystem asset, illustrated using arrows in the diagram. Flows to the ecosystem can be economic, social or can originate from the natural world, both its living and non-living components. Examples of flows to the ecosystem originating from each of the systems in the Joint Perspectives Model are given on the left. For example, investment of funds is an economic flow, while ecological succession can drive flows to ecosystems purely from within the living system, without any human intervention. Change in demand for ecosystem services, for example by increased human populations, is an indirect system change driver that can induce change in the flows to the economic, human cultural or living systems.

The SEEA–EEA identifies residuals, or waste, from human consumption processes as flows to ecosystems. If people's response to such flows is economic or social investment in repairing them, these investments also appear on the left of the diagram as positive system change drivers (flows to ecosystems).

3.1.3 Flows from ecosystems (including ecosystem services)

Shown to the right of the ecosystem asset in Figure 9 are flows from the ecosystem to the nested

1. Capacity is a function of the condition and the extent of the ecosystem, given as *quality* times *quantity* (capacity = quality x quantity).

economic, human cultural, living and physical earth systems. In SEEA–EEA terms, the flows from the ecosystem to the economic and human cultural systems are ecosystem services, while the flows to the living system (and the physical earth system) appear in the SEEA as intra-ecosystem flows and inter-ecosystem flows (SEEA–EEA p 22 Figure 2.2). In other classifications of ecosystem services, notably the Millennium Ecosystem Assessment, positive flows to the natural environment have been classified as 'supporting services' (see box 2 for further discussion). The negative impacts of changes in ecosystem capacity can also be conceptualised as flows from the ecosystem, hence the alignment with 'impacts' in the DPSIR framework.

In general, positive and negative flows from the ecosystem asset to the ecosystem itself, to other ecosystems and to people have been termed 'flows from ecosystems.' This acknowledges that ecosystems are blind to the outcomes of their processes and to how and whether these affect the economic and human cultural systems or other aspects of the natural systems. For example, floods are natural ecosystem processes with impacts usually considered to be disservices to the economic and human cultural systems. As with system change drivers (flows to ecosystems), this can depend on the perspective and time scale under consideration.

3.2 Using the account conceptual modelling framework for ecosystem accounting

The account conceptual modelling framework described above is a tool to help account framers and other participants to:

- develop an account subject conceptual model
- clarify the purpose of the account, link it to the account subject and identify the relevant account perspectives and participants and
- shape questions about the science behind the account that can be used to develop an evidence base, along with ancillary conceptual models, to present this science.

3.2.1 Using the framework to develop an account subject conceptual model for a particular account

Depending on the type of account being developed, different elements of the account conceptual modelling framework will be emphasised. The elements will then need to be specified including

Box 2 A note on ecosystem services

The SEEA takes the Common International Classification of Ecosystem Services (CICES) as its standard in recognising only three broad types of ecosystem services—provisioning services, regulating services and cultural services—all providing services to people. Unlike the Millennium Ecosystem Assessment, neither CICES nor SEEA–EEA recognise the category of 'supporting services', that is, services from ecosystems to themselves or to other ecosystems. SEEA does, however, recognise the existence of these flows as intra- and inter-ecosystem flows. In Figure 9, these are represented by flows from the ecosystem asset to the living and physical earth systems.

> The elements in the account conceptual modelling framework are placeholders. In the process of replacing them with specific information for a particular account, an *account subject conceptual model* emerges.

the asset under consideration, the account subject and its measurement units. Once the subject and accounting units are identified, the scientific assumptions underpinning the account should be clarified, as should questions related to the validity of these assumptions. Knowledge gaps should also become more apparent.

The elements in the account conceptual modelling framework are place holders. In the process of replacing them with specific information for a particular account, an account subject conceptual model emerges. It is important that this specification process involves all relevant account participants, including but not limited to representatives of the following groups: account framers, account users, account owners and any experts needed to clarify technical aspects of account subjects, accounting units, reporting units and datasets.

Developing an account subject conceptual model is a collaborative process. For efficiency and for transparency among account participants, a facilitated workshop is an appropriate way to develop the account subject model, unless a high degree of consensus already exists among the participants about the purpose, subject, perspectives, accounting units and the science underpinning the account.

Examples of account subject conceptual models for three types of accounts are presented in Figures 11 to 13 in the following section.

3.2.2 Using the account subject conceptual model to clarify the account purpose

While account framers will always set out with a purpose or motivation for developing an account, account subject conceptual models developed using the framework presented above will help to clarify the purpose or motivation of the account, as well as linking the purpose with the subject and account perspectives.

Using the framework, four basic types of accounts can be framed. These are accounts focusing on:

1. changes within ecosystem assets
2. flows from ecosystem assets to people (including ecosystem services) or ecosystems (including intra- and inter-ecosystem flows)
3. the impact of system change drivers (flows to ecosystems) on ecosystem assets
4. the impact of system change drivers on flows to people or ecosystems.

Each type focuses on one or more of the flows identified in Figure 9. Two of the account types, namely the ecosystem asset accounts and ecosystem service accounts, are identified by the SEEA–EEA (p 35). A third type accounts for pressures on ecosystem assets (positive and negative) from system change drivers. Account ready data from a monitoring program tracking pressures on ecosystems could be used to generate an account of this type.

In the fourth type of account, the impact of system change drivers on ecosystem services is considered, without any data on changes in the asset being available. In this case, a theory or hypothesis about the relationships among drivers, assets and ecosystem services (or other interactions) takes the place of ecosystem asset data in an account table. For example, we may have accounting tables presenting the area of bushfire activity through time in a water supply catchment and tables of the amount of drinking water delivered from the catchment. What links these two sets of tables is a theory about the impact of bushfires on catchment water delivery. The actual changes in the ecosystem operation of catchment forests due to fire activity are implicit but not the focus of the account.

Choosing which account type, or which combination of types, to use hinges on the purpose of the account.

Ecosystem asset accounts

If the purpose is to track the condition (quality) and extent (quantity) of an ecosystem asset or to track its capacity to deliver ecosystem services, then an ecosystem asset account, focusing on change in

Conceptual model for a landscape vegetation connectivity (LVC) account

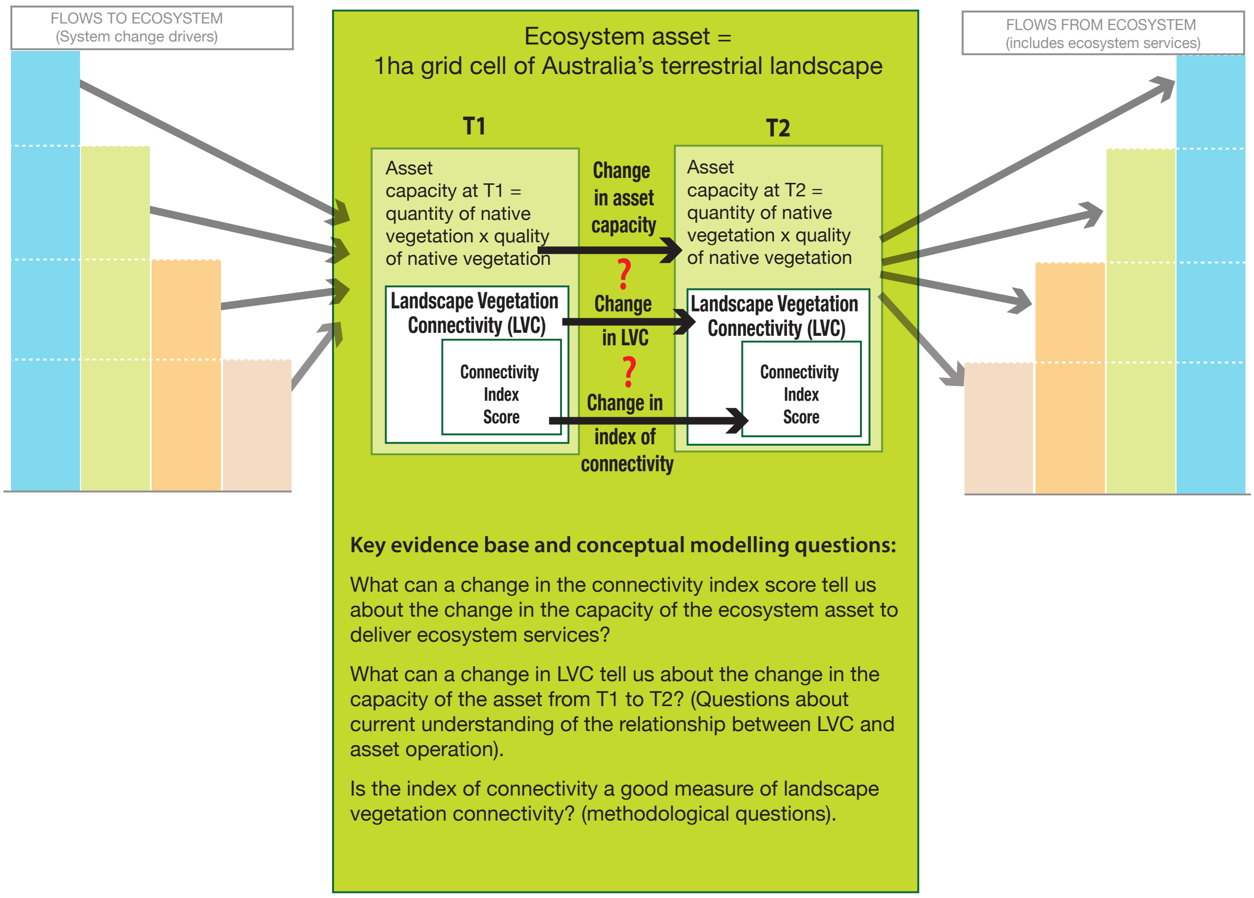


Figure 11. Using the account conceptual modelling framework to define the purpose and subject of an account that tracks the capacity of native vegetation to deliver ecosystem services. An index of connectivity is used as an indicator of asset capacity.

condition, extent or capacity from one accounting period to the next will be the appropriate account type. In terms of the DPSIR framework, this is equivalent, in concept, to measuring state at time 1 and state at time 2 and comparing them. The case study accompanying this guide, which uses an Australian landscape connectivity index (the National Connectivity Index) as an indicator of ecosystem capacity, is an example of such an account (see Figure 11).

From one accounting period to the next, account tables present the opening and closing values of Landscape Vegetation Connectivity (LVC) for an ecosystem asset, as measured by the National Connectivity Index (Storey, pers. comm.). Any change in LVC indicates a change in the capacity of the asset to deliver (unspecified) ecosystem services. The change in asset extent, condition or capacity reflects the impact of (unspecified) ecosystem change drivers and is likely to affect ecosystem services and inter- and intra-ecosystem flows. An example of an account table from an experimental landscape vegetation connectivity account is given below.

Ecosystem service (flows from ecosystems) accounts

On the other hand, if the account purpose focuses on ecosystem services, the emphasis will be on flows from the asset to one or more interactions with people or other ecosystems. In an example of this type, Schröter et al. (2013) estimate the capacity of a geographical region (Telemark, Norway) to provide a suite of ecosystem services. They also estimate the flow of each of these services, using comparable units. The purpose of their accounts was to assess the sustainability of the flow of services from an ecosystem asset in Telemark County. In the account tables, if the flow of services exceeded the capacity to provide them, then the flow was unsustainable for that account period (see Figure 12). To determine whether this was the case, the measurements used for both the capacity and flow accounts had to be in the same units, in this case, numbers of moose, a measurement from the living system perspective.

Table 1 An experimental landscape vegetation connectivity account table of changes in woody vegetation in the Burdekin River catchment between 1972 and 2011.

	Woody vegetation—Burdekin NRM Region		
	Area (ha)	**Area (ha) woody vegetation** ('natural habitat')	**Mean woody vegetation connectivity index**
Opening condition, 1972	14,067,800	7,350,507	69.48
Additions	n/a		0.56
Reductions	n/a		5.89
Closing condition, 2011	14,067,800	5,399,779	64.15

Conceptual model for an ecosystem service (moose) sustainability

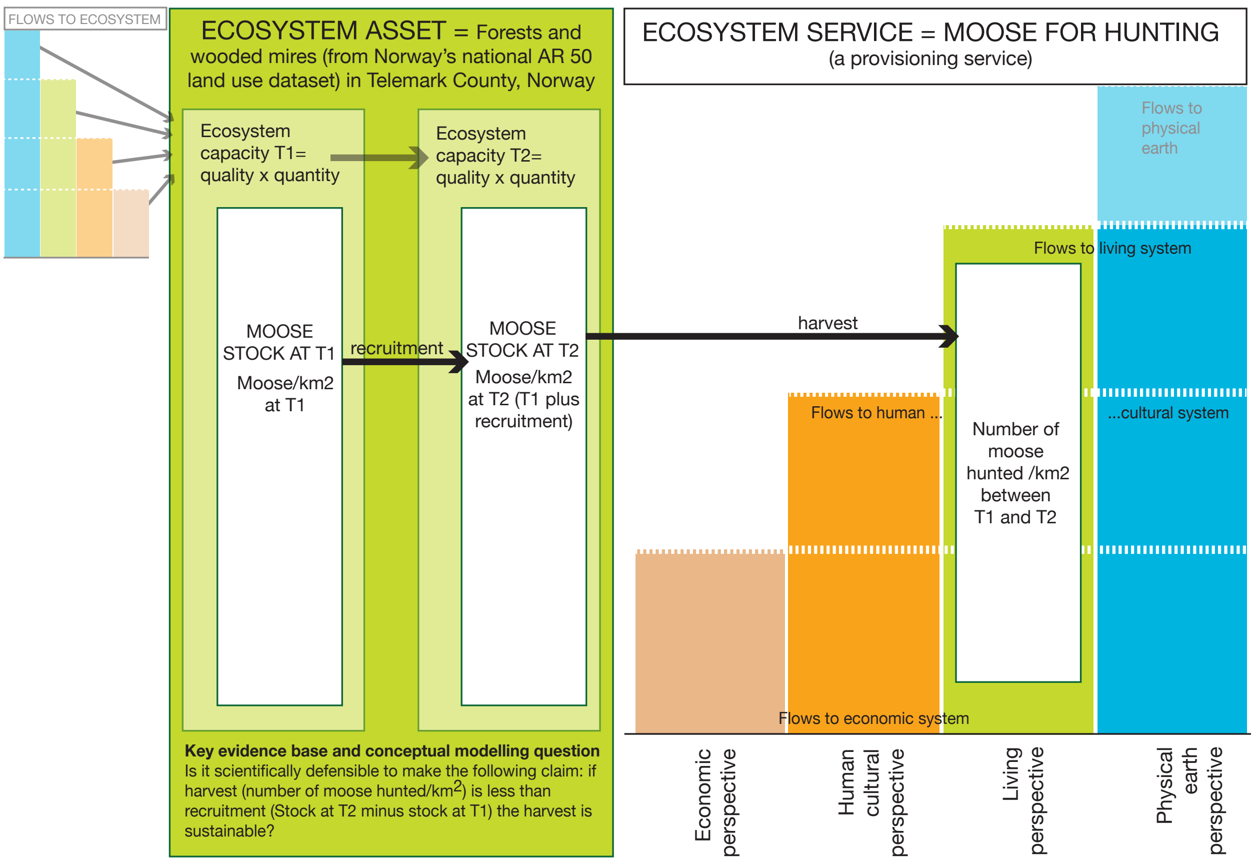


Figure 12. Using the account conceptual modelling framework to define the purpose and subject of an account to track the sustainability of moose hunting in Telemark County, Norway. The flows of interest are labelled 'recruitment' and 'harvest'. If harvest is less than recruitment, the flow is sustainable.

Accounts focused on drivers of change (flows to ecosystems)

Account purposes related to assessing the impact of drivers of change focus on the left side of the conceptual modelling framework. As an example, the account illustrated in Figure 13 allows users to track the levels of sediment reaching the barrier reef lagoon from the Burdekin catchment. Linking the sediment account to a reef condition account may also allow us to understand something about the impact of these sediments on the health of the reef ecosystem.

Here the account subject is sediment loads, as measured by the Bureau of Meteorology's eReefs Marine Water Quality Dashboard, which provides spatial modelling of a number of water quality variables in the Great Barrier Reef lagoon, including non-algal particulates (NAP), a sediment indicator. The eReefs dashboard also provides tabular data by natural resource management region and at various time steps (e.g. daily, seasonal, annual). Also produced annually, under the Reef Water Quality Protection Plan, is a Reef Report Card that gives data for reef condition based on water quality

Conceptual model for an account of the impact of sediment in the GBR lagoon, Burdekin Catchment

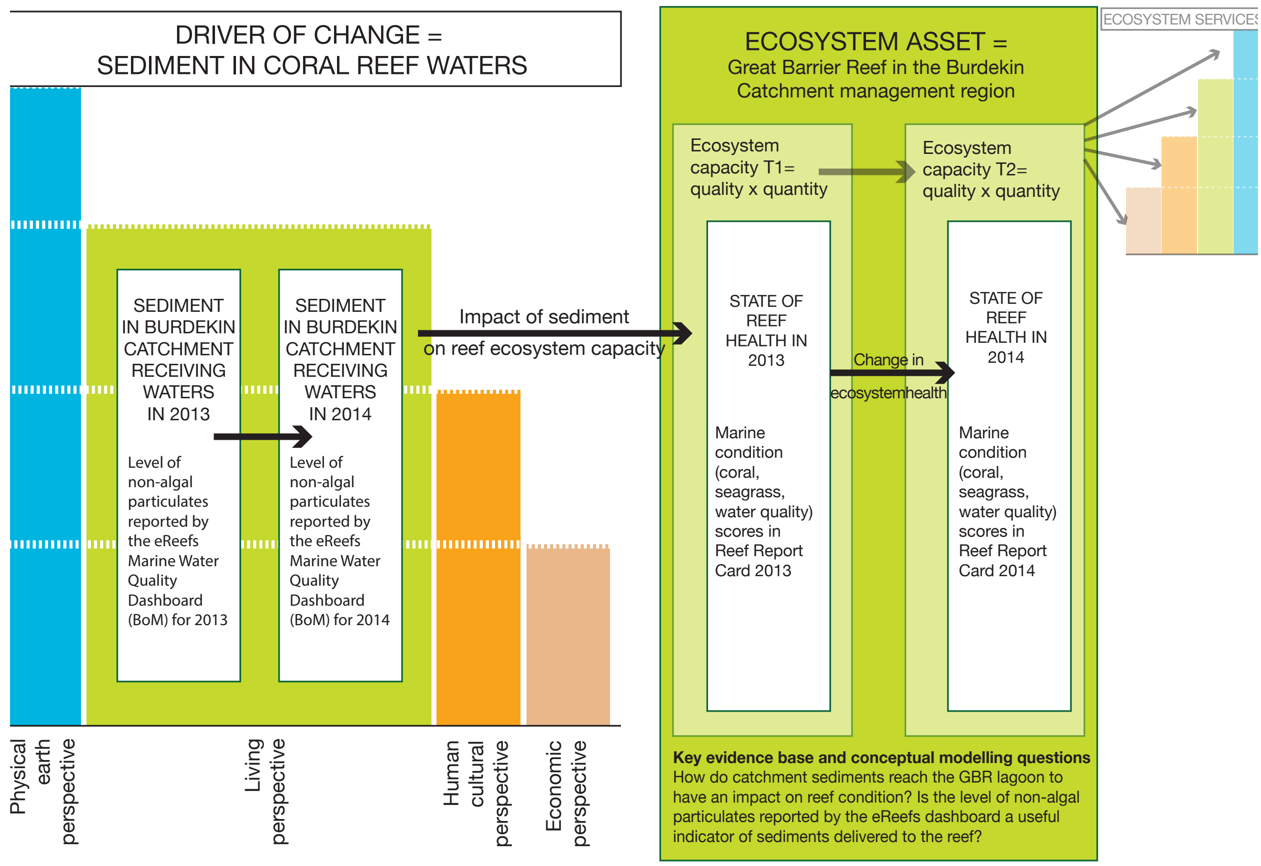


Figure 13. Using the account conceptual modelling framework to define the purpose and subject of an account tracking changes in catchment sediment loads and reef ecosystem condition.

and the condition of coral and seagrass. This data is reported on a five point scale (very poor, poor, moderate, good and very good) by natural resource management region.

Accounts based on these two data sources (eReefs Marine Water Quality Dashboard and the Reef Report Card) produced on an annual cycle, would give the opportunity to answer questions such as: is change in remotely sensed sediment loads from year to year linked with any measurable change in indicators of reef condition and hence the capacity of the reef to deliver ecosystem services? How soon after the change in sediment input occurs is there a correlated change in the state of the reef's condition as reported in the reef report card? These are accounting questions that could be answered using this type of account.

Of course the credibility of the accounts described above rests on the validity of the science behind the account, and of the instruments and methods used to provide the numbers for the accounting tables. Questions about the credibility of knowledge and metrics used in accounts are another class of question altogether and are regarded as evidence base/conceptual modelling questions or research questions. These questions are integral to the topic of this document. They are the subjects of the evidence bases and conceptual models that underpin the account. These questions are dealt with in later sections of this technical note.

The distinction between accounting questions and evidence base/conceptual modelling questions is important to understand and can be conceptualised in this way: the accounting questions are the ones that an account user is interested in. The purpose of the account is to answer these kinds of questions. On the other hand, the evidence questions are of interest to account producers. Asking these questions and answering them with evidence bases and conceptual models is what helps those producing the account to be confident that the account will be fit for its purpose.

The distinction between accounting questions and evidence base/conceptual modelling questions is important to understand and can be conceptualised in this way: the accounting questions are the ones that an *account user* is interested in. The purpose of the account is to answer these kinds of questions. On the other hand, the evidence questions are of interest to *account producers*. Asking these questions and answering them with evidence bases and conceptual models is what helps those producing the account to be confident that the account will be fit for its purpose.

3.2.3 Using the account subject conceptual model to specify the account subject and measurement perspectives

As well as helping account participants to identify the purpose of the account, the account conceptual modelling framework is also useful for defining the subject of the account, that is, what the account is measuring. For example, looking at the account of the sustainability of moose harvest in Telemark, Norway (Figure 12), should the subject of the account be 'moose' or 'moose hunting'? Answering this question is important for determining how, and from what perspective, the subject is to be measured.

Given that the purpose of the account is to determine whether moose hunting is sustainable, then counting the number of moose—a living system measure—is appropriate. In this case 'moose' and not 'moose hunting' is the account subject. On the other hand, if the account purpose was to do a cost benefit analysis of moose-hunting, as opposed to, say, clear-felling moose habitat for timber, then the subject is 'moose hunting' and counts are not the appropriate measure. This is because they overlook a number of benefits, such as the income provided to those who service the moose hunting industry or the health benefits and cultural services provided to those who participate in moose hunting—benefits experienced regardless of how many moose are caught. If 'moose hunting' is the subject and an economic perspective is taken, the units will be monetary. A process will be needed to identify all the valuable components of moose hunting and to cost them in monetary units.

Again referring to the moose hunting example, conversion to monetary units is required for a cost-benefit analysis but it is important in such cases to acknowledge that some things of value to people cannot be measured in dollars (or Kroner in this case). Methods such as contingent valuation can be used to estimate the monetary value of some cultural services to individuals but how are cultural services to the community, such as the sense of community cohesion that comes from carrying out traditional cultural practices, to be assessed in monetary terms? Using the account conceptual modelling framework to specify the purpose, subject and perspective for the account draws attention to what is potentially left out in ecosystem valuation. The formal acknowledgement of missing value helps to keep the process of environmental accounting clear and supports its legitimacy.

3.2.4 Using the account subject conceptual model to identify key assumptions and questions to develop an evidence base for the account

Once the purpose, subject and perspectives of the account have been clarified, questions will come to light about the scientific assumptions that underpin an account subject conceptual model.

The account subject conceptual model represents a broad hypothesis of cause and effect relationships between the system change drivers, the asset and ecosystem services as described in Section 3.2.2 above.

In the case of the account subject conceptual model for the landscape vegetation connectivity (LVC)

Using the account conceptual modelling framework to specify the purpose, subject and perspective for the account draws attention to what is potentially left out in ecosystem valuation.

The account subject conceptual model represents a broad hypothesis of cause and effect relationships between the system change drivers, the asset and ecosystem services as described in Section 3.2.2 above.

account as shown in Figure 11, the hypothesised relationships are between the ecosystem asset and landscape vegetation connectivity. Unpacking this a little further, the model hypothesises that changes in LVC can be used as an indicator for changes in the ecosystem capacity to deliver services.

In testing these causal relationships that underpin the validity of the model (and hence account), evidence must be sought to answer key questions about the relationships in the model. For example what does LVC capture about the characteristics of the ecosystem that allow us to imply some link with ecosystem capacity? What evidence leads us to think that enough of the variation in ecosystem capacity can be explained by LVC for this one characteristic to act as an indicator for change in capacity?

Further questions arise about the particular measuring instrument used to capture LVC—the National Connectivity Index for example. What are the methodological assumptions behind this index? Are these assumptions well-founded? What is the evidence for this?

These questions are all valid and relevant to the integrity of the conceptual model. They do however cover a very broad domain of topic areas. As described in chapter 4 below, 'mapping' the evidence domain to underpin these account subject conceptual models is an important first step in both the development of a supporting evidence base and to assist with the development of more specific ancillary conceptual models as discussed in chapter 5.

It is also important that topic expertise (here, in ecosystem science) is sought regarding the final questions that will be used to build the evidence library.

3.2.5 Adding an accompanying statement to the account subject conceptual model

An account subject conceptual model is a collaborative product of account participants and account subject experts. To make the model accessible to account users, a contextual statement should be written describing the assumptions that support the reasoning behind the account purpose. This will also contribute to the development of the account's contextual information, disclosures, notes, policies and statements.

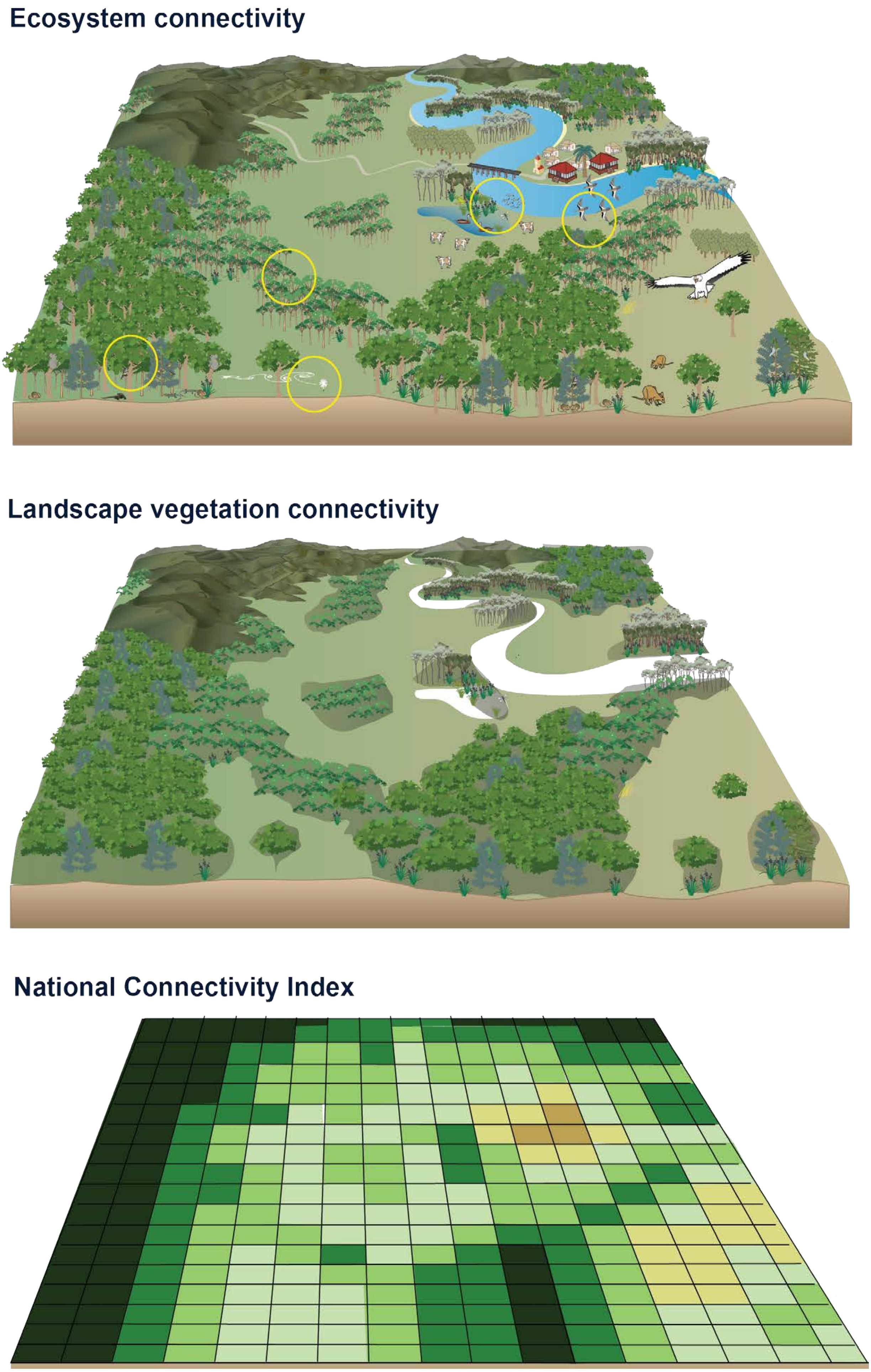


Figure 14. A pictorial conceptual model to explain the relationships between ecosystem connectivity, landscape vegetation connectivity and the National Connectivity Index.

Box 3 Developing an account subject conceptual model—a case study

A landscape vegetation connectivity index developed by the Commonwealth Department of Environment (the National Connectivity Index) was proposed as a potential indicator of change in terrestrial ecosystem capacity. The aim was to develop an experimental ecosystem account using the Index as an account subject. The purpose was to account for any change in ecosystem capacity using this indicator.

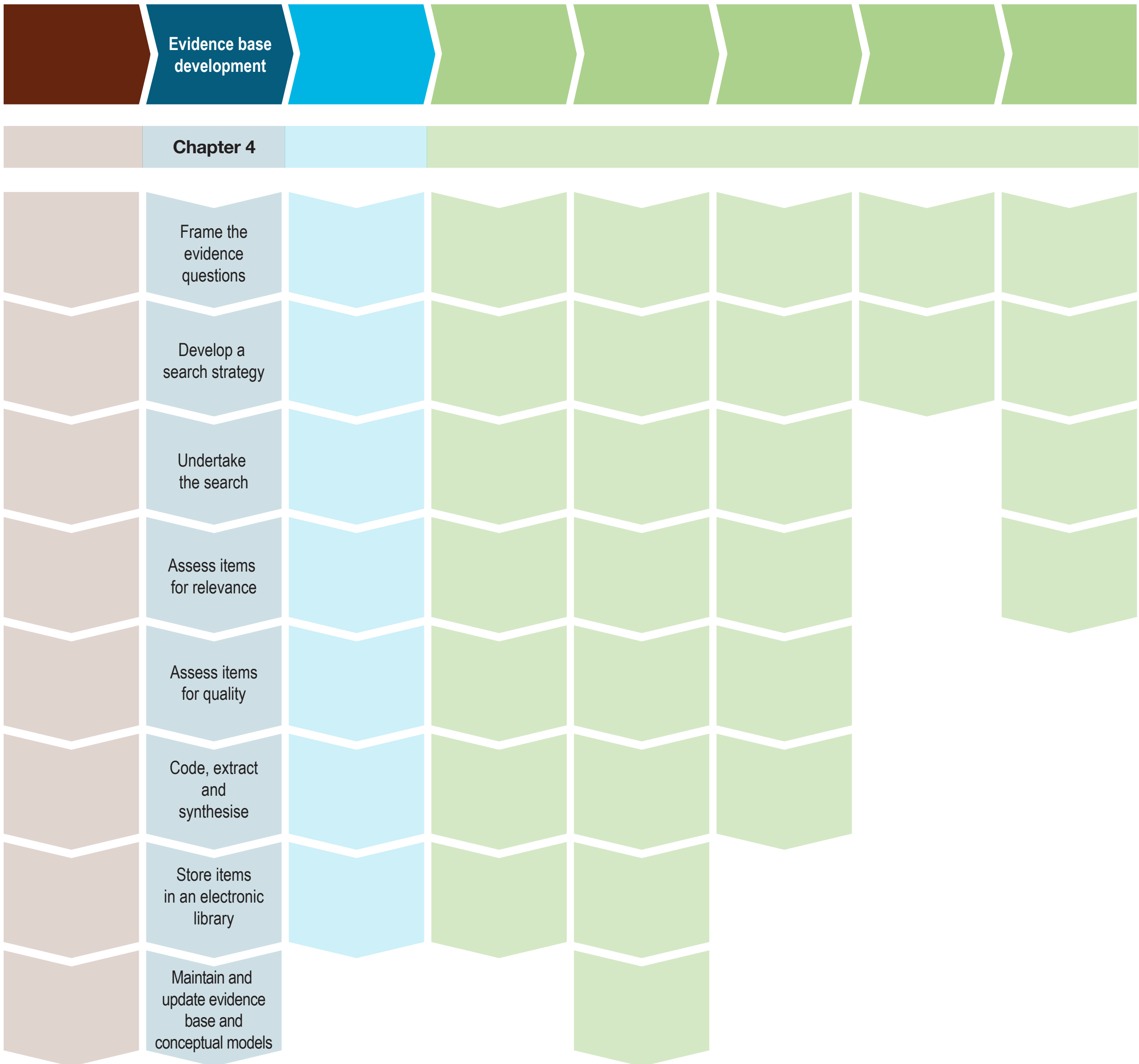
A preliminary workshop was convened to clarify the purpose, subject and scientific basis of the account. The following account participants were involved: the account producer, the account framer and those whose role was to develop an evidence base of science and conceptual models to investigate and if possible support the validity of the connectivity index as a way to measure ecosystem capacity.

The output of this workshop was the account subject conceptual model illustrated in Figure 11. In the process of drawing this model, the issues below were clarified and discussion continued until consensus was gained among the participants:

- The ecosystem asset was precisely defined.
- The purpose of the account was clarified in terms of accounting questions that could be answered using the proposed account e.g. 'Has there been a change in the capacity of the defined asset to deliver ecosystem services between time 1 and time 2?'
- The account subject was clarified—in this case landscape vegetation connectivity (LVC).
- The relationships between the purpose (to measure changes in ecosystem capacity), the account subject (LVC) and the measuring method (National Connectivity Index) were clarified.
- Key evidence base/conceptual modelling questions were defined to initiate the search for scientific evidence to underpin the account.

As well, the difference between accounting questions and evidence base/conceptual modelling questions was clarified among the participants.

These points of agreement about the conceptual structure of the proposed account were illustrated (Figure 11). In subsequent workshops associated with framing and producing the landscape vegetation connectivity account, this conceptual model would have helped to convey information about account purpose, subject, measuring methods and evidence base to other account participants.


Evidence base development
Chapter 4
Frame the evidence questions
Develop a search strategy
Undertake the search
Assess items for relevance
Assess items for quality
Code, extract and synthesise
Store items in an electronic library
Maintain and update evidence base and conceptual models

4 Developing an evidence base

While this section on developing an evidence base appears before the next section on developing collaborative conceptual models, the process of developing evidence-based conceptual models should be considered to be an iterative one, building the model and the evidence base in several stages as evidence is collated and assessed.

4.1 Principles in developing an evidence base

An evidence base aims to provide legitimacy and credibility to a conceptual framework that often describes a theory or hypothesis. For the purposes of environmental accounting the evidence base expands upon and provides legitimacy to the conceptual models that define the account subject, as shown in Figure 11 for example. A core principle of the use of evidence within environmental accounting is to ameliorate risk. This risk relates to how the environmental account is used to inform decision making. For example, the account may be used by government to inform policy or investment decisions. It is important therefore that the risk of making a poor decision due to little or untrustworthy evidence is reduced as best as possible.

Evidence can be used to increase the understanding of how something works, which is particularly important in complex systems such as those that operate in the social, environmental and economic domains of environmental accounting.

A better understanding of the cause and effect relationships linking system inputs, processes and outputs or outcomes provides greater confidence in the prediction of environmental responses.

Given the role of the evidence base in providing credibility and legitimacy to the account, it is important that a set of principles is used to develop and maintain the evidence base.

A better understanding of the cause and effect relationships linking system inputs, processes and outputs or outcomes provides greater confidence in the prediction of environmental responses. Increasing the predictability of environmental responses to human interventions reduces the risk of management failure. The role of evidence in mitigating the risks of environmental accounting is therefore critical.

An evidence base can help to shape environmental account conceptual models by revealing reliable information about the cause and effect relationships and the factors that influence these relationships.

Given the role of the evidence base in providing credibility and legitimacy to the account, it is important that a set of principles is used to develop and maintain the evidence base. The principles below are based on those that would be used in a systematic approach to developing an evidence base. The principles aim to reduce bias and uncertainty while increasing the confidence in the evidence.

Comprehensive representativeness. It is important to know that the evidence used to test the account subject framework and method is representative of the body of evidence available at the time of the enquiry. While the term 'representative' can have connotations of 'sampling' or 'balanced', in the case of evidence search and collation it is important to ensure that the evidence is also comprehensive within the resource constraints of developing the account. For this reason the evidence used should be referred to as having 'comprehensive representativeness'. A good *a priori* search strategy will ensure that the evidence meets this principle.

Transparency. Transparency is essential to ensure that the process can be reviewed for the purposes of learning or critique. Repeatability is essential to assist in necessary future modifications to the account or for developing new account subjects. As the process of developing an account framework can be conceptually challenging, thorough documentation can help communicate the process used. Transparency is also important for adaptive improvement.

Robustness. In order to gain credibility and legitimacy, an account evidence base must be developed with the appropriate rigor and scientific standards. Peer review, expert consensus and independent test such as a Kappa Analysis should be undertaken as a way of ensuring the process is rigorous.

Systematic process. To maintain comprehensive representativeness, transparency and robustness it is important that the process used:

- is well planned
- has a clearly pre-defined methodology
- conforms with highest standards possible (such as best available evidence) and
- is agreed upon and well-documented.

The following section provides a step by step process for developing an evidence base using the above principles.

4.2 Overview of steps

There are a number of sequential steps that can be used to develop an evidence base for environmental accounting. As discussed in Section 3.2.4, the evidence base will be used to underpin both the account subject conceptual model and any ancillary models created to clarify and communicate specific aspects of the account subject.

The account subject conceptual model clarifies the purpose of the account and provides a hypothesis of how this particular purpose is served by this account subject (e.g. how is a change in ecosystem capacity

Figure 15. Generalised steps in developing an evidence base for an environmental account.

reflected in a change in landscape vegetation connectivity?) Consequently, the evidence needs are initially driven by questions derived from the account subject conceptual model.

The account subject conceptual model describes a very broad set of relationships that constitute the hypothetical basis of the cause and effect relationships defining the account subject. The evidence gathering process in this case is one of 'mapping' the domain of available evidence using broad search terms resulting in evidence covering a wide range of topics (see Evidentiary 2015, for example). The evidence requirements for an ancillary model are much more subject specific, hence requiring a much more specific body of evidence.

The generalised approach for the development of an evidence base to support environmental account development is shown below. As illustrated, the process can be broken into three key stages—planning, search and storage, which include evidence relevance and quality assessment, and the last stage of evidence base maintenance.

> The account subject conceptual model clarifies the purpose of the account and provides a hypothesis of how this particular purpose is served by this account subject...
>
> ...the evidence needs are initially driven by questions derived from the account subject conceptual model.

4.3 Framing the evidence questions

The utility of evidence revealed from a systematic search to answer the candidate evidence question(s) is largely influenced by the specificity and structure of the question. Evidence is different to information or knowledge in that it addresses a specific question, hypothesis or assumption. In formulating a question that can be answered with evidence we try to develop an 'answerable question'.

An answerable question is one that can be directly answered by the available evidence. While this statement seems obvious, the subject matter, scale and specificity of the question all determine the utility and size of the body of evidence that can be used to answer the question. Ideally, the aim is to match the specificity of the question with what is known of the specific evidence in existing studies.

As previously discussed, there are two primary needs of evidence when developing an evidence base to support environmental accounts:

- to map the domain of evidence that underpins the relationships within the account subject conceptual model
- to validate the science within any ancillary conceptual models.

This step provides guidance on how first to frame the questions that underpin the account conceptual models.

4.3.1 Aim

The aim is to define clearly the questions that will be used to guide the evidence search. The initial questions are derived from the account subject conceptual model, which is anchored to the account purpose. Subsequent questions produce evidence that underpins more specific conceptual models, referred to as ancillary conceptual models. The process of deriving evidence bases and conceptual models is iterative and their purpose is to provide scientific validation for the account.

4.3.2 Actions involved

- Understand the topic area and relationships in the account subject conceptual model including any methodological questions about the account subject and how it is measured.
- Understand how and why the framing of a question is so important as the basis for the rest of the approach in developing the evidence base.
- Gain agreement from topic experts on the domain of the account subject conceptual model and for specific relationships within any ancillary models (this may be an iterative process).
- Develop broad questions that represent the relationships in the account subject model.
- Develop specific questions for key relationships in any ancillary models.

4.3.3 Key information

The following is a list of the key information requirements to complete this step:

- Understand the account subject and ancillary models associated with the account.
- Have as clear as possible, an understanding of the purpose of the proposed account.
- Identify the account participants, account users, topic experts and other audiences for the account and ensure they are engaged in developing the specific questions relating to the account subject.

4.3.4 Tips and tools

The following tips and tools will assist in completing this step:

- A well-defined and structured question also acts to provide scope, clarity and definition for the intended evidence. Agreement between the account participants about these aspects of the question is important. Guidance on structuring answerable questions can be found in the Collaboration for Environmental Evidence (CEE) Guidelines for developing Systematic Reviews (Collaboration for Environmental Evidence, 2013).
- Have to hand the *Environmental account framing workbook* (Bureau of Meteorology, 2013b) for the account and also the account subject conceptual model and any ancillary models already developed for the account.
- Topic expert input to review any candidate questions for the account subject is essential. Topic experts can assist with the development of key words or phrases and with the questions to assist the search.

4.3.5 Guiding questions

- What is our current understanding of the account subject including the account subject conceptual model and ancillary models?
- What science is essential to underpin the assumptions made in the account subject and ancillary conceptual models?
- What science do we need to link the account subject with the methods used to measure it?

4.3.6 Case study example

The account subject model shown in Figure 10 represents a hypothesis of the relationship between changes in landscape vegetation connectivity (LVC) and those of the ecosystem asset along with resultant changes in its capacity to deliver ecosystem services. This hypothesis is very broad in relation to the number and specificity of the relationships that it captures. The purpose of the account is also very broad, which is to see whether there has been any change in the capacity of an ecosystem to deliver ecosystem services to people, using landscape vegetation connectivity as an indicator of asset capacity. In order to understand the context of the relationships between LVC and asset capacity, evidence can be used to 'map' the domain of science behind these relationships. To do this we may develop some broad questions. For example:

- What is the concept of landscape vegetation connectivity and how is it referred to in the literature?
- Has LVC been directly studied?
- Is there a relationship between LVC and ecosystem operation (using the SEEA definition of ecosystem operation)?
- What is the relationship between LVC and ecosystem operation?
- How have studies measured the relationships of LVC and ecosystem operation?

How answerable are these questions using evidence from existing studies? Using the question 'What is the relationship between LVC and ecosystem operation?' a preliminary search for evidence would reveal that there are thousands of studies that have been conducted within this broad topic area, each study having being conducted at a specific scale, in a specific location or ecosystem, for a specific purpose, with a range of specific outcomes (Evidentiary, 2015).

It is highly unlikely that any one study would have captured the full range of all these attributes. A more answerable question for which we know evidence is likely to exist at a scale of specificity to match the question may be 'What impacts do vegetation corridors have on plant pollination?' This is now a question that will relate to a more defined body of evidence that can directly be used to answer this question. These more specific questions are the type that would be asked of any ancillary models used within the account while the broad questions would be used to map the domain of scientific evidence relating to the account subject.

4.4 Developing a search strategy

Conducting a systematic and comprehensive search is fundamental to building legitimacy and credibility of the evidence base and hence the account. The search should aim to minimise bias and deliver a robust body of evidence. A good search strategy will reduce the time and cost of developing the evidence base.

There are several elements of a good search strategy:

- a set of effective search terms structured into search strings
- a scoping search to assist in the development of search terms
- a list of search sources including databases, websites, search engines and organisations
- a set of criteria to filter for relevance (inclusion and exclusion criteria).

4.4.1 Aim

The aim of this step is to develop an *a priori* search strategy that will be used to guide the search for evidence, provide transparency of process, gain a shared agreement from the account stakeholders and build legitimacy of the evidence base. An outcome is to have a search strategy that will provide the best available evidence to answer the question(s) framed in Section 4.3.

4.4.2 Actions involved

- Use the questions developed in Section 4.3 to create a set of documented search terms using key words and related terms from the questions.

- Document the intended search sources—database, website, search engines and organisations.
- Document a set of inclusion and exclusion criteria to be used to filter the search results for relevance.
- Undertake a scoping search to refine the search terms and inform the inclusion and exclusion criteria.
- Seek input and agreement from account stakeholders.
- Refine the documented search strategy.

4.4.3 Key information

- questions developed in Section 4.3
- an agreed scope of search with account stakeholders including agreement of inclusion and exclusion criteria and search sources
- familiarity with Boolean operators to construct search phrases
- an understanding of 'best available evidence'—what it is and how it is derived
- suitable topic experts to review the strategy.

4.4.4 Tips and tools

- The development of search phrases is an iterative process. Refinement of the search terms will come from exploration of the literature and input from topic experts.
- Browse the web for resources to help understand and apply Boolean operators when developing search phrases. Information can be found at http://library.alliant.edu/screens/boolean.pdf
- Best available evidence can be thought of as a subset of all the available evidence that notionally exists. As evidence is searched, filtered for relevance and then for quality, the pool of evidence is refined towards the 'best available evidence'. The time and effort required increases with movement through this filtering step but in the process, confidence and certainty in the remaining evidence also increase (See Figure 16).
- Investigate the nature of on-line bibliographic databases such as JSTOR, Science Direct, Wiley Interscience, Scopus, Web of Science, DOAJ, TROVE, CSIRO Publishing, Springerlink and others. Each database contains collections of different journals (there is some crossover) focusing to a greater or lesser extent on the biophysical sciences, social sciences, engineering or other disciplines. It is good to be familiar with these databases so as to identify the most appropriate ones for different question types.
- When developing search phrases the practitioner will learn to balance sensitivity (getting all information of relevance) and specificity (the proportion of search returns that are relevant). Pick a topic and try increasing and decreasing the specificity of a search phrase by changing and adding search terms to it and look at the search results returned each time. If the search string becomes too specific relevant items will be lost, if it is too broad many items will appear that are not relevant.
- A scoping search will assist with refining the inclusion and exclusion criteria as the nature of the search results becomes clear.

4.4.5 Guiding questions

- What resources are available to conduct the search?
- What is the nature of the questions for which evidence is to be gathered? For example is the most appropriate evidence to answer the question of a quantitative or qualitative nature? Is acceptable evidence from methodological studies, from field case studies or both?
- What is the level of acceptable confidence required from the evidence, or how much uncertainty is acceptable?

- How broad or narrow will the scope of the search be when mapping the domain of evidence for the account subject conceptual model?
- What are the best search sources for the nature of the questions?
- Who are suitable topic experts to peer review the search?

4.4.6 Case study example

Consider the key question derived from the account subject conceptual model shown in Figure 11, 'What can changes in landscape vegetation connectivity tell us about changes in the ecosystem asset operation?'

First, the account purpose and subject can be used to consider what may be included and excluded as relevant evidence. In this case it may be considered important to include both pristine and modified ecosystem, ecosystems from anywhere in the world and landscape or vegetation connectivity at any scale. It may also be decided to select studies in any language from any date.

Similarly for exclusion criteria, in accordance with the account purpose marine and underwater ecosystems can be excluded as well as single species studies from overseas.

In developing search terms to map the domain of evidence relating to this question it is necessary to 'unpack' and provide synonymous terms for the two key phrases of the question—'landscape vegetation connectivity' and 'ecosystem asset operation' as follows:

- Landscape vegetation connectivity—landscape vegetation connectivity, landscape changes, vegetation connectivity, landscape connectivity, patch connectivity, ecological connectivity, functional connectivity, structural connectivity, vegetation clearing, revegetation, landscape fragmentation, landscape structure, corridor, ecological networks, connectivity corridor, vegetation corridor, riparian vegetation, riparian corridor, forest connectivity, forest fragmentation, land cover.

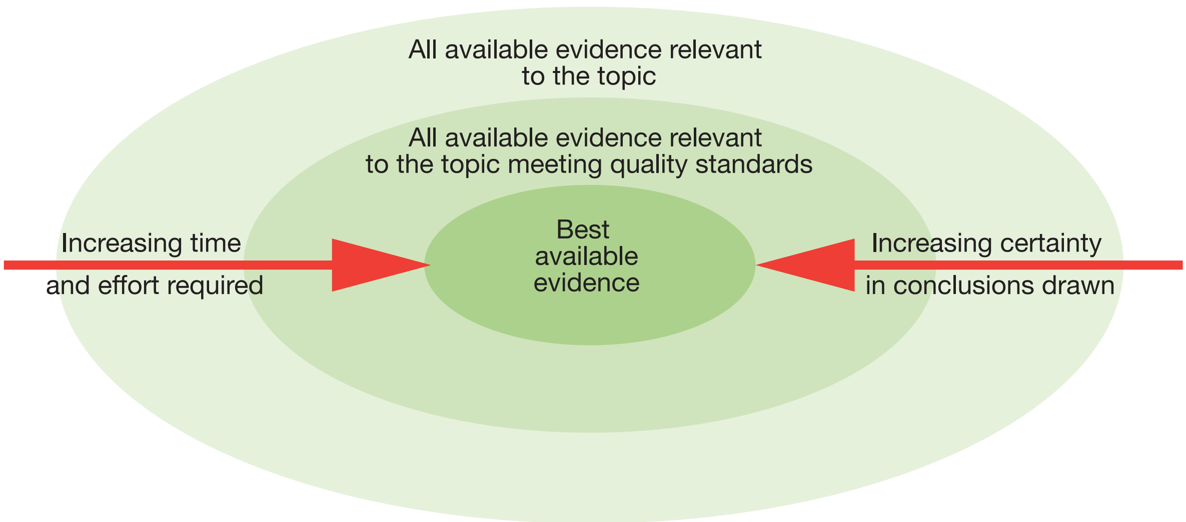


Figure 16. The aim of the evidence search is to discover and collate the best available evidence

- Ecosystem asset operation—The SEEA–EEA definition of ecosystem asset operation can be used as a guide here. The definition describes ecosystem operation relating to i) its structure, ii) its composition, iii) its processes and iv) its functions.

Undertaking a scoping search using a combination of these terms in search phrases would reveal that there are other terms that are commonly used for studies within this domain such as 'biodiversity' and 'habitat'. These terms are functionally more useful given the account purpose and the nature of existing evidence revealed by the scoping search. For the purposes of the exercise it is also assumed that habitat relates to the vegetative component only.

The search strategy may therefore be refined to include these terms and other synonymous terms in the search to provide the following additional search terms:

- Vegetation habitat elements: habitat, habitat connectivity, habitat network, fragmented habitat, habitat loss, habitat patch, habitat extent, habitat condition, habitat quality, wildlife habitat, habitat cover, habitat configuration.
- Biodiversity elements: biodiversity, species diversity, genetic diversity, genetic variation, variety, floral diversity, faunal diversity, biological diversity, ecosystem diversity, wildlife.

From these search terms, the following search string could be constructed:

> ('vegetation connectivity' OR 'landscape changes' OR 'landscape connectivity' OR 'structural connectivity' OR 'functional connectivity' OR 'vegetation clearing' OR 'landscape fragment*' OR 'corridor*' OR 'land cover') AND (habitat* OR 'habitat connectivity' OR 'habitat loss' OR 'habitat patch' OR 'habitat quality' OR 'habitat configuration') AND (biodiversity OR 'species diversity' OR 'flora* diversity' OR 'fauna* diversity' OR 'biological diversity' OR wildlife OR 'genetic diversity')

Testing would be undertaken using the search string to assess the relevance and volume of search returns. A modified search string may be developed based on this assessment. A more streamlined search string may be developed using more encompassing search terms. For example the search term 'connect*' may be used to replace 'vegetation connectivity', 'landscape connectivity', 'structural connectivity' and 'functional connectivity'. This term will also pick up words including 'connection', 'connected' and 'connecting'. There will however be many more non-relevant search returns. This is where the operator must seek balance between specificity and sensitivity.

4.5 Undertaking the search

The literature search should be undertaken following the search strategy developed. Undertaking a systematic and comprehensive search using the search strategy is one element that distinguishes a systematic review approach to searching from an ordinary literature review approach.

The scoping search provides familiarity with the literature and can give some clues as to the expected volume of literature that will be relevant to the question. There are no rules for how many search strings or search sources may be used but it is important to capture the question comprehensively.

The literature search often involves six sources:

- searching online literature databases and catalogues

- searching websites of organisations and professional networks
- searching the world-wide web
- searching bibliographies of key articles/reviews
- contacting key individuals who work in the area
- citation searches for key papers / included papers.

The resources available for the search will influence how many of these sources are used. In considering this, however, it is important to note that publication bias can be reduced by including searches of grey literature (unpublished studies).

Conducting searches is one of the most time consuming tasks of developing the evidence base but is also one of the most important. While the search strategy will assist the task, there is much 'on the job learning' for each topic.

4.5.1 Aim

To undertake a comprehensively representative search that will provide the best available evidence in the most effective and efficient manner. In doing so the search method and results will be well documented to provide transparency and credibility.

4.5.2 Actions involved

- Develop a search results statistics table to capture all the search results.
- Undertake the search with the pre-defined search strings using the selected and agreed search sources.
- Record all search results in the search results statistics table.

4.5.3 Key information

- search strings developed in Section 4.4
- familiarisation with the range of bibliographic databases available
- familiarisation with Boolean operators and other search protocols such as nesting, truncation, wild characters and proximity operators
- search tips and user notes available on most bibliographic database search sites
- a search results table showing the statistics of the results your search.

4.5.4 Tips and tools

- Searching should be done in a systematic manner to ensure that each search string is used for each of the selected sources. A search results table such as this hypothetical table shown on the following page can greatly assist this process.

- Get to know and use helpful search protocols such as those for:

  - Nesting: Different search engines execute your commands in different orders. One way of standardising this is to use round brackets to control the search sequence. For example the search term landscape AND (function OR analysis OR metrics) will find documents that contain one of the words in brackets (i.e. function or analysis or metrics) but only if they also contain the word 'landscape'.

  - Truncation: Most databases enable you to truncate the end of a word using an asterisk to replace the remaining letters. For example salin* will find the words saline, salinity, salinisation

  - Wild characters: A character such as a question mark can be used to replace a single letter in the middle of a word, which is useful for spelling variations. For example salini?ation will retrieve salinization and salinisation.

  - Proximity operators: These can be used to locate terms that are close to one another. One such proximity operator is w/#, which can be used to find two words that are # number of words apart. For example landscape w/3 function will find items where landscape and function occur within three words of one another

- If the number of search returns is large (> 500) a cut-off point can be used. Some pointers to assist in determining the cut-off point are:
  - If there are only a few relevant results in the first 100, (particularly near the beginning), then it may be unnecessary to search beyond 100 or 150 results.
  - If there are quite a number of relevant hits in the first 100–200 search returns but after that there is substantial tailing off of relevant results to just 1 or 2 over the next 50–100 hits then that is justification for ending the search.
  - Sometimes more than 300 items need to be searched per search phrase result. In this case it may be worth considering refining the search phrase used.
- Relevance of evidence can be determined using the inclusion and exclusion criteria. It is good to tend towards inclusion rather exclusion in cases of uncertainty. Note that the first stage of relevance filtering is based on the study title only.
- For more complex search strings try using the 'Advanced Search' tab that is usually present.
- Explore and become familiar with the 'Search Tips' assistance usually provided under the 'Advanced Search' tab on most databases.

4.5.5 Guiding questions

- How widely should we search given the resources available for conducting the search?
- What bibliographic databases are most appropriate for the question? How widely should other sources such as individual organisations be searched?
- What is the nature of the questions being asked—should they ideally be answered with quantitative or qualitative information?
- How will the evidence (to answer the questions/assumptions) be used? Will it impact on the account outcomes? If so how?
- What level of confidence in the evidence is required?

Table 2 An example of an entry in a search results table.

Search phrases used	Science Direct	TROVE	CSIRO Publishing	Web of Science	Google Scholar
('vegetation connectivity' OR 'landscape changes' OR 'landscape connectivity' OR 'vegetation clearing' OR 'landscape fragment*' OR corridor* OR 'land cover') AND (('habitat*) OR (biodiversity OR divers* OR wildlife))	85/1193 of the first 250	53/3153 of the first 250 (4) (from journals, articles and datasets)	13/58 of total 58	103/468,329 (28) of first 250	84/17,800 (15) of first 250

Interpretation note: The recording made for TROVE provides the following information: The search returned 3,153 results of which the 53 items were selected from the first 250 results. From the first 250 results 4 items had already been selected in previous searches. The TROVE results included those from journals, articles and datasets.

4.6 Filtering search returns for relevance

Filtering of evidence items from the search results is an important step to ensure that time is not wasted examining irrelevant studies in too much detail. The relevance is often assessed with regards to how transferable the study findings are to the question of interest (the external validity of the study).

Filtering of evidence items for relevance will occur at several stages in developing the evidence base. The first filter will occur when the inclusion and exclusion criteria are applied to the title and abstract of search returns before accepting the items to the evidence library. Finally evidence items will be culled based on reading the full text. At the stage of reading the full text, evidence items will be filtered based on both relevance and quality assessment. Items not relevant or of poor quality will be removed from the evidence library. It is good practice, in keeping with the principle of transparency, to record the reason for excluding evidence items from the library at the full text assessment stage.

4.6.1 Aim

To filter evidence items to ensure that the remaining items are relevant to the question and to minimise time wasted examining irrelevant material.

4.6.2 Actions involved

- Assess search return items based on title and abstract for relevance using the inclusion and exclusion criteria listed in the search strategy.

- Add relevant items to the evidence library (Section 4.9 deals with developing the library structure). When structuring the library, keep separate folders for items assessed on title/abstract and for those items assessed on full text.

- Assess the full text of library items for relevance based on the inclusion and exclusion criteria listed in the search strategy. The relevance of the study design to the question may be considered during the process of relevance assessment or during quality appraisal. This is discussed further in Section 4.7.

- Keep a record of reasons for exclusion based on relevance at the full text assessment stage.

- Do a Kappa Analysis to ensure there is consistency among those filtering the search items.

4.6.3 Key information

- inclusion and exclusion criteria listed in the search strategy

- the shell of an electronic evidence base for storing items considered relevant at both the title/abstract assessment and full text assessment stages (The structure of this shell is discussed in Section 4.9.)

- the account purpose—always important as a guide.

4.6.4 Tips and tools

- The greater the specificity of the question or assumption and the specificity of the inclusion and exclusion criteria, the easier the relevance filtering becomes. For example when filtering evidence for relevance to the broad question 'What can changes in landscape vegetation connectivity tell us about changes in the ecosystem asset operation?', many study variables need to be considered and a decision made as to the relevance of the study. On the other hand a more specific question such as 'How does reduced patch accessibility influence changes in genetic flow?' will have fewer variables that can be better defined for considering the relevance of the studies to the question.

- There are no general rules or standards regarding the relevance of study design to a question. What is important is whether the study design is 'fit for purpose' to meet the needs of the question or assumption.

- As a general rule, if you are unsure about the relevance of a study based on examination of the title and abstract then retain the study in the library for further full text examination.

- A good practice is to use two reviewers to undertake the relevance filtering process. In doing this, a test for consistency between the two reviewers can be undertaken. Both reviewers examine a random sub-set of studies and use the selection criteria to filter for relevance. The amount of agreement between the two reviews is statistically measured in a test called a Kappa Analysis. More information can be found at: http://www1.cs.columbia.edu/~julia/courses/CS6998/Interrater_agreement.Kappa_statistic.pdf and http://www.statistics.com/glossary&term_id=635

4.6.5 Guiding questions

- Are the inclusion and exclusion criteria with the search strategy adequate?

- What information can be gained from each study to help assess its relevance in answering the conceptual model questions?

- What is the purpose of the account and hence what is relevant and what is not? It is important to continually 'step out of the space you are in' to consider this question!

- Is it possible to unpack or further specify the account subject into a set of more specific cause and effect relationships that can be used to define more specific searches?

- Is there consistency among all the reviewers assessing the evidence for relevance?

- How were inconsistencies regarding assessment of search return relevance between reviewers resolved?

4.6.6 Case study example

Table 3 shows example studies excluded at the title/abstract stage from results of a search conducted using the following exclusion criteria for the search string: ('vegetation connectivity' OR 'landscape changes' OR 'landscape connectivity' OR 'vegetation clearing' OR 'landscape fragment*' OR corridor* OR 'land cover') AND (habitat* OR biodiversity OR divers* OR wildlife).

- marine and underwater ecosystems

- single species studies from overseas

- papers of theories or methods with no case study data.

Table 3 Example of a table to record reasons for excluding studies from an evidence base.

Search result study title	Reason for exclusion
A landscape perspective of the stream corridor invasion and habitat characteristics of an exotic (*Dioscorea oppositifolia*) in a pristine watershed in Illinois.	The study relates to a single species from overseas.
Conefor Sensinode 2.2: a software package for quantifying the importance of habitat patches for landscape connectivity	The paper reports on a method only.
Habitat quality in a hostile river corridor	The study relates to fish movement within an aquatic environment.

4.7 Appraising the quality of evidence items

Appraisal of evidence quality is at the core of using systematic review principles to develop an evidence base. Quality appraisal primarily aims to minimise potential error and bias in the evidence used. The ability of the evidence base to provide legitimacy and credibility to the account is largely determined by the quality of the search and the evidence used. It is important to remember that not all published research is good quality and not all good quality research is published in peer reviewed journals. The process of systematic search and quality appraisal is therefore imperative to attaining the best available evidence.

Quality appraisal of evidence, often called critical appraisal, can be described as 'the process of carefully and systematically examining research to judge its trustworthiness and its value and relevance in a particular context' (Burls, 2009).

It should be noted that evidence quality appraisal in the environmental sector is a new and emerging area of research. There are many different approaches used in other sectors such as health, education and justice, all equally valid for their intended purpose. While it is beyond the scope of this document to cover all approaches, some key principles are introduced to the reader, who is encouraged to seek further information about different approaches to quality appraisal that are fit for the desired purpose. Several references are provided in the Tips and tools section.

In the health sector, where critical appraisal has its foundations, an evidence quality pyramid has been developed based on experimental design where the highest quality evidence at the top of the pyramid is a double blind randomised control trial and down the bottom the poorest quality evidence is from expert opinion. No such convenience exists for the quality appraisal of evidence within the environmental sector! There are several reasons for this including a wider range of posed questions relevant to evidence synthesis, less emphasis on experimental design as the determining factor of quality and the need for lower standards of evidence admissibility.

Generally, quality appraisal applies to three aspects of studies—1) the process used to draw the conclusions 2) the findings themselves and 3) the applicability of the study findings to your question. Quality appraisal can be a challenging task that requires skills in appraising the significance of potential sources of bias and error in each of these aspects of environmental studies. Potential sources of bias include publication bias, selection bias, performance bias, measurement or detection bias and attrition bias. These biases influence the internal validity of the study.

Traditionally the environmental sector has used peer review and/or conflict of interest as surrogates to determine confidence in published environmental studies. In many instances these factors are not reliable and, in drawing conclusions, a range of other aspects of environmental studies must be considered in relation to the absolute and relative importance of sources of bias and error.

Quality appraisal of evidence should occur at two levels—1) for individual items of evidence and 2) for the whole body of evidence. Evidence quality appraisal of individual items will directly influence the confidence, credibility and legitimacy of the final body of evidence maintained in the evidence base. The quality of the overall body of evidence can be assessed by examining aspects such as the consistency of evidence items within the body.

While there are some aspects of quality appraisal that can be assessed for absolute quality such as fundamental flaws in the execution of experimental design, most aspects of quality appraisal are about the relative quality of the study to a) the defining question and b) other items of evidence. Inherent in this is further relevance assessment, appraising the relevance and applicability of the study to the question. Importantly this includes an assessment of the applicability of the study design to the question of interest.

The more specific a question is, the easier it is to assess the quality of an evidence item in relation to that question. It cannot be emphasised enough the importance of asking 'what makes the most fit for purpose evidence that can be used to answer the question of concern?'

An important part of undertaking quality appraisal is also becoming familiar with the language used in the literature. Terms such as 'quality', 'size', 'consistency' and 'strength' of evidence are often used interchangeably as are the terms confidence, reliability and certainty used to describe the utility of a body of evidence.

Finally it is important to consider how quality appraisal is applied to the development of the evidence base and in particular to any conclusions drawn from the evidence. There are several ways in which quality appraisal can be applied:

- to understand the quality of a study to assist in forming judgements about the overall confidence in the body of evidence
- to weigh studies so that different levels of confidence can be placed on studies
- to exclude low quality studies using absolute measures such as thresholds of quality or quality relative to other studies so as to maintain a body of evidence with a desired minimum standard
- to use within interpretation and discussion of conclusions drawn from the evidence.

4.7.1 Aim

The aim of quality appraisal is to develop a fit-for-purpose, robust and credible body of best available evidence to underpin the science of the account conceptual models. This body of evidence should be constituted of individual evidence items that are relevant, fit for purpose, transparent, robust and credible.

4.7.2 Actions involved

- Categorise each study by describing the a) type of study, b) the design and c) the method. Categorisation of study design is important, as different designs are more or less appropriate in answering different questions of concern. The skill of understanding the appropriateness of different study designs as 'fit for purpose' for answering different questions is one that is developed through experience.
- Assess the following aspects of an individual study using the Department for International Development approach (Department for International Development, 2013).
  - Transparency: High quality studies should reveal how the study has been designed, the methods used for data collection and analysis so that the study can be reproduced. It is also important whether the author has declared any study limitations or inconsistencies in results. In addition the independence of the study or potential conflicts of interest such as funding sources should be made transparent.
  - Reliability: The reliability refers to the accuracy and consistency of the measurement and analysis approach of the study. High reliability will result in consistent results when the study is repeated. Are there weaknesses in the measurement or analysis technique that may undermine the confidence in the results?

- Validity: There are several areas of validity that are important to consider. Firstly the validity of measurements that have been used in the study. Is the study measure or indictor suited to the study concept or question? For example is using the indicator of distance of movement suitable for a study aimed at measuring genetic flow? Secondly the integrity of the technique that the study uses to explore causal relationships is important including assessing if there are any confounding factors that are obscuring the result. Finally the external validity or transferability of the study findings to the question of concern is important.

- Appropriateness: The appropriateness of the study design to the question of interest should be assessed. Generally experimental research designs are more appropriate for answering questions about the effectiveness or magnitude of cause and effect relationships, whereas non-experimental designs (observational studies) are more appropriate to questions aimed at understanding causal mechanisms or the contextual factors that influence outcomes. For example, quality appraisal of evidence for the question 'Does reduced patch accessibility influence changes in genetic flow?' is considered. Higher quality studies in this instance would have statistically based conclusions and an experimental design that included a control or comparison group. Lower quality studies would include those of an observational type.

Another aspect for consideration is the appropriateness of any statistical methods used in analysing the results. Has a valid statistical method been used to analyse the results given the study design?

- Document the results in a quality appraisal table that records the assessment of each of the above factors. Making this assessment transparent is important for credibility.

- Assess the body of evidence. There are several characteristics of the body of evidence that are useful to assess:

  - Quality of the individual studies: Based on the quality appraisal undertaken of each individual item, an overall assessment can be made of the quality of the body of evidence. This assessment would describe the proportion of studies that are high quality, moderate or low quality.

  - The amount of evidence: While by itself the amount of evidence is generally not a good indicator, combined with the quality of the body of evidence it is important. Findings can be strengthened by corroboration by other results.

  - The consistency of the evidence: The amount of agreement of study findings within the body of evidence is important. Where there is not agreement, the reason for differences should be resolved as well as possible.

- Determine how the results of quality assessment will be applied to the use of the account evidence base. Evidence quality appraisal can be used to weight studies, exclude studies, apply thresholds of quality or to use within interpretation and discussion.

4.7.3 Key information

- understanding the nature of the relevant question regarding the appropriateness of evidence to answer the question

- understanding how to classify different study designs in relation to the study type, design and method

- understanding the key characteristics of studies that can be appraised for quality
- understanding how bias and error can influence the confidence in a body of evidence.

4.7.4 Tips and tools

- It is important to step outside the detail of the technical process and ask the question 'How can the results of this study be used to answer the question of concern?' In doing so it may well be that even if the study design has flaws, there are aspects of the study that are useful. These may be for example a greater understanding of contextual factors influencing causality.
- An example classification of study can be found at: http://www.teachepi.org/documents/courses/Classification%20Design.pdf. It is the characteristics of each study design that is important understand.
- Study characteristics that are important to appraise for quality are described at https://www.gov.uk/government/publications/how-to-note-assessing-the-strength-of-evidence
- An explanation of the different types of bias found in environmental studies is important to understand and can be found in Collaboration for Environmental Evidence, 2013, p 46.
- There are several comprehensive overviews for conducting critical appraisal (Gossall and Gossall, 2009; Gough, 2007).
- Gough et al., 2012, chapter 8, provides an excellent overview of quality and relevance appraisal for application outside the health sector.

4.7.5 Guiding questions

- Will the appraisal of the quality of evidence make a difference to the legitimacy and credibility of the account evidence base?
- Will using the best available evidence reduce the decision risks informed by the account evidence base?
- What are the types of bias and error found in studies?
- What are the key quality characteristics of individual studies that need to be considered?
- How has the study author reached their conclusions? Are there flaws in the process used to reach these conclusions?
- What are the characteristics of the body of evidence that need to be considered?

4.8 Coding, extracting and synthesising the evidence

After filtering for relevance and assessing for quality, the specific evidence within each item (key relevant text) needs to be extracted, stored in a standard format with the other evidence and then synthesised.

While it is beyond the scope of this document to provide instructions on different approaches to qualitative and quantitative synthesis, several useful resources are provided to assist in this task. The evidence extracted and the synthesis approach will be dependent on the question type. As discussed in Section 4.7 above, the nature of the evidence base question will influence the most appropriate evidence. For example the question 'Does reduced patch accessibility influence changes in genetic flow?' will ideally require quantitative data to answer most effectively. Synthesis of this data would most appropriately be undertaken using meta-analysis.

Other questions however that explore causal mechanisms may use qualitative data that describes the existence of causality and the contextual factors that influence this causality.

Conceptual models can also be used as a frame for the synthesis of evidence whereby evidence is synthesised for each cause and effect relationship in the model. Models can be used as a frame for organising and structuring evidence folders in within the evidence base. Using a conceptual model to frame the synthesis in this manner enables the strengths and weaknesses in evidence for each relationship to be explored. It also enables the factors that influence the magnitude and direction of each relationship (called effect modifiers) to be surfaced from the evidence.

> Models can be used as a frame for organising and structuring evidence folders in within the evidence base.

A conceptual model that represents a set of evidence-based cause and effect relationships for the account subject may be developed iteratively as the evidence is assessed for relevance and quality. As the evidence is assessed a hypothesis represented by a conceptual model such as that shown in Figure 17 below can be developed.

Figure 17 is a hypothetical example of the cause and effect relationships linking changes in LVC (spatial pattern and total available resources) with changes in species diversity. The model shows a set of numbered cause and effect relationships drawn from the evidence assessed. These numbered cause and effect relationships can be used to structure the evidence base as described in section 4.9 and provide a useful basis for synthesis.

More detailed ancillary models such as that shown in Figure 18 below can also be developed.

Ancillary models may be developed in response to a more detailed account question or as a method of further elaborating the science behind the account subject. While a model such as that shown in Figure 18 can be developed as a hypothesis for a more detailed question 'within' the existing account subject conceptual model, the ancillary model should be developed and validated through new evidence searches rather than trying to 'mine' the existing evidence base.

The folder hierarchy in the evidence base can be expanded to accommodate the more detailed cause and effect relationships in the ancillary model. Using this process the evidence base can be expanded in accordance with the needs of questions asked of the account subject.

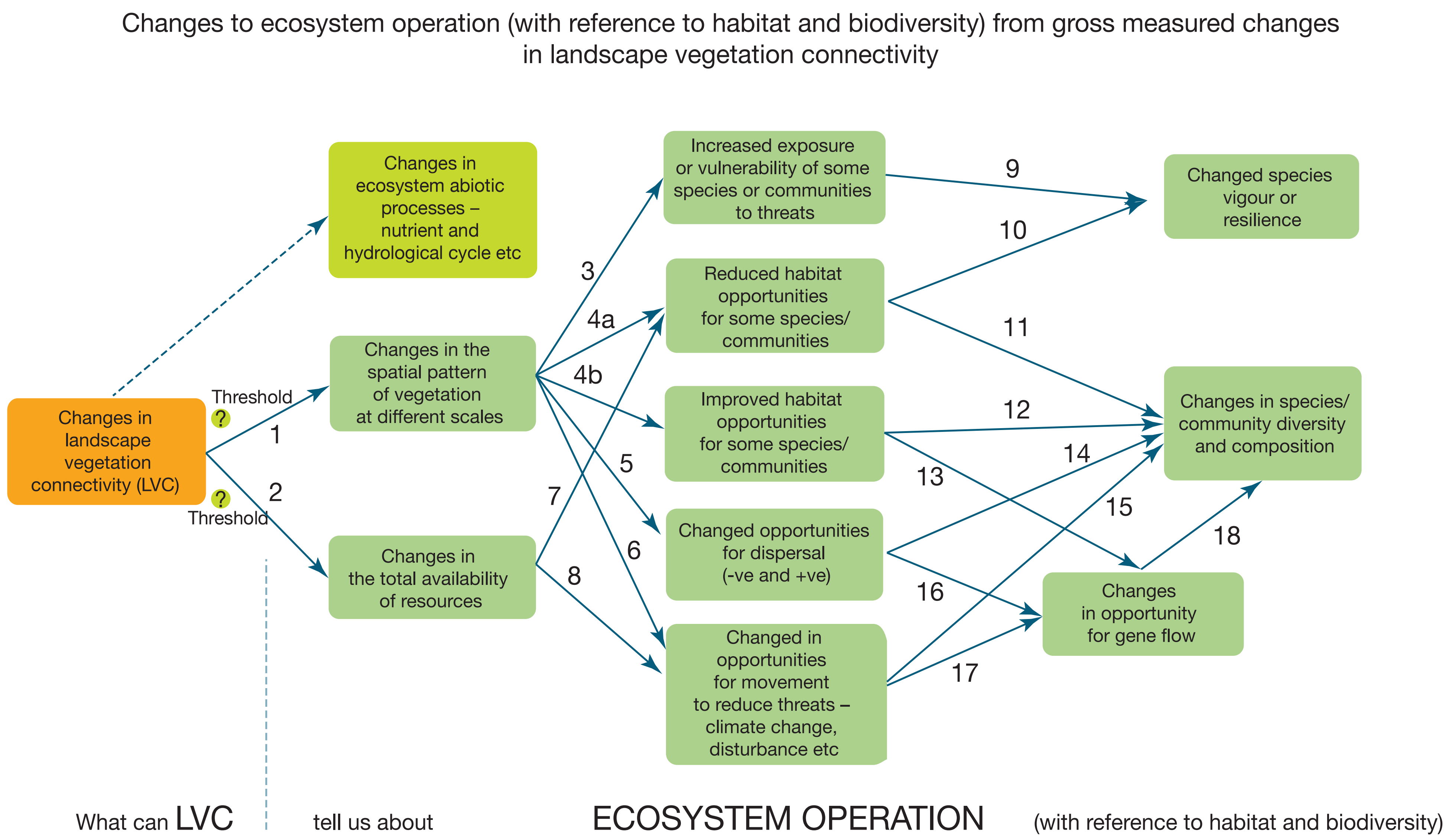


Figure 17. A set of evidence-based cause and effect relationships forming a hypothesis about the science behind the account subject question.

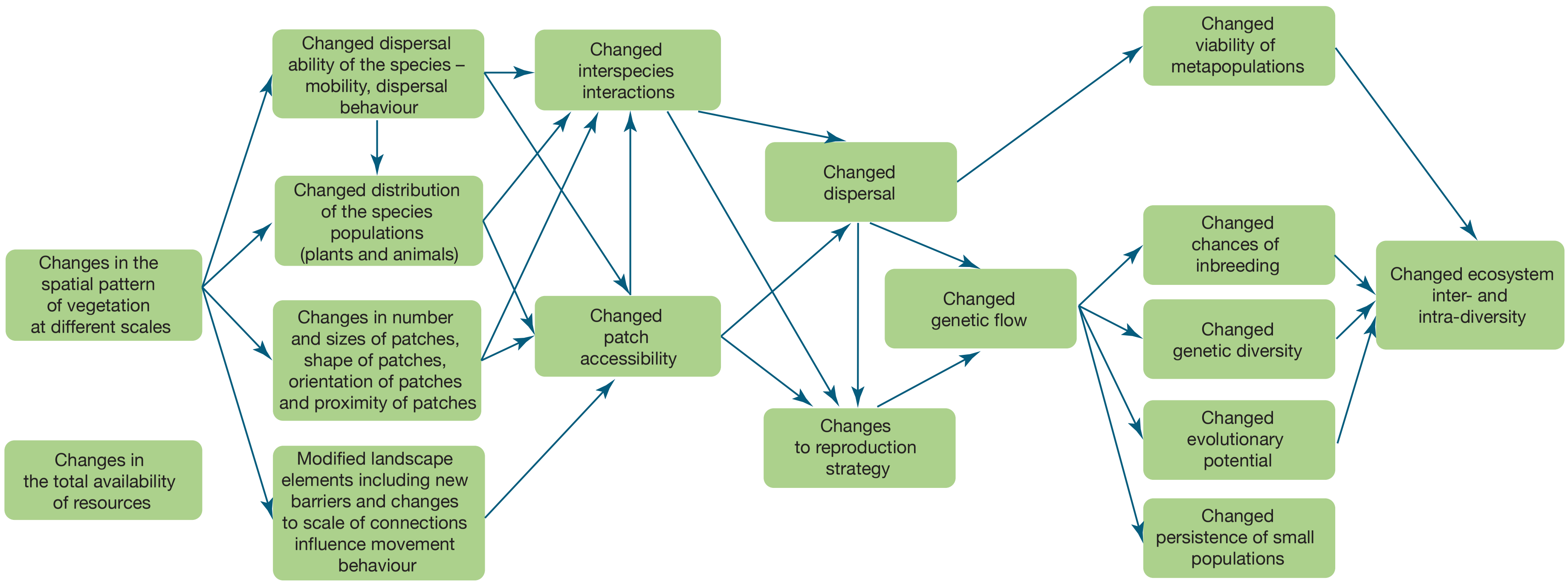


Figure 18. A hypothetical ancillary model developed showing the hypothesis about relationships between changes to LVC resulting in changes in dispersal and resultant influences.

4.8.1 Aim

To document the key evidence extracts in a standardised, transparent and repeatable manner to enable synthesis to occur.

4.8.2 Actions involved

- Develop a data extraction spreadsheet that identifies the specific data needs to answer the question.
- Gain account stakeholder agreement on the data extraction spreadsheet to ensure that no key information needed to answer the question is missing.
- Code or mark the exact information for extraction from the evidence item.
- Extract the evidence into a data extraction spreadsheet.
- Undertake synthesis of the evidence contained in the data extraction spreadsheet. This synthesis may be undertaken using a conceptual model as a frame.

4.8.3 Key Information

- The account purpose is critical—what goes into the data extraction spreadsheet will be the final information used for providing credibility and legitimacy for the account.
- Cover all evidence items that have been assessed for relevance and quality and are stored in the evidence base.
- The type of synthesis required to most adequately answer the question is determined.

4.8.4 Tips and tools

- Keep the data extraction spreadsheet to the minimum amount of information required to answer the question or assumption.
- An excellent summary of conducting narrative synthesis can be found in Popay et al., 2006.
- An overview of issues concerned with synthesis of evidence from diverse sources can be found in the National Institute for Health and Clinical Excellence, 2006.
- There are a number of software packages that enable coding of information within documents. Some of this software allows the user to code and tag relevant text and then to group all items with the same tag. This is very useful for qualitative synthesis in particular if evidence is being grouped on a thematic basis.

4.8.5 Guiding questions

- What information and how much is needed to answer the question?
- What is the nature of the question? Should the question most appropriately be answered using qualitative evidence, quantitative evidence or both?
- What approach to synthesis is most appropriate for the question?

4.8.6 Case study example

Table 4 shows the key information extracted as part of mapping the domain of evidence for the question 'What can changes in landscape vegetation connectivity tell us about changes in the ecosystem asset operation?' The spreadsheet is organised so that the key fields of data extraction are shown against each study. In this case evidence from each study has been extracted regarding the ecosystem relationships measured, the key findings from the study, the scale at which the study was made and any direct evidence of the relationships between LVC and ecosystem operation.

Table 4. An example simple data extraction spreadsheet

	A	C	D	E	F	H	I	J
1	**Context**		**Findings**					
2	**Reference**	**andscape locatior**	**What relationships are measured?**		**Ecosystem operation scale**	**What does LVC allow us to know about ecosystem operation?**	**Study Findings**	
58	Lunt, I.D., Winsemius, L.M., McDonald, S.P., Morgan, J.W., Dehaan, R.L., 2010.	Victoria	We aimed to estimate changes in woody vegetation cover within lowland grassy woodland and coastal ecosystems in Victoria from 1989 to 2005 to determine whether published reports of recent encroachment are representative of broad-scale ecosystem changes.	Changes in woody vegetation cover from 1989 to 2005 were assessed based on state-wide vegetation maps and Landsat analyses of woody vegetation cover conducted by the Australian Greenhouse Office's National Carbon Accounting System. The results show changes in woody cover within mapped patches of native vegetation, rather than changes in the extent of woody vegetation resulting from clearing and revegetation.	All lowland grassy woodland and coastal ecosystems (c. 6.11 x 105 ha) in Victoria, Australia. Four major ecosystems were analysed: Plains woodlands, Herb-rich woodlands, Riverine woodlands and Coastal vegetation.	At the scale of observation, woody vegetation cover increased in all lowland woodland and coastal ecosystems over the 16-year period. Thus, published examples of encroachment in selected coastal and woodland patches do appear to reflect widespread increases in woody vegetation cover in these ecosystems. This densification appears to be associated with changes in land management rather than with post-fire vegetation recovery and is likely to be ongoing and long-lasting, with substantial implications for biodiversity conservation and ecosystem services.	increased by 18,730 ha from 1989 to 2005. Woody cover within Riverine woodlands and within Plains woodlands each increased by > 7000 ha. At the patch scale, the mean percentage cover of woody vegetation in each polygon increased by > 5% in all four ecosystems: Riverine woodlands (+9.2% on average), Herb-rich woodlands (+7.6%), Plains woodlands (+6.7%) and Coastal vegetation (+5.9%). Regression models relating degree of encroachment to geographic and climatic variables were extremely weak (r2 £ 0.026), indicating that most variation occurred at local scales rather than across broad geographic gradients.	
59	Magrach, A., Larrinaga, A.R., Santamaria, L., 2012.		The connectivity of remnant patches of habitat may affect the persistence of species in fragmented landscapes. We evaluated the effects of the structural connectivity of forest patches (i.e., distance between patches) and matrix class (land-cover type) on the functional connectivity of 3 bird species (the White-crested Elaenia [Elaenia albiceps], the Green-backed Firecrown Hummingbird	We measured functional connectivity as the rate at which each species crossed from one patch to another. We also evaluated whether greater functional connectivity translated into greater ecological connectivity (dispersal of fruit and pollen) by comparing among forest patches fruit set of a plant pollinated by hummingbirds and abundance of seedlings and adults of 2 plants with bird- and wind-dispersed seeds.		Interpatch distance and matrix class affect animal movement in fragmented landscapes and may have a cascading effect on the distribution of some animal-dispersed species. On the basis of our results, we believe effort should be invested in optimizing patch configuration and modifying the matrix so as to mitigate the effects of patch isolation in fragmented landscapes.	Interpatch distance was strongly associated with functional connectivity, but its effect was not independent of matrix class. For one of the bird-dispersed plants, greater functional connectivity for White-crested Elaenias and Austral Thrushes (both frugivores) was associated with higher densities of this plant. The lack of a similar association for the wind-dispersed species suggests this effect is linked to the dispersal vector. The abundance of the hummingbird-pollinated species was not related to the presence of hummingbirds.	

4.9 Building and storing the evidence in an electronic library

Although this step appears after extraction and synthesis, the electronic evidence library will be developed iteratively as the account subject conceptual model is developed. Broad folder headings can be developed with further detailed sub-folders developed later as more specific ancillary models are developed.

The evidence library is the place where the best available evidence can be stored and used to demonstrate account credibility and legitimacy. It also provides a tangible tool to demonstrate continuous improvement of the evidence base over time as new evidence becomes available. Iterations of the library as reflected in the maintenance of the evidence base described in Section 4.10 below can be stored and demonstrated.

An evidence library should be a transparent, dynamic and interactive part of the evidence base and can be shared with account users or other interested parties.

4.9.1 Aim

To develop structured electronic library of evidence containing the best available evidence that directly meets the needs of the account purpose.

4.9.2 Actions involved

- Structure folders in the evidence library using the key cause and effect relationships from the conceptual models. The account subject and any ancillary conceptual models can be used for this purpose. This will be done iteratively, beginning during the scoping search, refined during the reading of abstracts and refined again based on full text reading and expert input.
- Name the folders using a standard naming convention that adequately describes the cause and effect relationship in the model.
- Migrate evidence from the broad folders established during the initial search into the more specifically named folders reflecting the cause and effect relationships in the account conceptual models.
- Full text of evidence items may be stored in-house on a local server or retrieved via a URL link in the metadata using licensing arrangement with publishing houses such as Routers.

4.9.3 Key information

- Select and become familiar with some suitable bibliographic management software.
- Have to hand any conceptual models that specify cause and effect relationships for which evidence is required.
- Source a bibliographic management software package that meets your needs. Ideally this will include:
  - a reliable and reputable software developer with good technical support
  - software that can be used on a range of browsers
  - a capacity to create a hierarchical folder structure with descriptive names
  - a capacity to share the library with account users or other interested parties
  - an ability to tag evidence items in the library
  - a word processor plug-in to enable easy citations to be made when writing documents

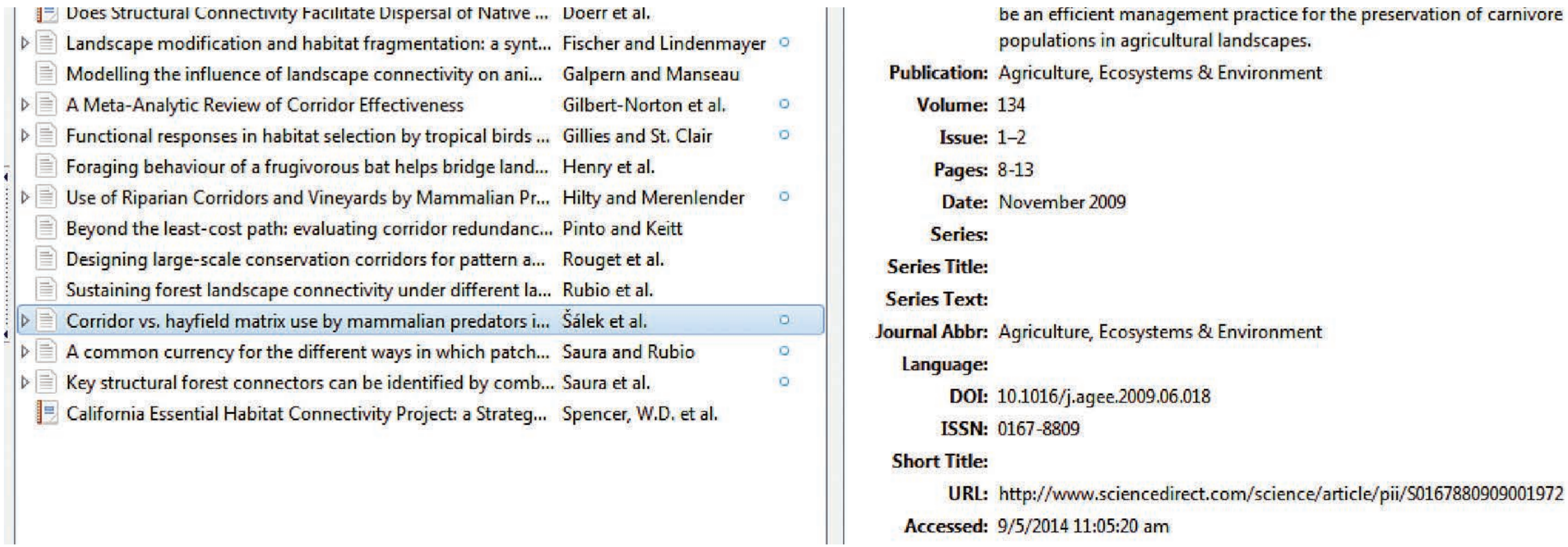


Figure 19. The full text of evidence items can be stored locally on a server, centrally on an in-house server or using the URL link to a publishing house source

– software with translators that 'speak' with a range of bibliographic databases such as Science Direct, Wiley Interscience, JSTOR, Web of Sciences, TROVE and search engines such as Google Scholar. This enables selection of search items to be added to a library with a click.

4.9.4 Tips and tools

- Use the cause and effect relationships of the conceptual models to form the folder headings for the evidence base. For example the folder name 'Changes in LVC—reduced habitat opportunities' reflects the model cause and effect relationship of changes in LVC (spatial pattern) and total resources available leading to reduced habitat opportunities for some species. If possible it is best to provide word based descriptions but sometimes this is not possible if multiple cause and effect relationships are used.

- It is useful to assign tags to each evidence item in the library to reflect key words relating to the evidence item. These key words can then be searched in the evidence base.

- When storing the full text of evidence items use standard naming conventions such as:

  – single author—Swann 2014

  – two authors—Swann and Jenkins 2014

  – three or more authors—Swann et al. 2014

  – if the name has already been used by another paper—Swann 2014a, Swann 2014b.

- The full text of evidence items can be stored locally on a server, centrally on an in-house server or using the URL link to a publishing house source as shown in Figure 19.

- What should be avoided is 'mining' the evidence base to extract evidence to answer new questions. Ideally, the cause and effect relationships existing within any ancillary models developed should be substantiated by new evidence searches as a new more specific set of terms may be relevant.

4.9.5 Guiding questions

- What are the software requirements for the evidence base?

- Who are the account users and what access is to be provided to them?

- What conceptual models and what relationships within models is evidence required for? If resources are not available to allow evidence to be collected for all relationships, there may be a prioritisation process to select which cause and effect relationships evidence is stored for.

- Are there any licensing issues with storing and providing access to full text items?

4.9.6 Case study example

The example evidence library shown in Figure 20 relates to the conceptual model shown in Figure 17. For this example the Zotero software has been used. The folder names shown in the far left window aim to be descriptive of the cause and effect relationships shown in the conceptual model. The middle window provides the title and author of the evidence item while the right hand window shows the item metadata.

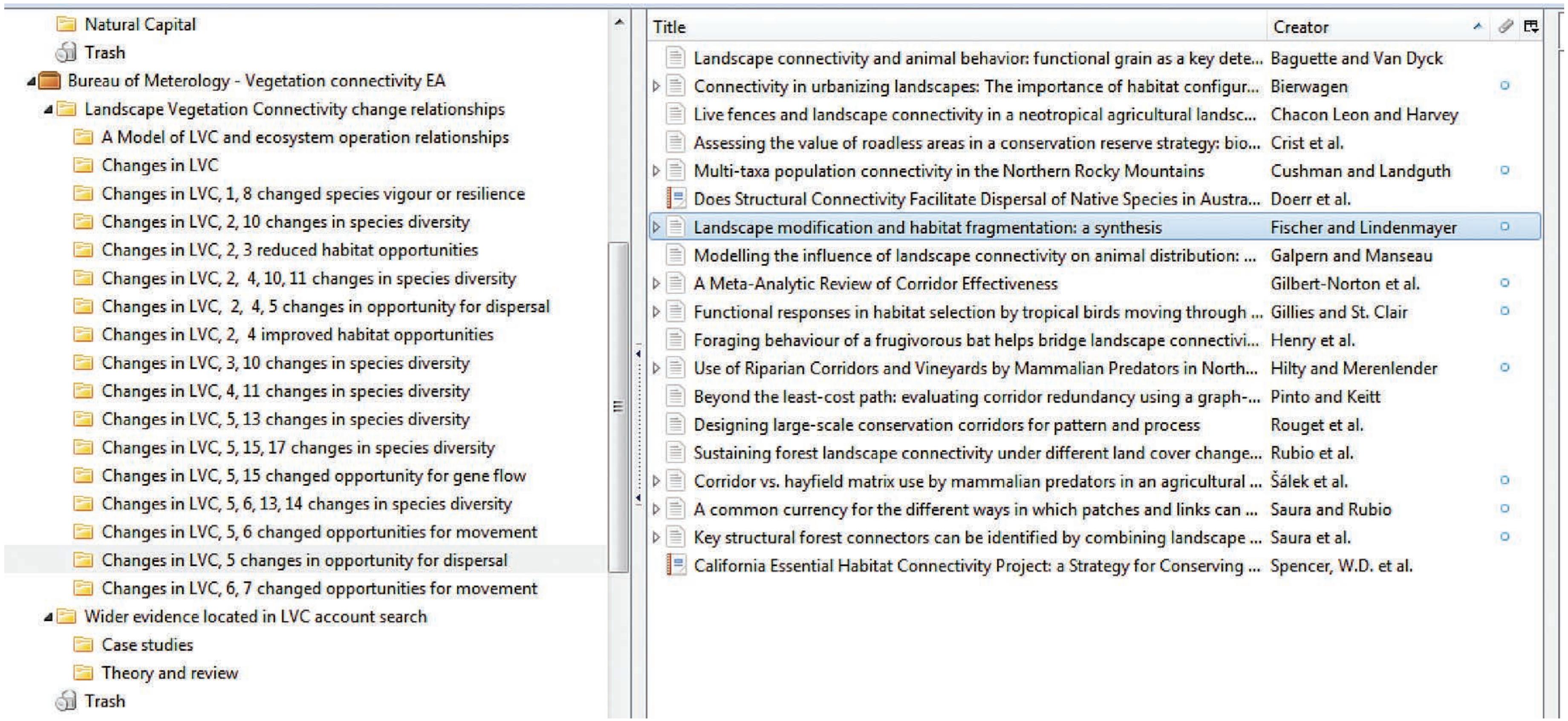


Figure 20. An example of a structured evidence library for the conceptual model relationships shown in Figure 17

4.10 Maintenance of the evidence base

While development of an evidence base requires considerable resources, the evidence base is essential to establishing the credibility and legitimacy of the account. Maintaining this credibility and legitimacy can be achieved through maintaining the best available evidence of the science that underpins the account. This requires updating searches for evidence on a regular basis with the frequency depending on the rate of research that is occurring within the topic area. Some areas of 'mature' research such as the effectiveness of riparian vegetation on reducing nutrient or sediment inputs to waterways will require a lower frequency of update compared with new or emerging areas of research such as genetic flows and landscape connectivity.[2]

One of the benefits of using a highly transparent and well documented approach to developing the evidence base, including the documentation of the search strategy, is that refresher searches can easily be undertaken in a consistent manner.

4.10.1 Aim

Maintenance of the evidence base ensures that the evidence base underpinning the credibility and legitimacy of the science of the account is maintained at 'best available evidence', is transparent and available to all stakeholders, and meets any current new standards.

4.10.2 Actions involved

- Agree on a frequency for updated searches to be undertaken and a plan to revise this frequency based on the rate of research in the topic area.
- Undertake refresher searches and add the new evidence items to the evidence base.
- Determine if the conceptual models require updating based on any new evidence.
- Update the conceptual models as needed.

4.10.3 Key information

- an understanding of the rate of research occurring in the account subject topic and related topics
- the search strategy developed in Section 4.4
- any new terms that are adopted by topic experts or within the literature.

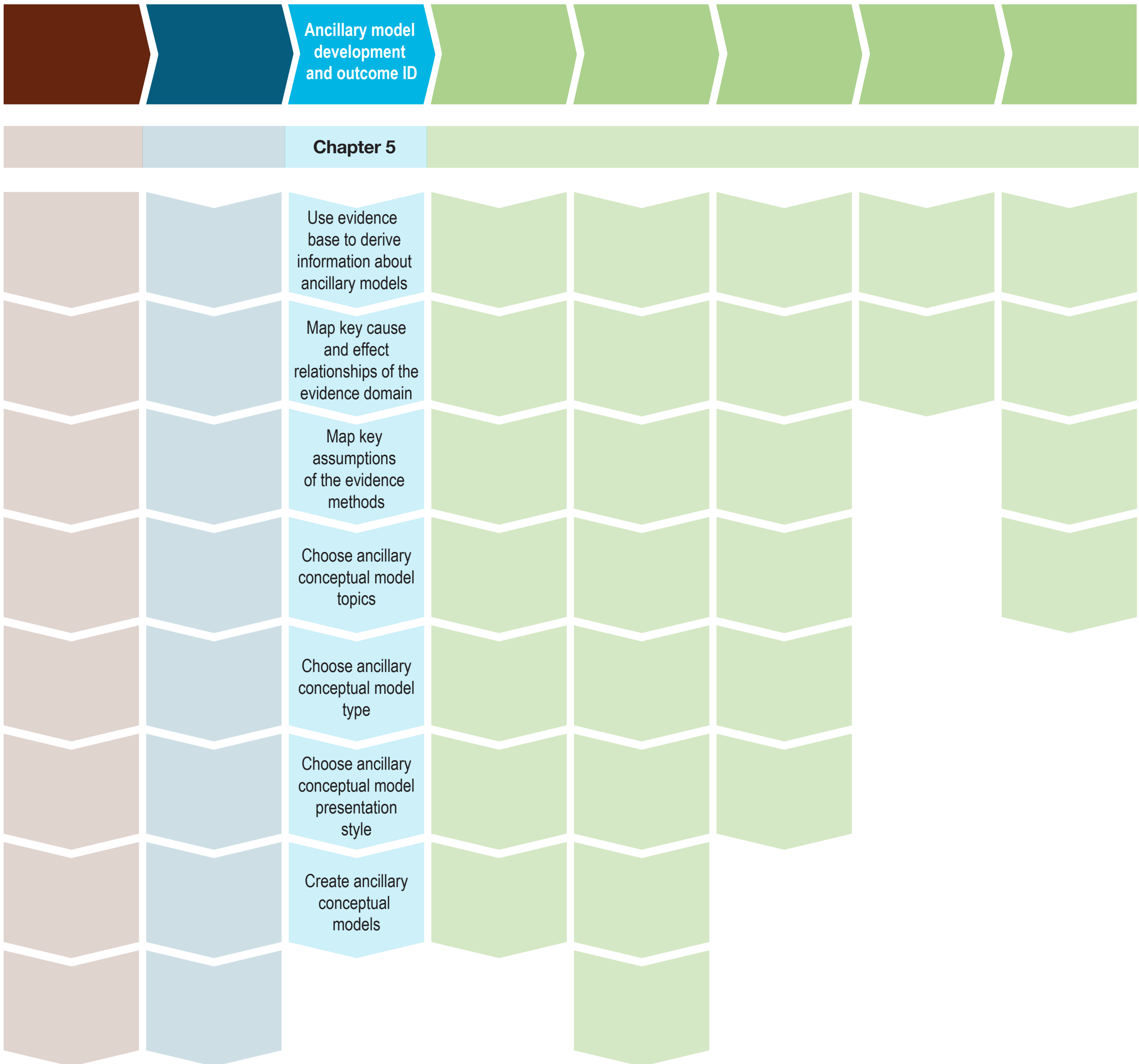
4.10.4Tips and tools

- Many bibliographic databases enable time specific searches to be conducted.
- Dedicating the maintenance of the evidence base to a small group of interested topic experts is a good way to encourage updates to be undertaken.

4.10.5 Guiding questions

- Does the evidence held in the evidence base represent the best available evidence?
- Do the conceptual models of the account represent the most up to date representation of the science?
- What new knowledge has been discovered and how does this influence the evidence base and conceptual models?
- Does the evidence base still meet the needs of the account subject including new questions that are being asked of the account?
- What are the consequences for the account of updating the evidence base and conceptual models?
- How will comparability of the account subject measurements across time be maintained?

2. Ideally accounts should be based on mature science, because changes to evidence bases and account conceptual models can lead to problems maintaining comparability across time of the account subject measurements (the numbers in account tables).


Ancillary model development and outcome ID
Chapter 5
Use evidence base to derive information about ancillary models
Map key cause and effect relationships of the evidence domain
Map key assumptions of the evidence methods
Choose ancillary conceptual model topics
Choose ancillary conceptual model type
Choose ancillary conceptual model presentation style
Create ancillary conceptual models

5 Developing collaborative conceptual models

As noted in chapter 4, the process of developing an evidence base and conceptual models for an account is iterative and interdependent. Once an account subject conceptual model and an initial evidence base have been developed, the next step in completing module 4 of the account framing process (see page 4 of this technical note) is to produce one or more ancillary conceptual models or sub-models to illustrate key aspects of the science behind the account. These could be conceptual models that clarify the current scientific understanding of the account subject or they could be models that address the methods used to link the account subject to its measuring units. In both cases, for the account to have legitimacy and credibility, the process of developing these sub-models should be a collaborative one that draws on high-level expertise.

5.1 The particular requirements of conceptual modelling for accounting

The application of rigour and, where available, standards are vital to effective conceptual modelling. For example, the authors of *Pictures worth a thousand words* (PWTW) (DEHP, 2015) raise the need for standardised methods in pictorial conceptual modelling to ensure the models are scientifically valid.

> *A point has been reached where pictorial conceptual models are now being considered for uses that demand the highest level of scientific rigour because of the scrutiny and consequences associated with their use…* (PWTW p 50)

Environmental accounting is an example of a conceptual modelling application where rigour is paramount. This is because the models are being used to capture and represent the information needed to value environmental assets, goods and services, whether in monetary or non-monetary units, for purposes of drawing up accounts.

Ideally, the following criteria should be met with evidence base and conceptual models for environmental accounting:[3]

- An adequate amount of evidence is available from multiple independent sources (scientific literature, expert opinion, community knowledge/values).
- Multiple independent peer reviews of the evidence are available.
- A high maturity of understanding is needed for all model elements in the account.
- A high level of consistency is required between conclusions drawn from the multiple lines of evidence.
- At least one high quality synthesis/review relevant to the account subject is required.
- No conflict of interest should exist (that is, no participant in developing the conceptual model and evidence base should have a vested interest in the production of the account).

While all conceptual models are hypotheses and therefore contestable, these criteria are designed to provide a scientific backing for the account that is as rigorous as it can be.

5.2 The need for standardised procedures

Conceptual modelling for environmental accounting is at an early stage of development and as yet, no formally accepted procedures exist to underpin

3. Acknowledgement: Carolyn Raine, Central West Catchment Management Authority, New South Wales.

the practice. Through time, standardised, agreed procedures will be needed for:

- the process of developing an evidence base for an account (the subject of the previous chapter)
- how to derive the subset of information from the evidence base and other sources that will be included in conceptual models (5.3)
- the process for refining the amount of information in a conceptual model so it fulfils its role of capturing and presenting the science behind an account and does so in a way that is neither too simple nor too complex (4.8, 5.3)
- how to choose participants in synthesis workshops so all disciplines and perspectives about the account subject are fairly represented and the process is transparent
- the methods used to conduct a synthesis workshop (appendix 1)
- the methods used within a synthesis workshop to resolve disagreements about science and handle knowledge gaps (appendix 1)
- the ways conceptual models are presented (chapter 2)
- the methods used to review and endorse conceptual models and evidence bases as suitable for accounting purposes (chapter 2, p 27)
- the process of updating evidence bases and conceptual models (chapter 2).

It is beyond the scope of the current work to produce a detailed set of methods approaching standard-readiness to meet this list of requirements. The chapters and sections noted in brackets after each dot point give varying amounts of guidance on each topic.

5.3 Deriving key information for ancillary conceptual models from the evidence base

The amount of information about an account subject can be vast. While the evidence-base extraction process yields a comprehensive and representative body of evidence relevant to the account, even with the focusing steps depicted in Figure 16 (p 59) there will be too much information in the initial evidence base to include in ancillary conceptual models. To tackle this challenge, a process is needed to identify the key information to include in these models. That process is driven by the following question.

What are the ‘key aspects of the science behind the account’ that must go into ancillary models in order for them to ‘capture and represent [conceptually] the information needed to value environmental assets, goods and services, whether in monetary or non-monetary units’? The paragraphs below step through the logic of identifying the most account-relevant information to include in ancillary conceptual models. Figure 21 presents this information in a diagram.

The first stage in ecosystem accounting is to produce an account subject conceptual model (such as the ones shown in chapter 3). This model allows us to identify the types of stocks and flows that will be represented in the account tables. These may be stocks of ecosystem assets, flows within ecosystems, or flows to or from ecosystems. As well as specifying the subject, the account subject model also helps clarify the account purpose, and choose the perspectives and measuring units. This process is described in chapter 3. The upper section of Figure 21 shows an account subject conceptual model for a landscape vegetation connectivity account.

In the next stage, evidence bases are developed using the key evidence base and conceptual modelling questions (chapter 4). The content of the evidence bases is focused and refined using questions about the links between the purpose, subject and measuring units of the account. These questions are essentially of two types.

Type 1 Questions about our current understanding of the account subject that probe why this particular account subject allows us to meet the account purpose. Examples of these types of questions are:

- What can changes to landscape vegetation connectivity over time tell us about the capacity of an ecosystem to deliver services?
- How do changes in annual sediment loads impact on the health of reef ecosystems?

Type 2 Questions about the account measurement methods to tell us why the measurement methods chosen for an account subject are suitable for measuring that subject. Examples include

- How does the National Connectivity Index measure landscape vegetation connectivity?
- How can remotely sensing ocean colour tell us something about the amount of sediment in the water?

Figure 21 illustrates how key questions about current understanding of the account subject and purpose are then used to drive the selection of ancillary conceptual models.

Mapping the evidence domain in terms of its key cause and effect relationships further specifies the relationship between the account subject and purpose (see Evidentiary, 2015).

In the next iteration of the conceptual modeling process, the evidence base findings are sorted into component elements (e.g. ecosystem characteristics, such as habitat type or connectivity) and into cause and effect relationships in order to better understand them. These elements and their relationships are the source of the key information to include in the ancillary conceptual models.

5.3.1 Question type 1: linking the account subject to the account purpose

The first type of question links account purposes with account subjects. If purposes are about tracking particular kinds of ecosystem stocks and flows, then ancillary conceptual models linking subject to purpose need to show elements of the account subject and the causal relationships among them that give rise to these particular stocks and flows.

For example, in the ecosystem asset account conceptual model where landscape vegetation connectivity (LVC) is the subject (refer to section 3.2.2 and Figure 11 for more details) and the purpose is to capture any change in ecosystem capacity between two times, there is a flow representing change in ecosystem capacity. In turn, the capacity of ecosystems to deliver services depends on key characteristics of an ecosystem's operation, such as its structure, composition, processes and functions.

The diagram that emerged from the LVC evidence domain mapping (Figure 17, p 70, chapter 4) unpacks the causal relationships between LVC and

In the next iteration of the conceptual modeling process, the evidence base findings are sorted into component elements ... and into cause and effect relationships in order to better understand them. These elements and their relationships are the source of the key information to include in the ancillary conceptual models.

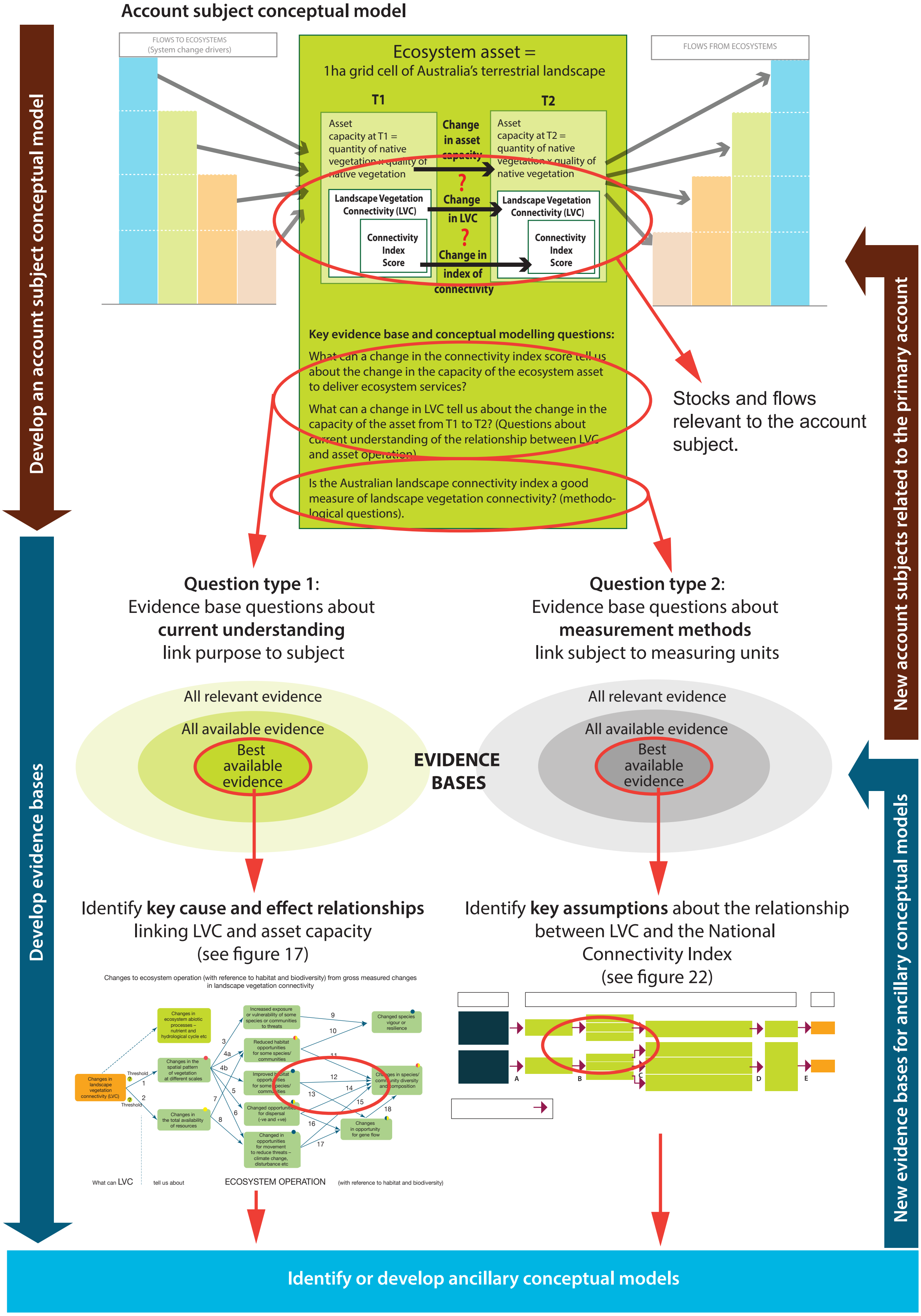


Figure 21. A summary of stages 1 and 2 of the evidence-based account conceptual modeling process. This diagram clarifies the process of deriving key information needed for ancillary conceptual models.

ecosystem operation. What is this diagram saying, in terms of the LVC account (subject) and its ability to track changes in ecosystem capacity (purpose)? Some examples of causal links are:

- Changes in the total availability of resources (2) lead to reduced habitat opportunities for some species/communities (4a) resulting in changes to species/community diversity and composition (12).
- Due to changes in the spatial pattern of vegetation (1) some species are more vulnerable to threats (3) and this changes their vigour or resilience (9).
- Changes in the spatial pattern of vegetation at different scales (1) change opportunities for biota to disperse (5) and thus the opportunity for gene flow in the ecosystem (15).
- and so on...

These causal links and the others illustrated in Figure 17 are ways that changes in landscape vegetation connectivity change the capacity of an ecosystem to deliver services. Each of these relationships tells us something about why LVC can be used as an indicator of ecosystem capacity. These relationships, which have come to light in a systematic evidence search, are potential subjects for ancillary models to support and illustrate the science linking the account subject (LVC) to the account purpose (tracking changes in ecosystem capacity).

As another example, in the hypothetical reef sediment account (see section 3.2.2), the subject is changes in reef condition related to sediment loads. The purpose of the account is to track changes in sediment inputs and changes in reef condition from year to year. One set of tables is used to track sediment inputs (a driver of ecosystem change) and a second set of tables tracks reef condition in the same area on the same time step. Linking these account tables may help understand the impact of sediment on the capacity of the Great Barrier Reef ecosystems to provide ecosystem services. So the elements and interactions of interest for ancillary conceptual models are (a) for the sediment tables, those that determine the dynamics of sediment movement into the reef lagoon and, (b) for the condition tables, those that link sediment loads to the functioning of the reef ecosystem.

5.3.2 Question type 2: linking the subject to measurement methods

The second type of evidence base question links measurement units to subjects. Conceptual models derived from this type of question need to show how the elements that comprise the units, and the relationships between those elements, represent the flows that are to be captured.

For example, the units of the National Connectivity Index roll up three elements of connectivity—habitat amount, core habitat amount and habitat separation. Behind each of these terms are assumptions about the definitions of 'habitat', 'core habitat' and 'separation', as well as assumptions about how to combine the elements to give a meaningful measure of LVC. These are the elements and relationships that need to appear in conceptual models illustrating how the National Connectivity Index captures meaningful information about the change in LVC across time. Each of these potential ancillary model topics is represented by a crimson arrow in Figure 22.

5.4 Developing ancillary conceptual models

In chapter 1, three roles were identified for evidence-based conceptual models in accounting. These were:

- to summarise the scientific knowledge behind the account subject and measurement methods (underpinning the credibility of the account)
- to achieve consensus among account participants about the science and the measurement methods, through collaborative conceptual model development (underpinning the legitimacy of the account)
- to communicate the science behind the account to users and other stakeholders.

The previous section outlined a process for deciding what to include in the evidence-based conceptual models developed to fulfill these three roles (now called ancillary conceptual models). This process is summarised as follows:

- Develop an account subject conceptual model to clarify the purpose of the account and link the account purpose to the account subject.
- Identify two types of evidence base and conceptual modeling questions: (1) questions about the current understanding of the account subject and (2) questions about the methods for measuring the subject.
- Use the questions to initiate the development of an account evidence base.
- Use evidence-base domain mapping to unpack the causal relationships between the account purpose and the account subject (i.e. what are the major causal links between the account subject and the account purpose?)

Example: developing an index to measure the state of ecological connectivity

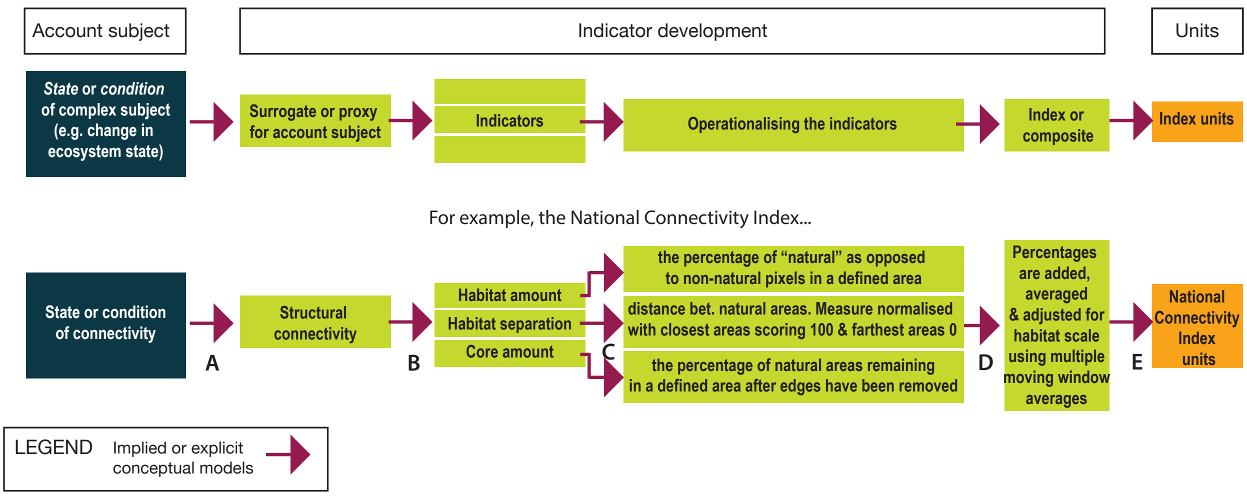


Figure 22. The crimson arrows represent assumptions made at various points in the development of the National Connectivity Index. Each of these relationships could be the subject of an ancillary conceptual model to present the science linking the account subject (LVC) with the units used to measure it.

- As well, use domain mapping to unpack the causal relationships between the account subject and the account units (i.e. what are the assumptions linking the account subject with the units developed to measure it?)

- Choose ancillary conceptual model subjects from among the identified causal relationships. One or more causal relationships can be unpacked in each conceptual model, depending on complexity of the chosen ancillary model subject.

To begin the process of developing an ancillary conceptual model, another evidence search should be conducted using terms chosen from the evidence domain map. In chapter 4, Figure 18 showed an example of an ancillary conceptual model that could be developed from the evidence base domain map shown in Figure 17.

To create such a model, causal links 1, 5, 16 and 18 in Figure 17 would be used to develop a new evidence base question: 'how do changes in the spatial pattern of vegetation at different scales (1) affect the opportunities for dispersal (5) and gene flow (16) that in turn influence species and community diversity (18)?' A new set of search terms is developed, following the process set out in chapter 4. The resulting evidence base, which will be much more restricted than the original account subject evidence base, is then used to develop an ancillary model such as the one shown in Figure 18.

In this model, each of the boxes represents a concept to emerge from the new evidence search. All are changes to characteristics of ecosystems that can occur in response to a variety of negative and positive flows to the ecosystem. Hence, they are all linked to the ecosystem's capacity to deliver flows to ecosystems and to people—ecosystem services in the latter case. The arrows in the model all represent the relationship 'leads to', for example: changed spatial pattern of vegetation leads to changed dispersal ability of species, changed reproduction strategies lead to changed genetic flow and so forth. The boxes and arrows all represent best available scientific knowledge that has emerged from an evidence search of the type outlined in chapter 4.

Ancillary conceptual models could be developed for each of the numbered links in Figure 17. Depending on the identified purposes for the account and for the conceptual models, these models are inputs for science synthesis workshops at the fourth stage of the conceptual modeling process outlined in Figures 6 and 7—information synthesis. At that stage, the ancillary conceptual models will be developed and refined by scientific experts and other knowledge holders with a view to achieving agreement on the best current understanding of the ecosystem characteristics relevant to the account.

Appendix 1 presents a process for running an information synthesis workshop derived from *Pictures worth a thousand words*.

5.5 Choosing model types

Conceptual modeling for ecosystem accounting is in its earliest stages of development so it is too soon to specify the use of particular types of conceptual models from among the many on offer. However, some guidance is given below, based on what the models have to achieve in relation to the account, that is, to shed as much light as possible on changes in ecosystem operation that accompany change in the account subject over successive accounting periods.

The key elements of any ecosystem conceptual model are system parts and relationships among parts (how the parts interact). In the simplest type of diagrammatic conceptual model, parts are represented with boxes, and relationships with lines or arrows (e.g. Figures 23, 24).

5.5.1 Conceptual model components

From this simple starting point, the literature on ecosystem conceptual modeling offers various typologies and an array of possible model types, developed for a range of purposes including enhancing ecosystem understanding, managing ecosystems and their relationships with human subsystems (e.g. society, economy) and communicating about how ecosystems function. Examples of different conceptual model types are: control vs. stressor models (Gross, 2003), control models, state and transition models and driver-stressor models (Fischenich, 2008), conceptual ecological models (driver, stressor, effect, attribute) (Ogden et al., 2005) and component, structure and process focused models (Manley et al., 2000).

In evidence-based conceptual modeling for environmental accounting, the emphasis is on the causal relationships among the modelled parts, as discussed in the previous section. Boxes represent ecosystem components (characteristics in SEEA terminology), or different types of flows to and from ecosystems. Because accounting is a periodic process with a regular time step (e.g. annual accounts), the boxes typically depict change in the ecosystem characteristic or the flow. In a more sophisticated model, different kinds of changes may be included in the boxes, for example increases and decreases can be signified with arrows up and down or plus and minus signs (for example Figure 23).

The conceptual models used for ecosystem accounting can be embedded in a conceptual framework, such as the DPSIR framework, with boxes of different colours and shapes representing the different parts of the framework. The example show in Figure 24 uses a Driver–Pressure–Vulnerability–State–Impact framework, with boxes of different shapes and colours representing each of these different framework elements, while round boxes represent different types of indicators.

Lines and arrows in ecosystem accounting models typically signify causal links such as ‘leads to’ or ‘results in’ but they may designate other types of relationships. For example in Figure 24, the arrow pointing to the orange capsule shaped box (a vulnerability) means ‘with’ and the one pointing away means ‘modifies’. Where lines and arrows have different meanings in a box and arrow conceptual model, these should also be distinguished by different shapes and colours or labeled to avoid confusion.

One important characteristic of models to consider is their ability to predict outcomes at different levels of specificity. Models used to represent ecosystems fall on a spectrum from conceptual to mathematical depending on how precisely they try to predict ecosystem behavior. At one extreme, conceptual models may simply show the important elements of a system with no explicit or implied prediction while at the other, sophisticated numerical models may predict exact changes in ecosystem variables.

The minimum requirements for a conceptual model for ecosystem accounting are:

- that they are scientifically credible, that is, their theoretical consequences are not contrary to what is observed in the 'real' world
- that they enhance understanding of the account subject
- that they say something about ecosystem behavior at the most basic level of prediction, namely, that changes in specific elements of the model lead to changes in other specific elements, without necessarily making any prediction about the direction or magnitude of those changes.

The ability to predict direction or magnitude of change can be very useful in modeling for ecosystem accounting but it is not essential.

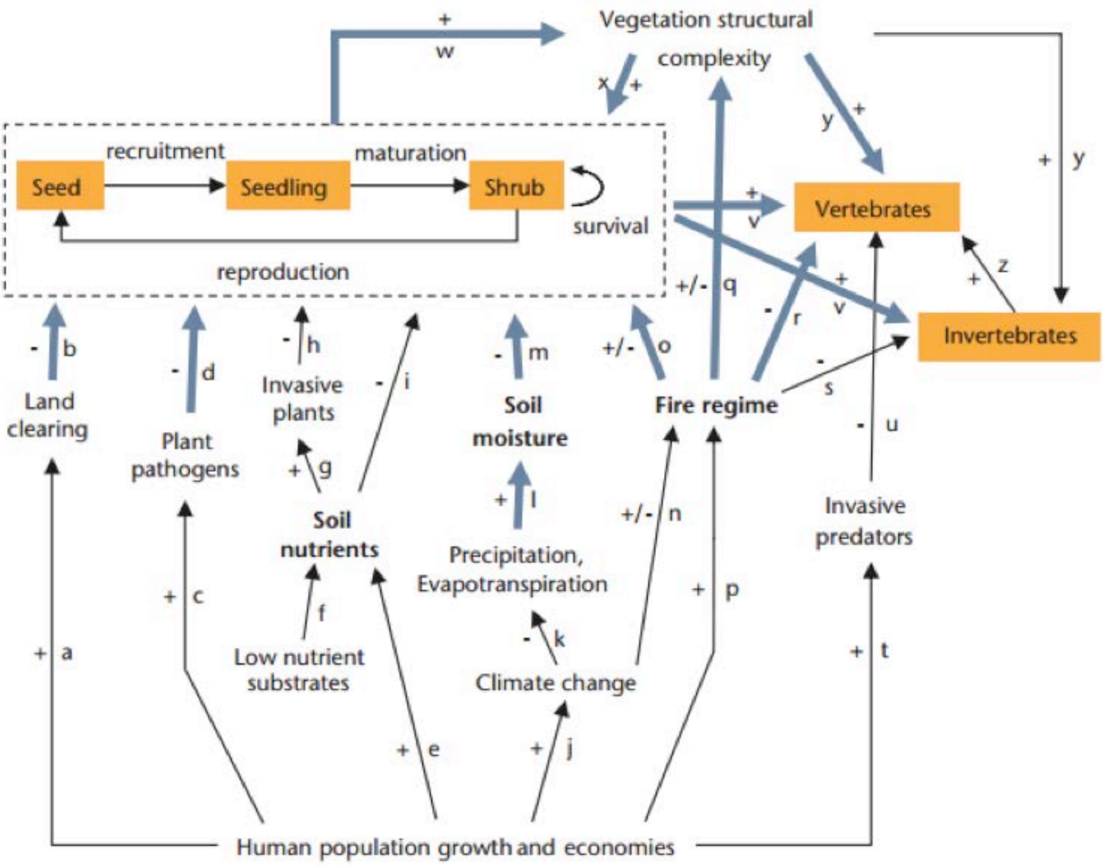


Figure 23. Conceptual model of heathland ecosystem dynamics. Arrows indicate processes and interactions (not exhaustive), annotated to show positive (+), negative (-) or variable relationships (+/-). Blue bold arrows represent processes covered by core long-term ecological studies. Bold type shows key drivers in the ecosystem. The dotted box indicates populations of sclerophyll shrubs are a key defining feature of the ecosystem influenced by key interacting processes. (Lindenmeyer et al, 2014)

5.5.2 Conceptual model presentation style

As well as variety in the kinds of parts and relationships conceptual models illustrate, there are various options for how these parts and relationships are presented, for example, Fischenich (2008) recognises five presentation types—narrative, tables, input/output matrices, box and arrow models and pictorial models. Different types of information lend themselves to different kinds of presentation but the choice of presentation will also depend on the intended audience of the models.

Descriptive texts and tables provide text-based summaries of concepts and relationships. Generally pitched at specialist audiences and often couched in technical language, such texts can be time consuming to interpret. They are usually the least accessible of the various conceptual models to a

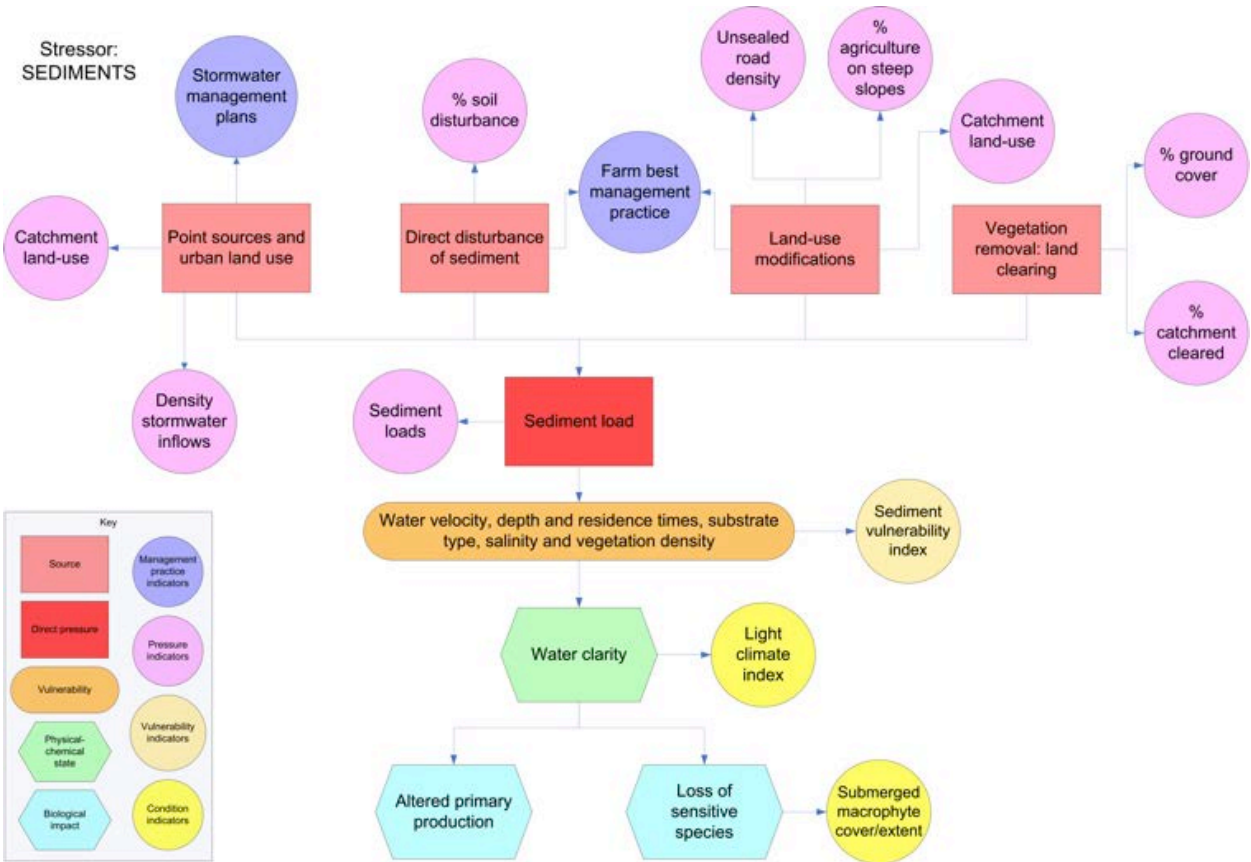


Figure 24. This box and arrow diagram represents a DPSIR-based conceptual model of the relationships within an aquatic ecosystem to the direct pressure of aquatic sediment load. (DERM, 2009 in DEHP, 2012, p5)

general audience but they can encompass a lot of information at a level of detail and analysis not possible for other model types. Descriptive text can also supplement other model types, to give context or further detail (DEHP, 2012).

Box-and-arrow-style diagrams have been popular for modelling ecosystems. Because they highlight ecosystem parts relationships with a bare minimum of visual elaboration, a great deal of information can be compressed into a small space. This characteristic can also be a disadvantage if the addition of more and more boxes and arrows leads to an unattractive mess, penetrable only to the person who made the diagram. In this situation, some sort of tabular lay-out may be more appropriate for the conceptual model. Another disentangling option is to use a drawing program (such as 'Doview') with interactive features that highlight the relationships of selected boxes and arrows so they stand out and are easier to follow.

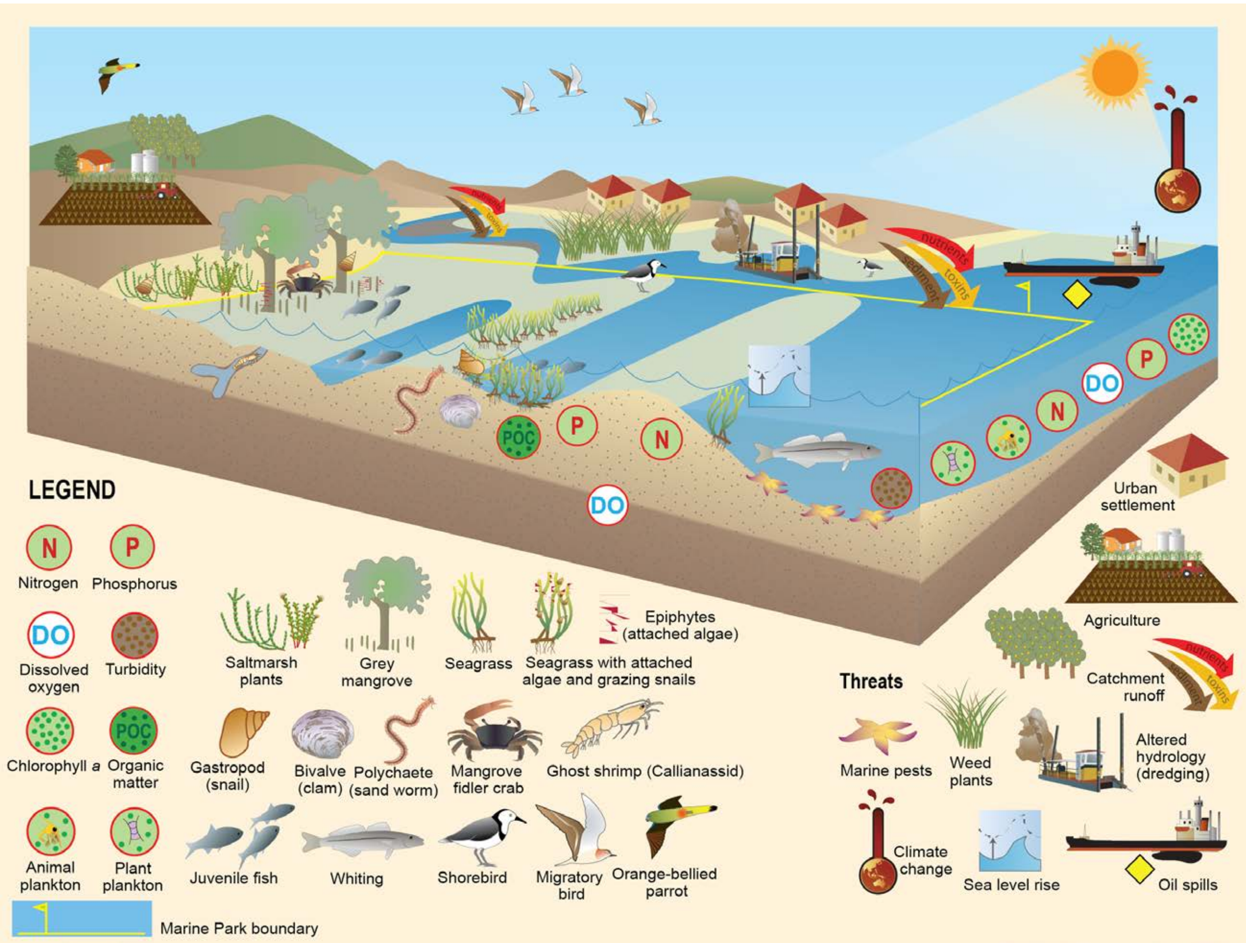


Figure 25. Pictorial conceptual model of a sandy enclosed coast showing ecosystem processes, and pressures on ecosystem capacity. (Source: Parks Victoria)

When conceptual models are used to describe specific processes such as ecological relationships and ecosystem dynamics, additional meaning can be added to the diagram by replacing labelled boxes with pictures ('icons') and adding a simple geographic or geomorphic 'base' as shown in Figure 25 and Figure 14 (p 49). Many people find these less abstract conceptual models more accessible, probably because such diagrams tap into their tacit visual and conceptual knowledge of the natural environment, making it easier to understand and relate to the information that the diagram is designed to convey.

Though pictorial models do not aim to identically replicate the real-world system they represent, they evoke it by presenting enough visual cues to give the viewer a clear context for the relationships, processes or elements the model seeks to explain. These diagrams have proven useful for communicating complex ideas to a wide range of audiences over a range of applications. They are suitable for conceptual modeling for ecosystem accounting provided they have been developed with the high level of scientific rigour required of the environmental accounting context. The Queensland Wetland Program's (2012) publication *Pictures worth a thousand words: a guide to pictorial conceptual modeling* is a valuable resource for anyone wanting to make conceptual models of this kind.

5.5.3 Creating ancillary conceptual models and completing the next stages

To progress through the remaining stages (4–8), it is recommended the reader uses the processes outlined in *Pictures worth a thousand words: a guide to pictorial conceptual modelling* (DEHP, 2012) produced by the Queensland Wetlands Program. Available at:

<http://wetlandinfo.ehp.qld.gov.au/wetlands/resources/pictorial-conceptual-models.html>.

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Appendix 1 Tips for running a successful synthesis workshop

One of the most important things to consider when running a synthesis workshop is the intention of the gathering. Both the workshop and the conceptual models developed need to be purpose driven. In preparing for the workshop, the following questions should be answered:

- What are the conceptual models for?
- How will the conceptual models be used?
- By whom will they be used?

The desired outcome may be to build a consensus of understanding among the group present—and those whom they represent—or it may be to gather information and understanding that will be represented on a conceptual model for other users. It is also important to consider what sort of information is needed to develop the conceptual model and at what level of detail. Answering these questions will help ensure that all contributors needed to cover the identified topics are invited. For example, to produce a conceptual model of climate change impacts on an area of intertidal wetlands, the following experts might be needed for a science synthesis workshop—depending on the questions to be answered:

- climate change modellers
- ecologists
- geomorphologists
- marine/estuarine experts
- terrestrial experts
- meteorological experts
- coastal/inshore hydrologists
- experts with an understanding of local land use and its impacts
- economists
- fisheries experts and representatives
- local landholders.

Pre-workshop preparation is essential

Being well prepared is the key to ensuring that the workshop runs smoothly and achieves its intended purpose.

- Ask the right questions. It is useful to know what is wanted from the group and to have an idea of how to focus the meeting to achieve this, as well as being familiar with the meeting processes to be used. Having a pre-prepared but adaptable list of questions can be useful.
- Have a good overview of what information is already available in the public domain. It is important to 'have done the homework' and value the science already completed, perhaps by some of the people who will be present. This step can also help with framing questions. As a result, the best use can be made of the time and expertise in the workshop.
- If possible, identify any gaps in the literature or areas where more detail or clarification is required.
- Plan a workshop process. This will be different depending on the number of people involved and the intended outcomes. A ten person meeting will be run differently to a fifty person workshop.
- Participants will find it useful to have a concept of what they are aiming for, in terms of the physical product of the workshop. One way to achieve this is to show examples of conceptual models from other studies.
- To start the process, it may also be helpful to prepare a draft conceptual model of the topic

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This section was sourced from *Pictures worth a thousand words: a guide to pictorial conceptual modelling*, Department of Environment and Heritage Protection, 2012.

under investigation (for example, a wetland)—even if this is only rough and may not be completely accurate. Correcting any mistakes will be part of the workshop process.

- The disadvantage of having a prepared draft is that it may focus people on providing design feedback rather than content expertise.
- Another option is to have a model base prepared—showing the site of interest—and then encouraging the addition of knowledge onto this base. This may be achieved either by having a large printout on a wall where the facilitator or scribe can capture comments, or by giving out printed copies of the base for the meeting attendees to draw on.
- Finally, a whiteboard or butcher's paper on the wall, used to record expert input in simple basic drafts, may be the most appropriate starting point (Figure A1).
- Choosing among these options will depend on participants' familiarity with conceptual models and the methods for creating them and also on the amount of encouragement and guidance they need to get involved in the workshop process.

Provide workshop participants with information about the context

Explain to participants the purpose of the overall project and its relationship to the synthesis meeting in which they will be participating. Explain how the conceptual model will be used.

Using an example of intertidal wetland climate change, questions that need clarification before the workshop would be based around the overarching question 'What is this conceptual modelling process and product for?'

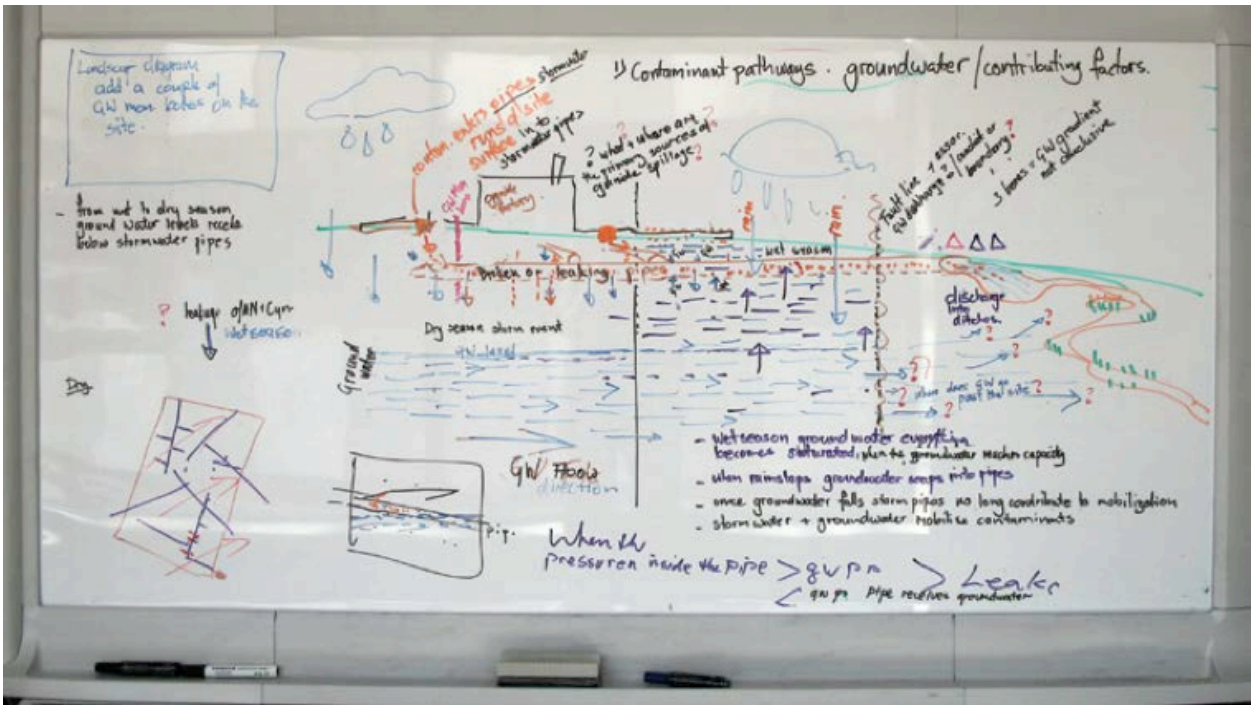

Figure A1. Capturing input from a synthesis workshop to develop conceptual models of groundwater contamination at an industrial site

Is it for:

- identifying key aspects that will be impacted by climate change
- establishing a baseline
- summarising current understanding
- other reasons?

Effective workshop process

A round table, consensus style workshop with a facilitator works well for synthesising science to develop an ancillary conceptual model.

- Good facilitation is the key to success. The role of the facilitator is to ensure that the process runs smoothly, rather than adding content to the workshop. Important functions of this role are engaging participants, keeping the group on track, clarifying, summarising, ensuring that quieter group members have a chance to contribute and that the meeting is not dominated by a few people. The facilitator also carries the major responsibility for moving the group toward consensus and flagging when it has been reached or not. In a synthesis workshop, failure to agree may simply signal a knowledge gap.
- Consider having a scribe as well as a facilitator. This person's role is to ensure that points made by group members are captured, either pictorially or in note form. A rough diagram on a whiteboard or butcher's paper, visible to all participants, is a good way to capture the developing synthesis as a precursor to making a finished conceptual model.
- Ideally, the person tasked with drawing up the final model in Illustrator (or by some other method) is present and can take the role of scribe. The rough picture made in the workshop will serve as a basis for the final drawing.
- The ideal size for this type of group is less than 15 members. Achieving consensus can be challenging in larger groups.
- If it is necessary to have a larger group of participants, there are numerous techniques available to help facilitate consensus. Small to large group consensus is one example. Participants break into smaller groups, based on thematic areas. One member of each group acts as a spokesperson in feeding back to the whole group. Sticky notes are useful to record ideas in larger groups. A scribe can collate the information on the notes and draft a synthesised diagram. This process was used in the synthesis workshop for the Great Barrier Reef coastal ecosystems pictorial conceptual models, which had 50 participants (see Figure 2.4 of Pictures worth a thousand words: a guide to pictorial conceptual modelling).

Starting the workshop

To begin, set the scene so participants know the purpose and context of the conceptual model/s they will be helping develop. Explain the process well and describe what a conceptual model is: it is neither a mathematical model, nor just a pretty picture. It shows processes as well as content. It is a way to display the information that is being synthesised in the workshop.

Introduce the workshop in such a way that people understand that:

- it will be interesting
- they can make a meaningful contribution
- the outcome to which they are contributing is important
- they will be using knowledge they already have to make a difference.

Synthesis workshops are an opportunity for two-way communication, offering a chance to 'bounce ideas around' in a dynamic group process that transcends the sum of its individual contributions. Attendees are generally positively motivated as they are being given an opportunity to contribute their understanding to a process and are not simply there to be told information. This aspect can be heightened if workshop organisers and facilitators show they have done their homework and are not just expecting attendees to repeat things they have already published comprehensively in the available literature. Rather, the purpose is to ensure that participants' important information is captured correctly, or to understand how it fits in with other things, or how it is relevant for this particular exploration of a site or issue. People generally enjoy telling the group what they know. The role of the facilitator is largely to keep people to the topic, summarise and help people move on.

Engaging participants in the workshop process

To encourage scientific experts to engage in the discussion, recognise:

- Scientists can hesitate to make statements they are not able support with evidence. It may be useful to introduce 'reliability factors' or 'confidence factors' by asking 'How sure are you of that on a scale of one to ten? Is it definite? Fairly likely? Just an educated guess but better than nothing?' This helps to get valuable information which might otherwise not be offered and to know the reliability of the information and whether recommending further research on this topic is a worthwhile outcome.
- As much as possible, get the source of any information offered. This helps with the reliability and robustness of the models produced and with checking for research gaps.
- Where differences in understanding or conflicts of opinion exist, enter into discussions if these differences are over a relevant point. Could attendees be looking at different timescales, aspects or seasons?
- If a conflict persists, recognise it as a knowledge gap that needs further research. In a situation where consensus cannot be reached, this helps people let go of the discussion. These points can then be captured in the model as knowledge gaps and help identify research projects.
- In facilitating the meeting it is vital to keep the group on task. When choosing whether to continue to discuss a point consider 'Is it important?' 'Is this detail critical to the hypothesis or purpose of the model?'

When engaging non-scientist experts, recognise:

- Experts exist outside scientific fields and they can make an important contribution to capturing current understanding.
- Non-scientist experts could include landholders, resource users, indigenous people, policy writers, long-time local residents, birders and conservationists, among others.

The inclusion of such participants can provide a vital reality check and may reveal things others have not considered.

Be clear about roles

It is important to distinguish between those providing information and the user audience. The first group will need to contribute and review the information but not be involved in user testing the models. The second group should review the models for language and usability and may or may not be involved in providing the information depending on the purpose of the conceptual models being developed.

Different kinds of models are capable of prediction at different levels of specificity. Models used to represent ecosystems fall on a spectrum from conceptual to mathematical depending on the precision of their ability to predict ecosystem behavior. At one extreme, conceptual models may simply show the important elements of a system with no explicit or implied prediction while at the other, sophisticated numerical models may predict the exact value of change in ecosystem variables.