Marine and Coastal Ecosystem Accounting: Port Phillip Bay

Report to the Commissioner for Environmental Sustainability

VICTORIA
State
Government
Environment,
Land, Water
and Planning

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Executive Summary

Environmental assets are fundamental to our economy and societal wellbeing. A healthy environment has unique intrinsic value and provides a wide range of benefits to people including the production of fresh food and fibre, nature based recreation and tourism, air and water filtration, and resilience to natural events. The ecosystems within Port Phillip Bay are essential to the culture, wellbeing and economy of Melbourne and Geelong and to all those who visit or live near the Bay. However, we have little or no information that links the condition and extent of Bay ecosystems to the services they provide and the benefits we receive.

This study builds on previous environmental-economic accounting undertaken by the Victorian Government to demonstrate the relationship between healthy bays and economic and societal wellbeing in Victoria. It has been produced to support the 2016 Victorian State of the Bays Report and aligns with the environmental reporting reform articulated in the Commissioner for Environmental Sustainability's State and Benefit Framework.

This study has used available data to produce a draft set of environmental-economic accounts for the Bay. The approach allows for the integration of terrestrial accounting with marine and coastal accounting to provide a more complete picture of both the economic and environmental relationships. The application of an integrated accounting framework across all environmental dimensions would provide a set of information that can be used to make decisions involving tradeoffs between the use and management of ecosystems in a transparent and consistent manner.

The key findings and recommendations of this study are:

- Robust, comprehensive and fit-for-purpose data is core to decision making. A lack of ecosystem health and spatially referenced data was a key issue in populating accounts for Port Phillip Bay. The development of marine ecosystem condition indicators is a key priority which should continue to be addressed by the Department of Environment, Land, Water and Planning and portfolio partners.
- Due to the absence of time series data, the change over time in the extent of ecosystems in the Bay was not assessed in this study. Measuring and reporting changes in marine ecosystems is a key objective to support the evaluation of the management of ecosystem assets to inform decision-making. If marine accounts were to be produced on an ongoing basis the collection of consistent time series data on ecosystem assets should be a priority. This study provides a set of demonstration accounts to illustrate how asset and condition accounts can be constructed to report change, and linked to changes in flows of ecosystem services.
- Pilot accounts developed for Port Phillip Bay illustrate the extent of ecosystem assets in five geographic areas. The reported areas are only indicative because the extent was derived from different studies using different methods over the last 15 years, rather than a single point in time. This study has used new and historical data which has been newly classified under the Combined Biotope Classification Scheme (CBiCS), which is being adopted in Victoria. The Victorian Government's EnSym tool was used to produce the accounts and can be used to report on different geographic areas within the Bay including swimming, aquaculture, local government and river outlet areas to support targeted policy and decision making.
- The Bay is providing water filtration services to Melbourne and the catchments by processing nitrogen that enters the Bay as catchment runoff or from the sewage treatment plant at Werribee. It is estimated that the Bay can processes over 5,000 tonnes of nitrogen per year and the value of this service is estimated at around $11 billion per year, which represents the costs that would be incurred to achieve equivalent denitrification through alterative means, such as upgrading infrastructure or wetland enhancement.
- Although seagrass makes up only four per cent of Bay ecosystems it delivers a diverse range of ecosystem services that provide benefits to the economy and the community – particularly water filtration, sediment stabilisation, maintenance of nursery populations and habitat, and carbon sequestration and storage, with recreation more indirectly linked. This case study is the first attempt in a Victorian context to use seagrass extent information to value benefits from key ecosystem services. It highlights the relationship between the state of ecosystems and the socio-economic benefits they provide.

- Seagrass ecosystems in the Bay provide important habitat services for a number of fish species including Australian anchovy, southern sea garfish and King George whiting. The value of these habitat services is reflected in the enhancement of fish stocks that has been estimated at a minimum of $6 million per year across the 7,350 hectares of seagrass in Port Phillip Bay.
- The Bay also provides benefits such as climate change mitigation through carbon sequestration, which is valued at up to $350,000 per year from seagrass ecosystems. A number of additional benefits from seagrass could be quantified in future work for recreational fishing, aquaculture, recreation and amenity.
- The process of producing accounts for the Bay has revealed opportunities for the further application of the System of Environmental-Economic Accounting (SEEA) in the areas of water and waste (emission) accounts. These accounts are important for providing an understanding of inflows to the Bay as a result of economic activity in surrounding catchments. By linking economic activity in the catchments via the water and waste accounts to the condition of the Bay it is possible to build a more comprehensive picture of the impact on Bay ecosystems and the services they provide and the benefits we receive.

This is the first time marine and coastal environmental-economic accounting has been undertaken in Australia.[1] The findings of the report are preliminary however they provide useful insights into areas for further research. The core accounting model used in this study can be used as a guide to focus future research to improve our understanding of the relationships between the marine and coastal environment and the social and economic wellbeing of Victorians.

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[1] The Australian Bureau of Statistics is investigating an expansion of its Great Barrier Reef accounts to include marine and coastal assets.

Glossary

Avoided cost	The costs that would have been incurred in the absence of ecosystem services (eg the cost of water filtration by artificial means if a wetland was destroyed or degraded).[2]
Benefit	Goods and services that are ultimately used and enjoyed by people and which contribute to individual and societal wellbeing. Benefits are distinguished from ecosystem services (which contribute to the generation of benefits) and from wellbeing (to which benefits contribute).[3]
Consumer surplus	A measure of the benefits to consumers from the consumption of a good or service. It is measured as the value of the demand for a good or service (through the amount that an individual is willing to pay for it) additional to the price actually paid for it.
Cultural services	Non-material ecosystem outputs that have symbolic, social or intellectual significance for individuals or communities. Examples include recreation, spiritual, social and cultural connection, landscape amenity, health and wellbeing, social cohesion and involvement.[4]
Economic contribution	The economic contribution measures the employment and valued added to the local, state and national economies associated with expenditure on specific goods or services. The total economic contribution consists of the direct contribution of a market activity (eg value of gross operating surplus, labour income to staff and taxes paid minus subsidies) and flow on effects stimulated across other sectors (eg through the purchase of intermediary inputs).
Ecosystem assets	Spatial areas containing a combination of biotic (living) and abiotic (non-living) components and other characteristics that function together.[5]
Ecosystem services	The contributions ecosystems make to the benefits gained in economic and other human activity. They are generated through ecosystem processes reflecting the combination of characteristics, intra-ecosystem and inter-ecosystem flows.[6]
Environmental assets	Environmental assets are the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity.
Environmental-economic accounts	System of data and information reporting used to describe environmental assets and flows of ecosystem goods and services and their linkages to the economy and society.
Ecosystem accounting	Statistical framework for organising biophysical data, measuring ecosystem services, tracking changes in ecosystem assets and linking this to economic and other human activity.
Intermediate ecosystem services	Are flows between ecosystem assets that reflect ongoing ecosystem processes. An example is the flow of water between ecosystem assets via rivers.
Provisioning services	Tangible goods that can be exchanged or traded, as well as consumed or used directly by people. Examples include food, water and other raw materials.[7]

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[2] TEEB (2010) 'Chapter 5: The economics of valuing ecosystem services and biodiversity' in *The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations*, p. 17.
[3] United Nations (2014) *System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting*, United Nations, New York, p. 152.
[4] United Nations (2014) *System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting*, United Nations, New York, pp. 42.
[5] United Nations (2014) *System of Environmental-Economic Accounting 2012: Central Framework*, United Nations, New York, pp. 13-14.
[6] United Nations (2014) *System of Environmental-Economic Accounting 2012: Central Framework*, United Nations, New York, p. 14.
[7] United Nations (2014) *System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting*, United Nations, New York, p. 42.

Regulating services	Regulating services result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes. Examples include climate regulation, watershed regulation such as purification, flood control and biological processes, including pest control, pollination and genetic diversity.[8]
Supporting services	Supporting services or intra-ecosystem flows are flows within ecosystem assets that reflect ongoing ecosystem processes. Examples include nutrient cycling, maintaining soil health and enhancing the habitat to native species, which both benefit specific ecosystems directly, but not society or the economy.

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[8] United Nations (2014) *System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting*, United Nations, New York, p. 42.

1. Introduction

The Victorian Government has been developing the capacity to produce environmental-economic accounts for a number of years. This study builds on previous environmental-economic accounting work to demonstrate the relationship between healthy bays and economic and social wellbeing in Victoria. The extent and condition of ecosystem assets in Port Phillip Bay is discussed and linked to ecosystem services and the benefits people and society enjoy.

In late 2012, the Australian Bureau of Statistics (ABS) produced *Land Account: Victoria, Experimental Estimates, 2012*.[9] The ABS land accounts contain information on land cover, land use and the value of land at the catchment level. The information provided in the land accounts provides a link between Victoria's ecosystems and economy.

This link was further explored in March 2013 by the Victorian Government with support from the ABS when it published experimental ecosystem accounts that focused on terrestrial ecosystems.[10] The experimental accounts demonstrated that it is possible to provide information on ecosystems and their changing condition through time in an accounting format that is consistent with the United Nations System of Environmental-Economic Accounting (SEEA).[11] The accounts were designed to present information that is comparable over time and across regions, allowing users and policy-makers to objectively review the outcomes of natural resource management decisions in a terrestrial context.

In February 2015, the Department of Environment, Land, Water and Planning (DELWP) and Parks Victoria published *Valuing Victoria's Parks – Accounting for ecosystems and valuing their benefits*.[12] Using the SEEA guidelines an initial set of experimental ecosystem accounts was developed for the Victorian parks network. The accounts provided a snapshot of park ecosystems and their key features, while ecosystem service flow accounts provided a snapshot of the quantity of services delivered across the parks network. The report found that ecosystem accounts based on the SEEA can play an important role in informing the community about the connection between having healthy, resilient parks and Victoria's economy and community wellbeing. Further, the approach can support park and public land planning, investment, management and evaluation decisions for parks as well as informing policy and supporting funding models to maintain parks' environmental assets, while maximising their value to the society.

In December 2015, the Commissioner for Environmental Sustainability (CES) published the *Framework for the Victoria 2018 State of the Environment Report: State and Benefit*, marking the commencement of an environmental reporting reform to underpin the development of future State of Environment reports. The Framework helps the CES in addressing the long-term goal of environmental reporting to "inform community, policy and decision making to improve environmental outcomes and ultimately, protect and enhance the benefits we obtain from our environment"[13]. The State and Benefit Framework is aligned with international initiatives such as the SEEA and the United Nations Sustainable Development Goals.

The Victorian Government has also commenced the adoption of environmental-economic accounting following internationally accepted standards in the SEEA through its strategy *Valuing and Accounting for Victoria's Environment*. The Strategy aims to integrate environmental-economic accounting into government reporting, program evaluation and forward looking decision-making.

There is potential for Bay accounts to link to terrestrial accounts to enhance decision making. For example, Bay accounts can inform decisions about the management of terrestrial ecosystem assets in the catchment which impacts on the level of nutrients in the bays and marine ecosystems. The Bay accounts can also link

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[9] Available at http://www.abs.gov.au/ausstats/abs@.nsf/mf/4609.0.55.002

[10] Eigenraam, M., Chua, J. and Hasker, J. (2013) *Environmental-Economic Accounting: Victorian Experimental Ecosystem Accounts, Version 1.0*, Department of Sustainability and Environment, Victoria.

[11] United Nations (2014) *System of Environmental-Economic Accounting 2012: Central Framework*, United Nations, New York.

[12] Department of Environment, Land, Water and Planning and Parks Victoria (2015) *Valuing Victoria's Parks*, available at http://www.delwp.vic.gov.au/news-and-announcements/valuing-victorias-parks

[13] Commissioner for Environmental Sustainability (2015) *Framework for the Victoria 2018 State of the Environment Report: State and Benefit*, Victoria, p. 3.

to the park accounts piloted in *Valuing Victoria's Parks*. Parks Victoria manages over 53,000 hectares of marine national parks and sanctuaries, and the area within parks that rivers run through is 47,905 hectares. Since all three studies (terrestrial accounts, parks accounts and this one) use the same environmental-economic accounting framework, it is possible to meaningfully compare and cross reference information to support decision making and reporting.

This study will inform the 2016 Victorian State of the Bays Report. The aim is to examine what data are available to develop ecosystem accounts for the Bay, build and present a set of pilot accounts, and finally to make recommendations about future data collection and methodological challenges. This study will contribute to a broader reform agenda surrounding the management and monitoring of marine and coastal habitats.

Section 2 provides background information on environmental-economic accounting and how it is useful for organising information about the Bay to support decision making and policy analysis, including a hypothetical worked example of accounts to show how they can be used to report changes in extent and condition over time and link to changes in the benefits they provide. Section 3 outlines the information requirements, discusses the data used in the pilot accounts for Port Phillip Bay and identifies knowledge gaps. Section 4 presents a spatially referenced set of ecosystem asset accounts for the Bay. Section 5 provides a more focused set of accounts based on a case study of seagrass condition, and connects these assets to socio-economic wellbeing through the valuation of selected benefits. The case study demonstrates how environmental-economic accounting links ecosystems with socio-economic wellbeing and details the steps involved in assessing the condition of seagrass ecosystems and the services it can provide.

2. Overview of Environmental-Economic Accounting

Melbourne and its surrounds depend on ecosystems for the production of fresh food and fibre, nature based recreation and tourism, air and water filtration, and resilience to natural events. Port Phillip Bay has unique intrinsic values that are essential to the culture and wellbeing of people in Melbourne and Geelong. The ecosystems within the Bay provide benefits in the form of tourism, recreation, climate control, food, and other goods and services.

Many of these benefits are inadequately incorporated in traditional measures of progress, such as gross domestic product (GDP) or employment growth. Traditional measures of economic and social performance do not take into account the extent and condition of ecosystem assets and our reliance on them. There is increasing demand from policy makers and program managers for a more integrated and holistic approach to understanding the interactions between the environment and the economy.

In 2012 the United Nations launched the first international statistical framework for the environment titled the System of Environmental-Economic Accounting (SEEA). SEEA is a framework for linking economic activity to the quantity and quality of environmental assets. It provides standards that build on the principles of the System of National Accounts (SNA) that is used to measure GDP, national wealth and other social and macro-economic variables.

The SEEA framework covers minerals, energy, water, fisheries, land and ecosystems, biodiversity, agriculture and forestry. Some information on these assets is reported in standard economic accounts following the SNA. However, the SEEA extends the SNA by including the extent and condition of environmental assets and how changes in them impact on individuals and society. A key feature of the SEEA is the recognition and quantification of the linkages between environmental assets and social and economic wellbeing. For instance, current SNA accounting does not show degradation of environmental assets as a cost against income earned from economic production. Using the SEEA it is possible to account for degradation of environmental assets and link that to economic actors, income, decision making and potentially adjust GDP.

The SEEA outlines concepts, definitions and classifications for compiling environmental, social and economic statistics into accounts. Information in the accounts can be used to derive coherent and comparable indicators, inform asset management, and provide information to measure progress towards policy goals. A coherent and integrated approach to the measurement and valuation of environmental assets is the cornerstone of evidence-based decision-making.

Environmental-economic accounting can be used at different scales for different purposes. At the national and international level, accounts can be used for raising awareness, informing measures of progress and priority setting. At the local level, accounts can be used to inform resource allocation (return on investment) and evaluate policy and programs. Table 1 lists a range of environmental-economic accounting initiatives at different scales.

Table 1 – Examples of environmental-economic accounting initiatives

Scale and purpose	Initiatives
Program level Accountability, evaluation	– DELWP pilot accounts for program investments in native vegetation and threatened species (2015), environmental markets (2010 – current)
Regional and state level Priority setting, resource allocation, raising awareness	– Australian National University Central Highland Accounts (2016) – Parks Victoria and DELWP project: Valuing Victoria's Parks (2015) – ABS pilot ecosystem accounts for the Great Barrier Reef (2015) – Wentworth Group's trial of environmental condition accounts for ten Natural Resource Management (NRM) regions across Australia (2014) – DELWP Victorian Experimental Ecosystem Accounts (2013) – ABS Land Account: Victoria, Experimental Estimates (2012)
National level Priority setting, measuring progress	– ABS Australian Environmental-Economic Accounts (annually since 2014) – Statistics New Zealand Environmental-Economic Accounts (2014) – Canadian Environmental-Economic Accounts (2014) – Human Activity and the Environment 2013: Measuring ecosystem goods and services in Canada (2013) Ecosystem accounts: – Netherlands Experimental Water Quality (2011) – Canada Wetland (2012) – UK Natural Capital Freshwater (2015) Other: – DEFRA UK National Ecosystem Assessment (2012, 2015)

2.1 Marine and Coastal Ecosystem Accounting

Victoria's marine and coastal assets are fundamental to the economy and societal wellbeing. They contribute to Victoria's liveability and sustainability by providing clean water and air, habitats for species, and are the basis for many Victorian industries such as aquaculture and tourism.

Accounting for marine and coastal assets is quite different to accounting for terrestrial environmental assets. For instance, the boundaries of terrestrial assets and the associated economic owners or managers are generally clearer. Further, the services provided by terrestrial assets can be more easily attributed to the asset itself and the economic owner. This connection between economic owners and terrestrial assets makes the environmental-economic link more transparent for policy and decision making. The boundaries of marine and coastal ecosystems are difficult to observe and ownership is often assigned to areas of water rather than areas of a marine ecosystem.

Economic owners may be private or public entities. For instance, state and national parks are managed by the government on behalf of society to protect Victoria's ecosystem and biodiversity, protect culture and heritage, and connect people with parks, and provide ecosystem services to the public in general.[14] The link between users of the assets and the economic owner (government) is less clear and the distribution and assignment of benefits is more difficult. However, it is still possible to examine the extent of the assets (parks) and estimate the services they provide to users (visitors) and hence estimate the benefits they obtain.

Marine and coastal assets are similar to parks, but they have more characteristics of 'common pool resources' than parks. This means that excessive use of marine and coastal resources for production or

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[14] Department of Environment, Land, Water and Planning and Parks Victoria (2015) *Valuing Victoria's Parks*, available at http://www.delwp.vic.gov.au/news-and-announcements/valuing-victorias-parks

consumption purposes may cause problems of congestion or overuse and degradation. While the core resource in marine or coastal areas (eg water, fish) is protected or nurtured in order to allow for its ongoing use, many of the associated goods and services can be harvested or consumed so there is a risk of over consumption. For a body of water, such as the Port Phillip Bay, there is a point at which the use of goods and services may reach capacity and some users could be prevented from accessing them or alternatively the capacity of the Bay to provide services may be exhausted. The overuse of an asset that results in a fall in its capacity to provide services would be reported in an accounting framework as degradation.

A key challenge in developing accounts for Port Phillip Bay is to incorporate the concept of common pool resources and recognise it in the accounts. This issue is particularly important when considering the nutrient processing services the Bay provides to many different users (beneficiaries).

2.2 Overview of Port Phillip Bay

Port Phillip Bay is very large and shallow. Its greatest depth is 24 metres and almost half the Bay is less than 8 metres deep.[15] The Bay's 264 kilometres of coastline is almost continuously populated and includes Victoria's two largest cities – Melbourne and Geelong. The Bay itself is 1,950 square kilometres and its catchment area is 9,790 square kilometres.

Port Phillip Bay is not a homogenous environmental asset but is made up of a series of ecosystem assets each providing services to one another and in aggregate to people in Melbourne and surrounding catchments. Port Phillip Bay contains a variety of ecosystems (assets) including saltmarsh, mangroves, seagrass, rocky reefs and soft sediments. Figure 1 illustrates some of the Bay's ecosystem assets (reef and seagrass), services and benefits (fishing, water purification through the removal of nitrogen), and the relationship between the catchment and the coast. These ecosystems deliver important ecosystem services that people benefit from. For example, soft muddy sediments at the centre of the Bay support the process of denitrification where nitrate is converted into nitrogen gas and released into the atmosphere.[16] This ecosystem service is essential for removing (processing) nitrogen that is flushed into the Bay via the catchments or the Western Treatment Plant. Soft muddy sediments provide a benefit to the community by helping to maintain the Bay's water quality and reducing the risk of algal blooms which can impact on recreation, tourism and aquaculture. Further this benefit has a high economic value because if the Bay were not processing those nutrients then they would need to be removed by some other mechanical or industrial means.

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[15] CSIRO (1996) *Port Phillip Bay Environmental Study: The Findings 1992-1996*, report for Melbourne Water, p. 7.
[16] CSIRO (1996) *Port Phillip Bay Environmental Study: The Findings 1992-1996*, report for Melbourne Water, p. 23.

Figure 1 – Port Phillip Bay and catchment[17]

Ecosystem assets	Ecosystem services	Benefits
Seagrass	Denitrification	Recreation and tourism
Saltmarsh	Habitat and species	Fishing and aquaculture
Reef	Carbon sequestration	Climate change mitigation
Sediments		

Although the scope of this study is limited to Port Phillip Bay, it is important to recognise the connection between catchment and marine ecosystems. Inter-ecosystem flows from the catchment impact on ecosystem assets in Port Phillip Bay. Similarly, people receive benefits in the Bay that are linked to ecosystem assets in the catchment. A key example of this is swimming and other water-based recreation. The benefit people derive from swimming in Port Phillip Bay is influenced by water quality, which is linked to ecosystem assets in the catchment – such as wetlands and riparian vegetation – that provide water filtration services. This example shows how benefits can be realised in the Bay from management of ecosystems in the catchment.

Protecting or better managing wetlands in the catchment would increase the benefit people get from recreation in Port Phillip Bay. Improving agricultural based ecosystem (farms) management to reduce nutrient runoff would have a similar effect. Environmental-economic accounting provides an integrated information base for evaluating trade-offs in managing assets in both the marine and terrestrial contexts.

2.3 Environmental-Economic Accounting: Core Model

Figure 2 outlines the core model that will be used for accounting in this study. The core model links ecosystem asset extent to condition and services to estimate the benefits they provide to the economy and society. The following sections explain the core model in the context of the Bay.

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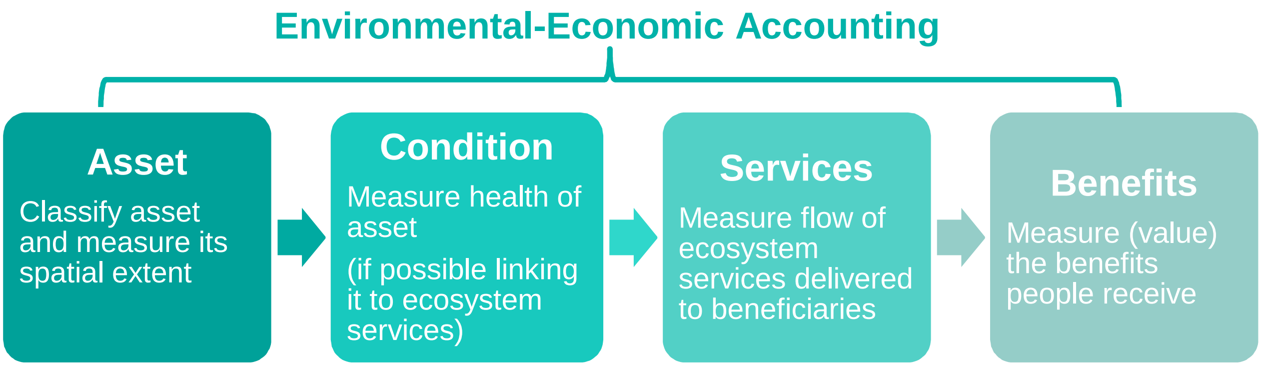
[17] Source: Adapted by DELWP from Environment Protection Authority (2016).

Figure 2 – Integrating the measurement of environmental assets and valuation of their benefits



2.3.1 Assets

Ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together.[18] In accounting terms, ecosystem assets are stocks (say hectares of land) which deliver a flow of ecosystem services. Ecosystem assets are measured at a point in time using two key metrics – extent (ha) and condition. Port Phillip Bay is made up of a number of ecosystem assets such as seagrass beds, saltmarsh, mangroves, rocky reefs and soft sediments.

In the first instance, it is important to understand the extent of the assets because this, with condition, determines the flow of ecosystem services. Also, ecosystem assets provide services that are spatially significant and in some instances relevant to other ecosystems. For instance, seagrass may be providing local nursery habitat for fish but once the juveniles come of age they move to another ecosystem and live to adulthood (there are also numerous species that live to adulthood in bays and then breed in open oceans, and vice versa). Further, there may be different types of seagrass providing different types of services – not all seagrass provides nursery habitat.

Ecosystem assets must be classified so they can be consistently organised within the environmental-economic accounting framework over time. This study uses the Combined Biotope Classification Scheme (CBiCS). CBiCS is a relatively new scheme that adapts components from the Joint Nature Conservation Committee – European Nature Information System (JNCC-EUNIS) and the United States' Coastal and Marine Ecological Classification System (CMECS). CBiCS provides a unified scheme for classifying all marine habitats and biotopes and is consistent with the terrestrial classification of vegetation biotopes and biotope complexes (e.g. Ecological Vegetation Classes (EVCs) and EVC communities in Victoria). CBiCS is a hierarchical scheme that enables the incorporation of a variety of information sources of disparate types and levels of resolution. The classification hierarchy is outlined in Figure 3.

From a marine and coastal ecosystem accounting perspective, information at the habitat complex level is often most useful, as it identifies different ecosystem assets such as seagrass or mangroves. Although ecosystem assets can sometimes be disaggregated at the species level, this is rarely useful for broad assessments of ecosystem services and benefits, given the current state of knowledge about the relationship between marine and coastal ecosystem assets and the services they provide. However, information at the biotope level (Level 5) may be relevant for specific issues or very localised natural resource management.

A key advantage of hierarchical classification schemes is that data can be aggregated to higher levels (eg biotope complex level to habitat complex level) for reporting purposes. This means that data collected at more granular levels can be aggregated and used for a variety of purposes.

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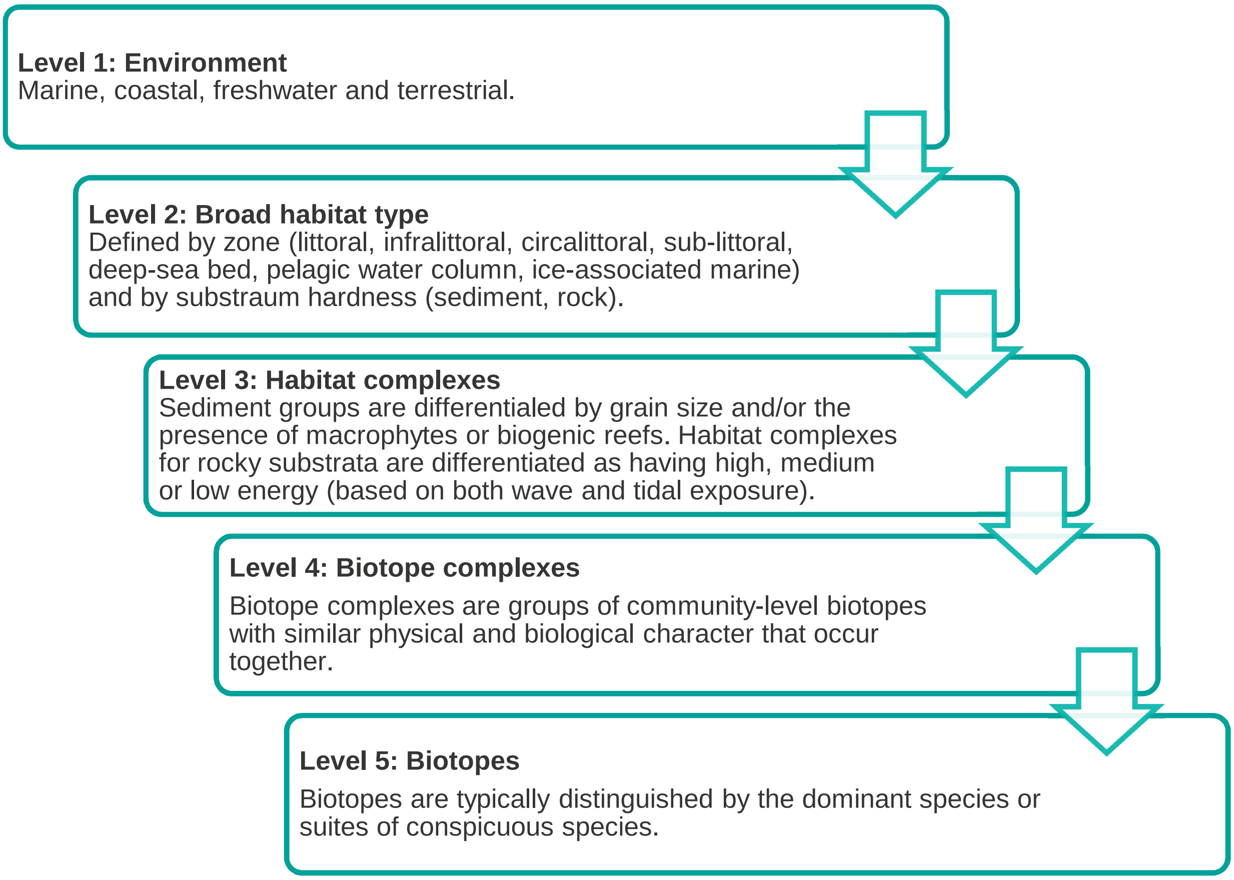
[18] United Nations (2014) *System of Environmental-Economic Accounting 2012: Central Framework*, United Nations, New York, pp. 13-4.

Figure 3 – Combined Biotope Classification Scheme (CBiCS) hierarchy



Level 1: Environment
Marine, coastal, freshwater and terrestrial.

Level 2: Broad habitat type
Defined by zone (littoral, infralittoral, circalittoral, sub-littoral, deep-sea bed, pelagic water column, ice-associated marine) and by substraum hardness (sediment, rock).

Level 3: Habitat complexes
Sediment groups are differentialed by grain size and/or the presence of macrophytes or biogenic reefs. Habitat complexes for rocky substrata are differentiated as having high, medium or low energy (based on both wave and tidal exposure).

Level 4: Biotope complexes
Biotope complexes are groups of community-level biotopes with similar physical and biological character that occur together.

Level 5: Biotopes
Biotopes are typically distinguished by the dominant species or suites of conspicuous species.

Source: Adapted by DELWP from Edmunds and Flynn (2015)

DELWP is in the process of adopting CBiCS and the marine and coastal mapping standard with existing mapping being reclassified in accordance with the scheme, commencing with Port Phillip Bay, Western Port and Gippsland Lakes and then the Victorian open coast.

The framework for delineating spatial areas for ecosystem accounting consists of ecosystem assets (EA), basic spatial units (BSU) and geographical areas (GA). Conceptually, ecosystem assets are contiguous areas (collections of BSUs) of a single ecosystem type (eg an area of seagrass beds). Generally, accounting will be done at an aggregated level (area) that may include multiple EAs and only part of some EAs (ie only part of a seagrass EA may be inside a specific geographic accounting area). Using a grid of BSUs allows for aggregation to different boundaries for different purposes. For this study the Environmental Systems Modelling Platform (EnSym) has been used.[19]

Geographic areas can be based on administrative or management boundaries such as local government areas, catchment regions or park areas. They can also be based on large-scale natural features and processes. For example, Australia’s landscapes have been classified into several geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information. For this study, Port Phillip Bay has been divided into five geographic areas – Central, Corio, Exchange, Hobsons and Intertidal. The geographic areas used in this study are shown in Figure 4.

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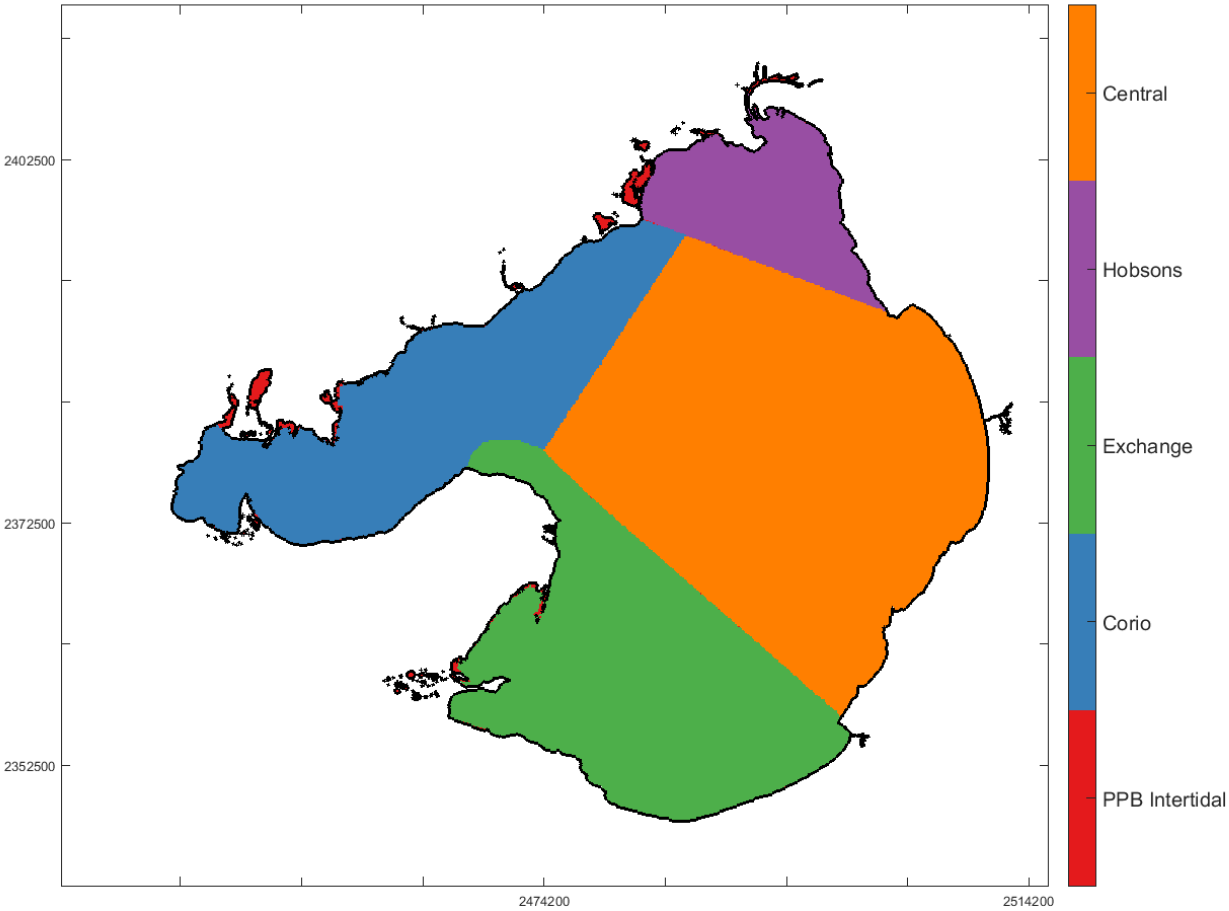
[19] For more information see https://ensym.dse.vic.gov.au/cms/

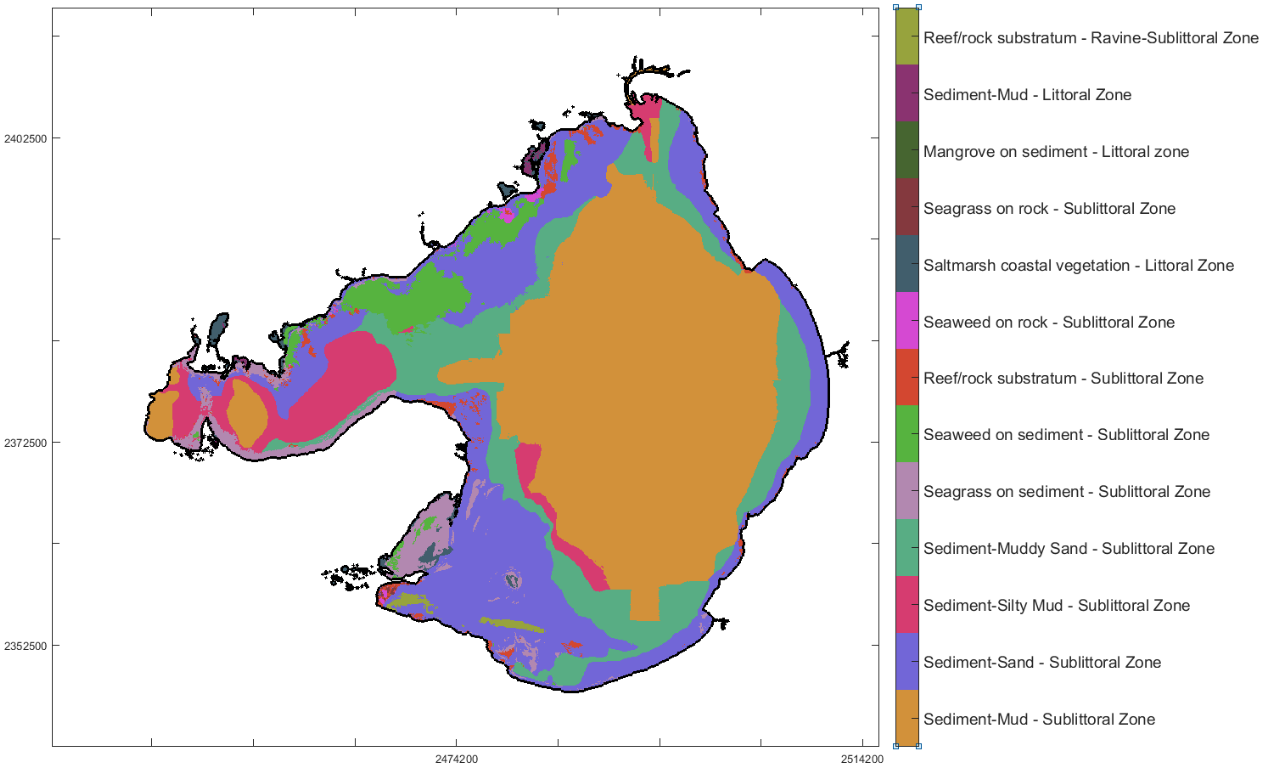
Figure 4 – Geographic aggregations for Port Phillip Bay accounts



Source: DELWP EnSym

Bay habitats are illustrated in Figure 5. It shows very large areas of muddy sediment in the centre of the Bay and in Corio Bay (in the western arm of the Bay) which are responsible for water filtration services (the removal of nitrogen from the water). On the western side of the Bay there are also large areas of seaweed communities, seagrass and coastal salt marshes which are important habitat for a number of species.

Figure 5 – Port Phillip Bay habitats



Source: DELWP EnSym

2.3.2 Condition

Ecosystem assets are characterised at a point in time using two key metrics – extent and condition. Extent is a spatial measure (such as hectares), while condition describes the quality of ecosystem assets. Condition is important because it underpins an ecosystem assets capacity to fully function and provide ecosystem services. An ecosystem asset that is in good condition will generally generate more services than one in poor condition, if all other things (such as people) remain the same.

Crucially, a condition metric must be an indicator of the health of the specific ecosystem asset. For example, to use bird population as a condition metric, the bird population must be directly related to the health of the asset (such as a wetland), and not influenced significantly by anything else. A change in the condition metric must reflect a change in the health of the asset and its ability to function and provide services. Once indicators are chosen and measured, the task from an accounting perspective is to develop methods that support comparison and aggregation across asset classes. Being able to understand the relative condition of different ecosystem assets is core to the accounting approach. For this, indicators should be developed based on a benchmark or reference condition.

In an accounting context, changes in condition encompass both natural changes and changes induced by economic activity. For instance, if there is an extended wet or dry period this may have an impact on the condition of an asset and its ability to function. Alternatively, an economic activity may be undertaken (say dredging) that mobilises materials in the Bay resulting in a change in condition for some assets. It is important to differentiate between the changes in condition in order to understand the drivers and possible policy/management responses. For instance, if condition is falling solely due to extreme climate conditions it is likely very little can be done from a local management point of view in the short term.

Due to a lack of suitable data for this study it was not possible to populate condition accounts for Port Phillip Bay. However, there are a number of metrics which can be linked to Port Phillip Bay ecosystem assets that could be explored for future use. These are discussed in Section 3.3, Table 6.

2.3.3 Services

Ecosystem services provide the link between ecosystem assets and the benefits derived and enjoyed by people. They are generated through ecosystem processes reflecting the combination of asset characteristics, intra-ecosystem and inter-ecosystem flows.[20] Conceptually, the provision of ecosystem services and their benefits to people can be described as a natural production process. The diverse nature of ecosystem services and their beneficiaries has motivated the development of an ecosystem service classification system outlined in Table 2 below.

Table 2 – Ecosystem service classification

Ecosystem Service	Definition	Examples
Provisioning services	Tangible goods and services that can be exchanged or traded, as well as consumed or used directly by people.	Provision of food, water and other raw materials.
Regulating services	Ways in which ecosystems control or modify parameters that define the environment of people; these are ecosystem outputs that are not consumed but affect individuals, communities and populations and their activities.	Climate regulation; watershed regulation such as purification and flood control; and biological processes such as pest control, pollination and genetic diversity.
Cultural services	Non-material ecosystem outputs that have symbolic, cultural or intellectual significance.	Recreational services; spiritual and cultural connection; landscape amenity; health services; social cohesion and involvement.
Supporting services	Ecosystem functions that support and enable the maintenance and delivery of final services	Habitat for species

Source: Adapted from CICES for SEEA Experimental Ecosystem Accounting (2014).

A fourth category of ecosystem services, known as 'supporting' services, has been identified to describe services within ecosystem assets that support and enable the maintenance and delivery of services in general. Care should be taken when assessing the benefits from ecosystem services to eliminate double counting and ensure that only benefits to people from final ecosystem services are valued.[21]

Within the SEEA only final service flows are quantified which includes those that can be linked directly to production and consumption activities, and human wellbeing. However, when undertaking ecosystem accounting it is important to recognise the dependences that exist between ecosystems and to measure and report services moving between them.

2.3.4 Benefits

While the intrinsic value of healthy ecosystems needs to be recognised, the valuation of benefits aims to assess the contribution ecosystems make to our economic and social wellbeing.[22] Ecosystem services provide socio-economic benefits to people. Some benefits – such as tourism or commercial fishing – take place in the economy and have observable market transactions. Other benefits are non-market – such as recreation or climate change mitigation through carbon sequestration. Benefits can be assessed in qualitative and quantitative terms or in monetary terms via economic valuation techniques.

The purpose of the valuation will determine the type of economic values that will need to be estimated. For example, reporting *total* value (the *total* benefit provided by an asset) is relevant to assess the economic

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[20] United Nations (2014) *System of Environmental-Economic Accounting 2012: Central Framework*, United Nations, New York, p. 14.

[21] TEEB (2010) 'Chapter 5: The economics of valuing ecosystem services and biodiversity' in *The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations*, p. 12.

[22] Note that there are two different (but often related) types of value used in accounting and economic frameworks. Exchange values are used by accountants to measure the value of economic activity or transactions that are consistent with System of National Accounts (SNA) or SEEA definitions and international standards. Exchange values exclude consumer surplus. Welfare values are used by economists to measure the net economic gain (or change in welfare) associated with a specific land use, proposed policy or investment. Welfare values include consumer surplus. A comprehensive discussion of types of value and use in environmental-economic accounting can be found in Department of Environmental, Land, Water and Planning (2015) *Valuing Victoria's Parks*, pp 15-45, available at http://www.delwp.vic.gov.au/news-and-announcements/valuing-victorias-parks

contribution of a given asset, while estimation of the *change* in value coming from an asset is more relevant to appraisals of management or policy options being assessed. A counterfactual baseline scenario is generally required to assess the increase or decrease in benefit under alternative policy or management scenarios.

This study assesses the total value of some of the benefits from Port Phillip Bay ecosystem assets at a point in time – it does not consider changes in benefit. As environmental-economic accounts become more comprehensive and time series are recorded, the capability to model changes in benefits under different scenarios will evolve.

There are a range of techniques available for valuing the benefits provided by ecosystem services in monetary terms. Market valuation is the preferred valuation method. However, as many benefits from environmental assets are not traded, or are not traded with sufficient volume, other techniques are suitable to replace market values. Selecting the right technique for each situation will depend on a number of factors such as:

- the type of economic and environmental data available
- the ecosystem service (some techniques are suited to particular types of ecosystem services)
- time and budget available
- availability of experienced practitioners.

Non-market valuation is being increasingly used across a number of sectors, including health, transport and the environment, noting that a high standard of rigour is required to deliver credible values. Its use in economic analysis helps by providing a more complete picture of welfare outcomes.

2.4 Biodiversity Accounting

As a component of biodiversity, species form the biotic elements of ecosystems and have an important role in how ecosystems function and deliver ecosystem services that support economic activity and human wellbeing.

Specific species can also contribute directly to economic activity and wellbeing. For instance, some species are important for providing food or medicines used by local communities and in commercial activities. Other species may contribute to wellbeing due to their charismatic and iconic nature which is valued on the basis of aesthetics, characteristics and behaviour, or because of the cultural status given to them.[23]

Species accounts may support the following analytical uses:[24]

- Comparing current trends in species status with information on economic activities and other drivers of species loss.
- Exploring trends by organising the information required to support trend analysis (for instance, via interpolation or forecasting).
- Organising information on species for aggregation and communication across all scales.
- Communicating the relationships between species, ecosystems and the supply of ecosystem services.
- Providing objective statistics to report on policies related to species and ecosystems.
- Exploring future trade-offs by organising species information required to support scenario modelling.
- Informing cost-benefit or ecological return on investment analyses.
- Supporting expert judgement on species status and trends by organising available information on the observations of species.

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[23] UNEP-WCMC (2016) 'Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA'.
[24] UNEP-WCMC (2016) 'Exploring approaches for constructing Species Accounts in the context of the SEEA-EEA'.

For this study a limited set of species accounts are discussed in Section 3.3, Table 6.

2.5 Measuring Change: Demonstration Set of Accounts

Due to the scarcity of data for accounting in marine and coastal areas (relative to terrestrial areas) this section provides a worked example of demonstration accounts to show how they can be used to analyse change over time when time series information is available. While extent and condition accounts at a point in time can be informative, the full potential of accounts is realised by measuring and reporting change over time. In particular, accounts can help to address the following questions:

- What Port Phillip Bay ecosystem assets have significantly changed in extent or condition?
- Why have assets been changing?
- How do these changes impact on key ecosystem services?
- What is the impact on social and economic wellbeing from changes in the extent and condition of Bay ecosystems?
- What are the costs associated with managing Port Phillip Bay ecosystems in order to maintain both their extent and condition in order to preserve a given set benefits (ecosystem services)?

The following accounts illustrate a hypothetical example of how accounts can be used over time to evaluate changes in extent, condition and ecosystem services.

The extent account below presents the areas recorded for five different ecosystem assets (EA) at two points in time, which are referred to as ‘opening stock’ and ‘closing stock’. In this demonstration, the total area includes the five ecosystem types and built assets (ports). Through identification of additions and reductions to stock, this account helps explain changes over time.

The example extent account (Table 3) shows that the case study region maintains a large representation of ecosystems one, three and four across both periods. However, the account also indicates that significant changes have occurred. A hypothetical port expansion has affected both ecosystems four and five (managed regression). Since ecosystem four provides habitat for rare species, offsets (managed expansion) were required in a different area (resulting in a managed regression of ecosystems one and three). New measurement techniques uncovered ecosystems that were thought to belong to a type but have now been shown to be another type, shown as upward reappraisals for ecosystems one and two (and downwards reappraisals for ecosystems four and five). Overall, the reductions in stock of ecosystems due the port expansion and natural regression outweigh the managed additions in stock across the five ecosystem types.

The changes in ecosystem extent are fundamental to understanding how our landscapes and seascapes are being shaped and used. The information helps contextualise the impact of government programs, investments and regulation, urban and infrastructure developments, along with impacts of natural events that may need to be managed or responded to (eg climate change adaptation). It is also possible to map where the changes have occurred using software like EnSym.

Table 3 – Example extent account for all ecosystems (hectares)

	EA1	EA2	EA3	EA4	EA5	Ports	Total
Opening stock (start year)	5,456	687	5,165	9,871	458	98	**21,735**
Additions to stock							
Managed expansion				600		750	1,350
Natural expansion		100	600		150		850
Upward reappraisals	80	275					355
Total additions to stock	80	375	600	600	150	750	**2,555**
Reductions in stock							
Managed regression	220		380	600	150		1,350
Natural regression	550	175		125			850
Downward reappraisals				275	80		355
Total reductions in stock	770	175	380	1,000	230	0	**2,555**
Closing stock (end year)	4,766	887	5,385	9,471	378	848	**21,735**

Note: 'EA' as in EA1…EA5 refers to hypothetical ecosystem assets, 'managed expansion' refers to investments in restoration or establishment of ecosystems, 'managed regression' is the opposite and includes clearing for example to develop transport infrastructure, 'natural expansion' refers to natural regeneration, and 'natural regression' describes natural degradation. Reappraisals are changes from improved measurements or revised classifications systems.

The example condition account (Table 4) summarises the area of ecosystems under a hypothetical condition measure (scale of 1 to 10) over time. This format of the accounts helps to understand broad changes in condition over time. For example, the account below indicates that across *all ecosystems* there is an increase in condition as the area of ecosystems in 'excellent' condition increases by 200 per cent. The area of ecosystems in poor condition decreases by 13 per cent. Some of the largest areas that were originally in the medium condition category have moved into the good or excellent condition categories. Note that if data are available more detailed condition accounts can be created (similar to the extent account above), to identify which ecosystem types have changed condition and why.

Table 4 – Example condition account for all ecosystems (hectares)

Condition score	0-1 poor	2-4 fair	4-6 medium	6-8 good	8-10 excellent	Total
Opening	4,977	3,246	10,386	2,164	865	21,637
Closing	4,177	3,760	6,266	4,177	2,506	20,887
Change	-649	649	-3,895	2,164	1,731	
	-13%	20%	-38%	100%	200%	

Note: Condition information applies to natural ecosystems only (built assets are not included).

Finally, with a set of accounts that provide the core information on ecosystem changes (extent and condition), the next step is understanding how these changes are likely to affect ecosystem services. Ecosystem services can be measured (eg fish abundance or catch, number of visitors to marine parks or anglers) or modelled (eg carbon sequestration, nursery habitats, waste assimilation – regulating services will more likely need to be estimated). Depending on the data available accounts can be produced to measure overall change in the past, or to inform assessment of *expected* forward looking change under potential alternative management options (as part of planning options and project appraisals).

The account in Table 5 below outlines how different physical flows can be mapped against ecosystem types. Additional accounts can be produced for each ecosystem service at a given point in time to identify the flows between relevant parties (both ecosystems and economic players) acting as suppliers and users, which is a standard way to present all transactions across sectors of the economy (also known as supply-use tables).

Table 5 – Example indicators of ecosystem services

	Indicators of ecosystem services (annual flows)									
	Seafood production (fishing & aquaculture)		Nursery habitats		Waste assimilation		Carbon sequestration		Recreational fishing	
	Y1 mean (SD)	Y2 mean (SD)	Y1 mean (SD)	Y2 mean (SD)	Y1 mean (SD)	Y2 mean (SD)	Y1 mean (SD)	Y2 mean (SD)	Y1 mean (SD)	Y2 mean (SD)
Ecosystem	Volume in the market (kg)	Volume in the market (kg)	Nursery habitat suitability (score)	Nursery habitat suitability (score)	Removal of nutrient excess (kg/m3)	Removal of nutrient excess (kg/m3)	Carbon sequestered (kT)	Carbon sequestered (kT)	Angling activity (# fishing trips)	Angling activity (# fishing trips)
EA1	-	-	0.4 (0.2)	0.4 (0.3)	40 (10)	41 (10)	-	-	1,030 (78)	1,000 (35)
EA2	3,099 (31)	3,214 (24)	-	-	71 (55)	70 (50)	-	-	990 (73)	1,290 (70)
EA3	-	-	-	-	40 (10)	41 (10)	1,563 (263)	1,675 (400)	1,260 (92)	1,560 (95)
EA4	1,321 (27)	1,315 (60)	-	-	40 (10)	41 (10)	-	-	1,100 (92)	1,200 (90)
EA5	-	-	0.8 (0.2)	0.7 (0.2)	50 (10)	55 (10)	-	-	700 (57)	570 (47)

Note: 'EA' as in EA1…EA5 refers to hypothetical ecosystem units, SD refers to standard deviation.

3. Data and Information

3.1 Information Hierarchy

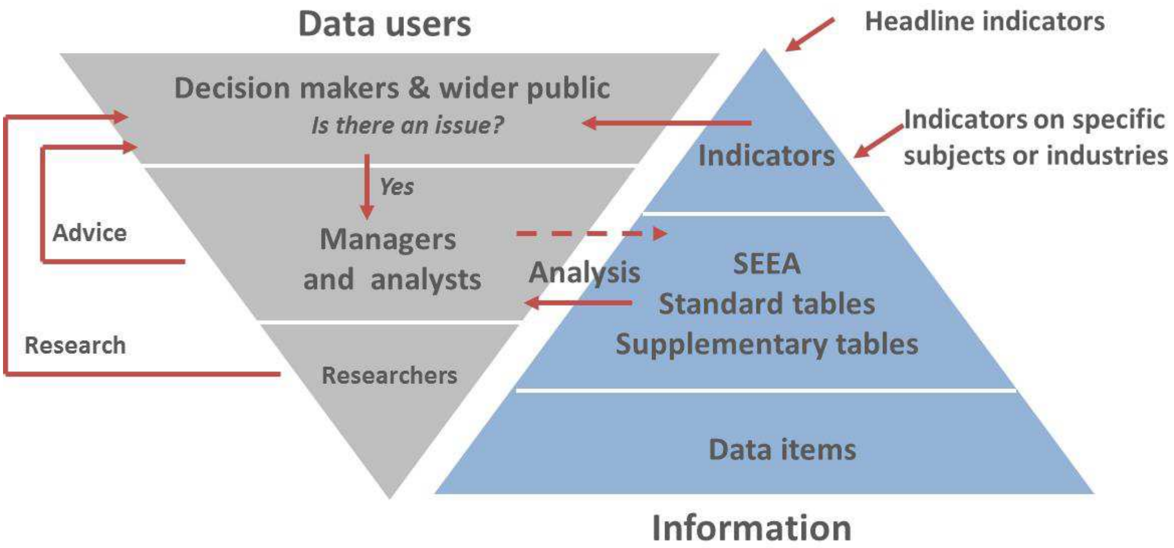
Environmental-economic accounting is a system for organising statistical data about environmental assets and the ecosystem services they provide. Accounting does not necessarily require the collection of new data, although the process of completing accounts often highlights knowledge and information gaps.

Environmental indicators are often derived from available information which is piecemeal and may not directly relate to ecosystem assets. This makes it difficult to understand the condition of specific assets to evaluate the benefits they provide to the economy and society.

As environmental-economic accounting is essentially a system for organising data, it does not propose a single headline indicator. However, comprehensive accounts can be used to generate a wide range of indicators for different purposes and descriptive statistics with many potential analytical applications. This means that the same accounts can be used for different program and policy needs over time. If the data do not exist, then further data may need to be collected whilst ensuring any new data collected follows the principles of the core model.

Figure 6 illustrates how environmental-economic accounting sits between basic statistics and indicators, and provides a consistent framework for organising information using common concepts, terms and definitions.

Figure 6 – Aggregation of basic statistics into accounts and indicators



Source: Vardon, M et al (2012) 'The System of Environmental-Economic Accounting for Water: development, implementation and use'. Published in *Water Accounting – International Approaches to Policy and Decision-making*.

A long-term vision is to have comprehensive accounts that can be used to derive coherent and comparable indicators and measures of progress towards policy goals. The process of populating accounts will help identify key data gaps and ensure that indicators are linked to the assets being managed. The environmental-economic accounting framework can inform decisions about which data to collect and the quality of data needed for a particular purpose.

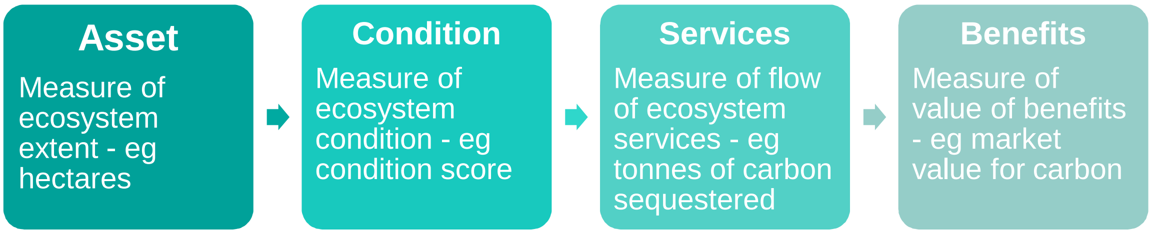
Although threats to environmental assets come into environmental-economic accounting, it is not in itself a threat assessment framework. Accounts simply present information on the stocks and flows associated with ecosystem assets (including flow of ecosystem services) at one or more points in time, which can then be used to identify, measure and value socio-economic benefits. Threats (such as invasive species) affect the condition of an ecosystem asset, which in turn affects the flow of ecosystem services and the benefits to people. This differs from the Driving forces, Pressure, State Impact, Response (DPSIR) framework, which is used to describe multiple causal biophysical links between threats and impacts on ecosystems. Accounts inform policy and decision-making through statistics and indicators on ecosystems and incorporate the benefits ecosystems provide. As such, environmental-economic accounts and the DPSIR framework are complementary.

Environmental-economic accounting can be used to analyse trends and causal relationships by monitoring the condition of ecosystem assets over time and understanding links to socio-economic benefits. Supporting statistical analysis and scenario modelling is part of the long-term vision for environmental-economic accounting.

3.2 Data Requirements and Sources

Comprehensive accounts require spatially referenced quantitative environmental, economic and socio-demographic information. Figure 7 shows the type of data required at different stages. All data must be spatial in that it can be directly or indirectly referenced to a location and hence linked to an ecosystem asset.

Figure 7 – Data required for environmental-economic accounts



Ecosystem extent accounts require spatial data on the area of different ecosystem assets. Ideally the data will be classified according to a hierarchical classification scheme so it can be aggregated within geographic areas for reporting. This study uses the latest habitat mapping data classified under the Combined Biotope Classification Scheme (CBiCS).[25] This new classification system directly incorporates mangrove and coastal saltmarsh mapping data[26], and historical seagrass mapping[27] was refined using new data.

Ecosystem condition accounts require spatial data on the condition of ecosystem assets. This can be a metric that provides a composite condition score, or a single measure that is representative of ecosystem condition, or it can be a series of measures. Crucially, a condition measure must be an indicator of the condition of a specific ecosystem asset and can be used to infer the capacity of an ecosystem to function and provide services. As noted earlier, condition data for marine ecosystems emerged as a key gap in this study, which meant that ecosystem condition accounts were not produced for this report.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is currently working with DELWP to develop marine indicators for four key ecosystems in Port Phillip Bay and Western Port Bay: unvegetated sub-tidal soft sediments; vegetated sub-tidal soft sediments; sub-tidal rocky reefs; and inter-tidal vegetated soft sediments. There is potential for these indicators to be incorporated into the environmental-economic accounting framework as condition metrics in the future.

3.3 Metrics Available for Port Phillip Bay in the Accounting Framework

A number of metrics currently available for Port Phillip Bay are mapped below against the four components of the environmental-economic accounting framework – extent, condition, services and benefits. Biodiversity metrics could be used to represent condition features (if appropriate as noted above), and they can also be linked to ecosystem services. This table shows that the information is partial for some ecosystems, particularly seagrass beds and sublittoral sediments.

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[25] Edmunds,M., Ierodiaconou, D., Flynn, A. and Ferns, L.W. (In prep) *Marine biotope mapping: a new hierarchical ecosystem classification system for Victoria.*

[26] See Boon, P. et al (2011) *Mangroves and coastal saltmarsh of Victoria: distribution, condition, threats and management*, Victoria University, Melbourne.

[27] See Blake, S. and Ball, D. (2001) *Victorian Marine Habitat Database: Seagrass mapping of Port Phillip Bay*, Marine and Freshwater Resources Institute, Queenscliff.

Over time, it will be important that the information collected across Port Phillip Bay ecosystems is able to provide a more complete and balanced picture of not only ecosystem condition, but also ecosystem services and their linkages to community and economic activity.

Table 6 – Existing Port Phillip Bay metrics against DELWP environmental-economic accounting framework

Classification	Asset extent	Asset condition	Ecosystem services	Benefits	Species Accounts*
Saltmarsh Mangrove	Extent of mangrove-saltmarsh communities (embayment scale) Extent of mangrove-saltmarsh communities (selected sites)	Saltmarsh condition – abundance, habitat hectare condition scores (PPB) Shorebird habitat quality at foraging sites (PPB) – extent and topography of intertidal habitat			Shorebird census at foraging sites (PPB) – number individuals Shorebird food at foraging sites (PPB) – biomass of invertebrates
Seagrass	Seagrass extent		The growth of seagrass-dependent species (fish)	King George whiting (juvenile fish per net haul) Snapper (juvenile fish per 1000 m^2) Sand flathead (juvenile fish per 1000 m^2)	King George whiting (juvenile fish per net haul) Snapper (juvenile fish per 1000 m^2) Sand flathead (juvenile fish per 1000 m^2)
Muddy sediments		Denitrification efficiency	Tonnes of nitrogen removed	Clean water	

Source: DELWP. *The species information for King George whiting, snapper and sand flathead may be included in benefits if they are harvested or in species accounts for records on their conservations status.

Future data collection would benefit from applying the core accounting model in order to link data collection to policy analysis and decision making for Bay assets. For instance, data may be collected to:

- understand the extent of an asset and how it is changing;
- understand the condition of an asset and how it is changing; or
- understand the link between an ecosystem's condition and its ability to provide a suite of services.

By publishing environmental-economic accounts on an ongoing basis it is possible to understand data gaps and invest in data collection based on policy and management needs.

3.4 Water Quality Monitoring

The Environment Protection Authority (EPA) undertakes water sampling at eight sites in Port Phillip Bay on a monthly basis. Six of the sites have been sampled since 1990. These sites provide a balance between areas that are close to major Bay inflows from the surrounding catchments and the Western Treatment Plan (Hobsons Bay, Newport, Patterson River and Long Reef) and others that are distant from terrestrial inflows (Popes Eye and Central Bay).

The data collected includes[28]:

- **Nutrients -** Nitrogen and phosphorus are essential nutrients for plant and animal growth. Excessive levels of nutrients can greatly impact aquatic plants and subsequently environmental water quality, by promoting the growth of organisms like blue-green algae.
- **Turbidity -** Turbidity is a measure of water clarity (how clear the water is). High turbidity (low clarity) is caused mainly by large concentrations of sediments that are washed off catchments into streams and rivers, and ultimately into the Bay. High levels of sediments can significantly impact the health of aquatic ecosystems.
- **Metals** - Metals occurring naturally in the earth's crust are released into the environment from the physical and chemical weathering of rocks. However, metals produced by humans are found in industrial and municipal waste products, urban and agricultural runoff, atmospheric deposition and antifouling paints applied to marine vessels. Most metals are toxic to organisms above certain levels.
- **Salinity -** Salinity refers to how much salt is in the water. The water in rivers and streams is usually fresh, oceans are salty and estuaries are highly variable depending on tides and freshwater flows. Most aquatic organisms have evolved to function within an optimal salinity range and tolerate natural cycles within this range.
- **Dissolved Oxygen -** Dissolved oxygen (DO) refers to the amount of oxygen contained in water. Most aquatic animals and plants need oxygen to be above a certain level, and this level can vary depending on the organism. Either too little or too much oxygen in the water can have negative impacts on their physical wellbeing.
- **pH -** pH is a measure of acidity or alkalinity of water ranging from acidic (pH less than 7) through to neutral (pH 7) and alkaline (pH greater than 7). Most aquatic organisms require pH to be within a particular range. If pH is outside this range, the effects can be detrimental to aquatic animals and plants.
- **Chlorophyll-A -** Chlorophyll-A is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Concentrations of chlorophyll-a are measured in the water to assess the level of algae. Higher concentrations can indicate poorer environmental water quality.

Understanding water quality is very important as many of the functions within the Bay and within ecosystems are influenced by nitrogen, total suspended solids and other water quality components. A recent study on seagrass resilience found that while the broad distribution of eelgrass (*Zostera nigricaulis*) can be explained by wave exposure and depth, there are localised areas of presence and absence that vary over time, meaning that water quality factors such as nutrients and sediments are likely to be drivers.[29] This illustrates the importance of gathering appropriate data to understand the drivers of changes in the extent and condition of ecosystem assets. If the drivers are primarily natural (wave exposure) there are limited options from a policy and management perspective. However, if the driver is water quality there are more options available. There may also be spatial variation with respect to the impacts, for instance some areas may be driven by wave exposure and others by water quality. This indicates that water quality alone is not a suitable indicator of ecosystem condition within the Bay.

Figure 8 shows the water quality index for four sites in the Bay: Corio Bay, Hobsons Bay, Popes Eye and Central Bay. Hobsons Bay is where inflows to the Bay are received from the Yarra and Maribyrnong Rivers. Following a prolonged period of drought in the lead up to 2010, nutrient loads to the Bay increased in 2010-11 as a result of increased rainfall.[30] This correlated with a decrease in water quality in Hobsons Bay. Corio Bay is located off the main area of Port Phillip Bay, and due to its position water circulation is more limited than in the rest of the Bay.[31] The flushing time (where all the water is replaced by new water) is in the order

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[28] http://yarraandbay.vic.gov.au/assets/water-quality

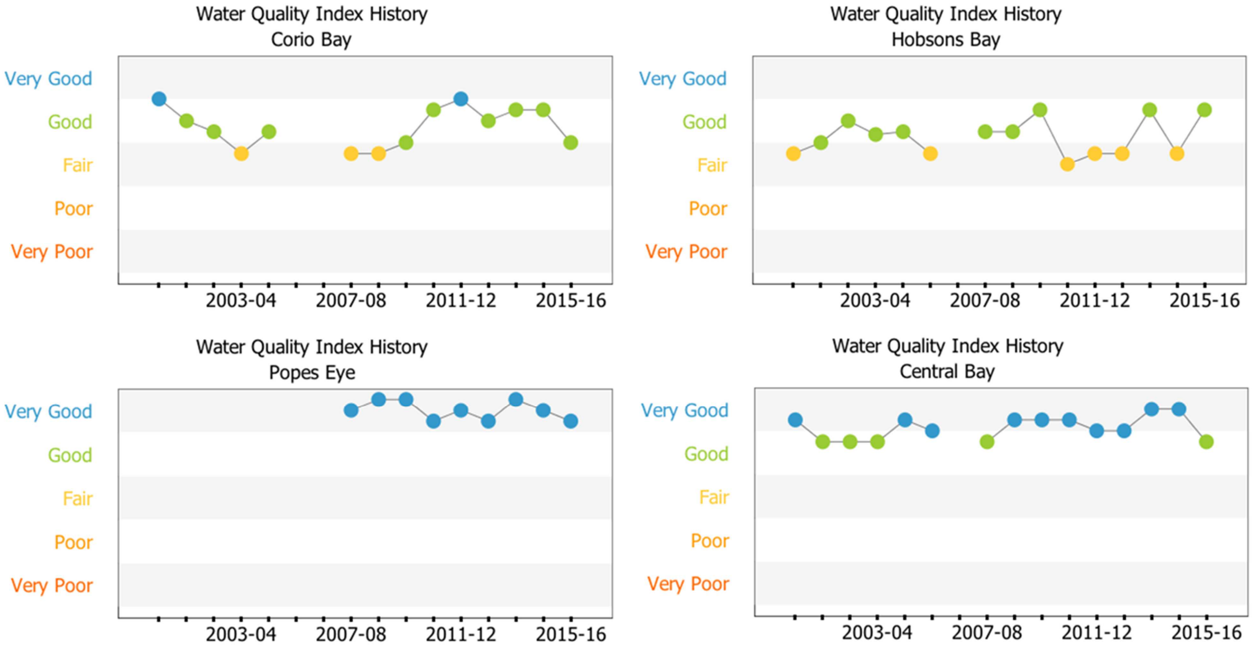
[29] Jenkins, G., Keough M. et al (2015), *Seagrass resilience in Port Phillip Bay: Final report to the seagrass and reefs program for Port Phillip Bay*, University of Melbourne.

[30] Commissioner for Environmental Sustainability Victoria (2013) *State of the Environment Report 2013*, p. 183.

[31] CSIRO (1996) *Port Phillip Bay Environmental Study: The Findings 1992-1996*, report for Melbourne Water, p. 8.

of six months.[32] This means that water quality may take longer to change in both a positive and negative direction, making Corio Bay particularly sensitive to nutrients and other inputs. Both Popes Eye and Central Bay represent areas that are quite distant from terrestrial inflows to the Bay and have shorter flushing times (particularly Popes Eye), thus their water quality generally remains good to very good. It is clear that levels of, and changes in, water quality vary greatly across the Bay, meaning that localised information is required for the development of management and policy approaches for ecosystem assets.

Figure 8 – Water Quality Index



Source: Yarra and Bay (2016).

There are a number of ecosystems in Port Phillip Bay that perform vital water filtration services by removing nitrogen from the water and reducing the incidence of algal blooms. The key provider of denitrification services are sub-tidal soft sediments in the centre of the Bay.

Figure 9 shows the total nitrogen loads that entered the Bay between 1996-97 and 2014-15 from six different sources. The sources include the Yarra, Werribee, Dandenong and Maribyrnong catchments, the Western Treatment Plant, and other sources.

Water filtration by ecosystems is very important to the cities of Melbourne and Geelong and all those who visit or live near the Bay. It is estimated that the Bay can processes around 5,000 tonnes of nitrogen per year from the catchment. The value of this service is estimated at around $11 billion per year, which represents the costs that would be incurred to achieve equivalent levels of denitrification through alterative means, such as upgrading infrastructure of wetland enhancement.[33]

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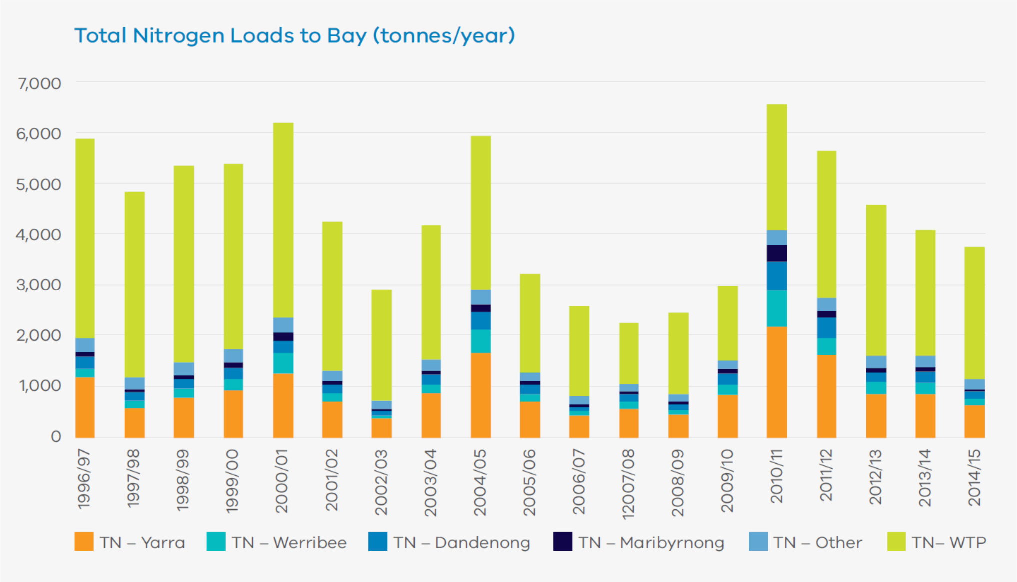
[32] Jenkins, G., Keough M. et al (2015), *Seagrass resilience in Port Phillip Bay: Final report to the seagrass and reefs program for Port Phillip Bay*, University of Melbourne, p. 37.

[33] Department of Environment, Land, Water and Planning (2015) *Protecting Victoria's Environment – Biodiversity 2036 – Consultation Draft*, p. 47.

Figure 9 – Nitrogen loads to the Bay



Source: Draft Port Phillip Bay Environmental Management Plan 2017-2027: Supporting Document

Although water quality may not be a suitable indicator for the condition of marine ecosystem assets, such as seagrass, water quality is a key condition indicator in water accounting. Water accounting is a subset of the System of Environmental-Economic Account (SEEA) which could be explored in relation to Port Phillip Bay. It can be linked to waste accounting and ecosystem accounting to present a more comprehensive picture of the relationship between waste residuals from catchments (eg nitrogen inputs to Port Phillip Bay), water quality, and the condition of ecosystems and flow of ecosystem services.

4. Port Phillip Bay Pilot Ecosystem Accounts

This section presents pilot ecosystem accounts for Port Phillip Bay. The accounts are a snapshot of the location and extent of ecosystem assets. Ideally accounts will have an opening and closing balance and show change in assets and ecosystem services over time, providing information for government reporting, investment and program evaluation and forward looking decision-making. However, this requires time series data which is not yet available for Port Phillip Bay. An important caveat for the accounts presented below is that the spatial data was collated from different years over a 15 year period. Consequently, the accounts are an approximation of current state, based on the best and most recent information available.

4.1 Ecosystem Asset Extent – Accounts

This section presents stocks of ecosystem assets under the Combined Biotope Classification Scheme (CBiCS). The accounts presented are for different levels of the CBiCS hierarchy:

- broad habitat level
- habitat complex level
- biotope complex level

Assets are described for the five areas shown in Figure 4 – Central, Corio, Exchange, Hobsons and Intertidal. The five geographic areas are also aggregated to give a total for the whole of Port Phillip Bay. The total spatial area is 196,315 hectares.

Table 7 outlines ecosystem assets at the broad habitat and habitat complex levels. The three broad habitat types in Port Phillip Bay are littoral sediment, sublittoral rock and sublittoral sediment. Sublittoral sediment is the most common broad habitat, with almost 190,000 hectares across the Bay. The vast majority of this area is mud and sand – over 174,000 hectares. The Central area contains over 84,000 hectares of mud and sand – over 99 per cent of the Central area (85,099 hectares).

The largest stocks of seagrass beds are found in the Corio and Exchange areas, with 3,280 and 3,733 hectares respectively. The Corio area also has the largest stock of seaweed communities – 7,385 hectares. This data is spatially mapped in Figure 5.

Table 7 – Port Phillip Bay ecosystem assets (hectares)

Broad habitat	Habitat complex	Central	Corio	Exchange	Hobsons	Intertidal	Total
Littoral sediment	Mangrove					4	4
	Mud					274	275
	Saltmarsh coastal vegetation		87	475	5	1,868	2,435
Littoral sediment total			87	475	5	2,147	2,714
Sublittoral rock	Ravine			798		11	809
	Rock (unclassed)	299	471	760	902	48	2,481
	Seagrass			209			209
	Seaweed		298	64	3	5	369
Sublittoral rock total		299	769	1,832	904	63	3,868
Sublittoral sediment	Mud	69,923	3,391	7,393	3,922	234	84,863
	Muddy sand	8,935	5,898	10,656	3,872	8	29,369
	Sand	5,800	11,064	23,458	6,921	312	47,555
	Seagrass	1	3,280	3,524	123	209	7,138
	Seaweed		7,087	352	431	14	7,884
	Silty mud	141	9,737	2,113	905	28	12,925
Sublittoral sediment total		84,800	40,457	47,498	16,175	804	189,734
Total		**85,099**	**41,313**	**49,804**	**17,085**	**3,014**	**196,315**

Table 8 presents ecosystem assets at the biotope complex level. This data has been extracted from the extent account presented in Table 7, and sums to the total area of seagrass ecosystems in Port Phillip Bay. The most common types of seagrass are *Zostera* (long eelgrass and short eelgrass) and *Ruppia*, totalling around 6,500 hectares. There is a smaller amount of *Halophila* (a small, ephemeral seagrass) and *Amphibolis*, which occurs on sublittoral rock in the Exchange area of the Bay. Seagrass stocks make up less than four per cent of Port Phillip Bay's total ecosystem assets, but they deliver ecosystem services that provide significant benefits, see Section 5 (Seagrass Case Study).

Table 8 – Port Phillip Bay ecosystem assets – focus on seagrass, saltmarsh and mangrove (hectares)

Broad habitat	Habitat complex	Biotope complex	Total
Sublittoral rock	Seagrass	*Amphibolis* stands	209
Seagrass on sublittoral rock total			209
Sublittoral sediment	Seagrass	*Halophila* beds	138
		Zostera and *Ruppia* beds	6,444
		Unspecified	556
Seagrass on sublittoral sediment total			7,138
Total			**7,347**

4.2 Ecosystem Asset Condition

As previously discussed, ecosystem condition accounts require spatial data on the health of ecosystem assets. This can be a single metric or a composite of several metrics to create a condition score.

For this study, water quality monitoring data was made available by the Environment Protection Authority and HydroNumerics. Dissolved oxygen data are available for eight discrete points around the Bay (see Figure 10). Dissolved oxygen refers to the amount of oxygen contained in water, and is a critical measure of the living conditions for oxygen-requiring aquatic organisms, such as fish. The data cannot readily be used to populate spatial accounts, however it can be used to understand changes in dissolved oxygen in different parts of the Bay over time.

Table 9 shows levels of dissolved oxygen at the Corio Bay water quality monitoring site from 1990 to 2014. Dissolved oxygen is not a direct measure of the condition of Bay ecosystem assets (such as seagrass), as levels of dissolved oxygen can be influenced by a number of factors such as inflows to the Bay. For example, nutrient inflows to the Bay can substantially reduce dissolved oxygen concentrations. However, if dissolved oxygen levels fall to critical levels as a result of inflows it is possible the condition of ecosystem assets may fall as well. It is useful to monitor oxygen levels to help understand the overall condition of the Bay and how changes in dissolved oxygen may be impacting on ecosystem assets and the services they are providing.

Dissolved oxygen is also an important ecosystem service provided by some assets. For example, seagrass contributes to the oxygenation of oceans by generating oxygen through photosynthesis. Monitoring nutrient inflows, dissolved oxygen levels and the extent and condition of seagrass jointly can provide information on the overall condition of the Bay and help guide policy and management decisions.

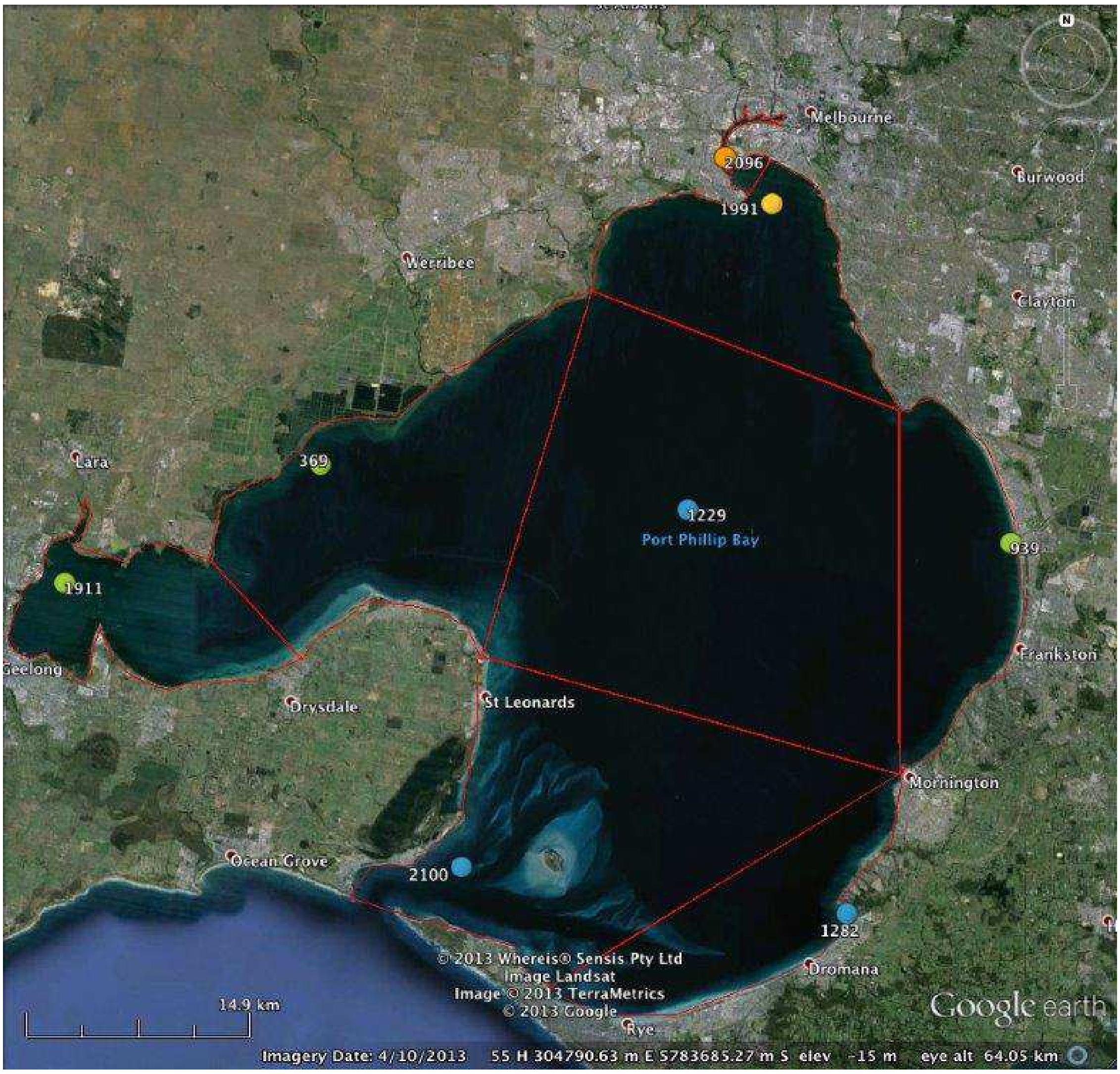
Table 9 – Average values of dissolved oxygen in Corio Bay

Year	Dissolved oxygen (MG/L)	Percent saturated dissolved oxygen (%)
1990	8.18	104.9
2000	8.30	106.6
2014	7.64	98.3

Source: DELWP analysis of data from Environment Protection Authority and HydroNumerics

Condition data for marine ecosystems has emerged as a key gap in this study, meaning that ecosystem condition accounts could not be produced for this study. CSIRO is currently working with DELWP to develop marine indicators for four key ecosystems in Port Phillip Bay and Western Port: un-vegetated sub-tidal soft sediments; vegetated sub-tidal soft sediments; sub-tidal rocky reefs; and inter-tidal vegetated soft sediments. There is potential for these indicators to be incorporated into environmental-economic accounting.

Figure 10 – Port Phillip Bay water quality monitoring points



Source: Environment Protection Authority and HydroNumerics (2016).

4.3 Ecosystem Services and Benefits

Ecosystem services must be linked to an ecosystem asset, so the relationship between the quantity and quality of the asset and the flow of ecosystem services can be understood. A list of ecosystem services relevant to Port Phillip Bay ecosystems is provided in Table 10. However, few of the ecosystem services can be explicitly linked to assets and quantified.

Due to high levels of nutrient inflows to the Bay a key ecosystem service provided by marine ecosystems in Port Philip Bay is denitrification, which is provided by sub-tidal soft sediments in the centre of the Bay and is critical for processing nutrients. Seagrass beds in Corio Bay are important ecosystems for native fish species that sustain Victoria's unique aquatic biodiversity, while reefs towards Frankston support well-known species sought for recreational or commercial fishing.

As ecosystem service accounts were unable to be produced for the whole of Port Phillip Bay ecosystems, this study has opted to focus on identifying, quantifying and valuing the benefits from selected ecosystem services delivered by seagrass. This is discussed in Section 5 (Seagrass Case Study).

Table 10 – Overview of ecosystem services related to Port Phillip Bay

Provisioning services	Regulating services	Cultural services
Uncultivated marine plants, algae and animals for food Nutrients and natural feed for cultivated biological resources (aquaculture)	Bioremediation chemical detoxification/breakdown of pollutants by plants Dilution, filtration and sequestration of pollutants – water, removal of organic materials from waste-water by biogeochemical processes, filtration of particulates, sequestration of pollutants in organic sediments Water flow regulation – regulation of timing and magnitude of water run-off, flooding Atmospheric regulation – capture of carbon dioxide and climate regulation Water cycle regulation – oxygenation of water, retention and translocation of nutrients in water Life-cycle maintenance, and habitat and gene pool protection – pollination, seed dispersal, maintenance of habitat nursery population and habitats Pest and disease control (including invasive alien species) – control of pathogens	Non-extractive recreation – landscape and seascape character and biodiversity species for snorkelling, diving, recreation Information and knowledge – landscape character, habitat and species for scientific research and education Spiritual and symbolic – landscape character and biodiversity of species of cultural heritage values, sense of personal and group identity (sense of place), spiritual and religious function Non-use – ecosystem capital for future generation of ecosystem services

Source: Adapted by DELWP from CICES classification in United Nations 2013, System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting.

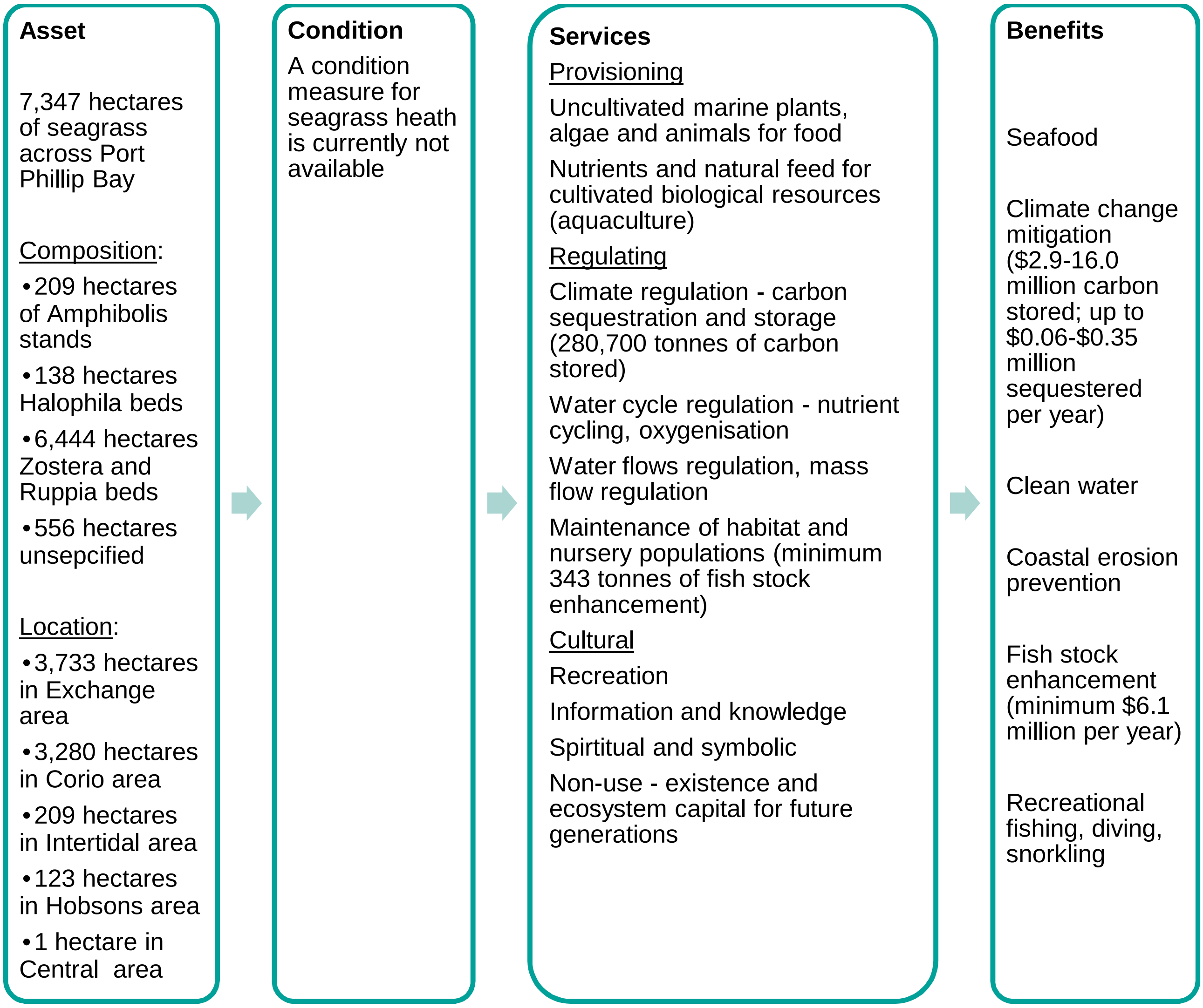
5. Seagrass Case Study

This case study shows how an environmental-economic accounting framework can be applied – both conceptually and quantitatively – to seagrass ecosystems to demonstrate the link between biophysical information and socio-economic benefits.

The accounts presented in this section provide a snapshot of seagrass ecosystems in Port Phillip Bay, as time series data was not available at the time of this study. Nonetheless, they provide useful initial information on the location of seagrass beds and the ecosystem services and benefits they can provide. Going forward, the accounts can provide a robust reference point against which to compare future information to report on changes to asset and support the assessment of program/policy investments.

The key findings relating to seagrass are outlined in Figure 11 and discussed below. Note that the services and benefits listed are those that could be identified, quantified or valued in this study. It is not an exhaustive list.

Figure 11 - Seagrass in an environmental-economic accounting framework



Asset

7,347 hectares of seagrass across Port Phillip Bay

Composition:

- 209 hectares of Amphibolis stands
- 138 hectares Halophila beds
- 6,444 hectares Zostera and Ruppia beds
- 556 hectares unsepcified

Location:

- 3,733 hectares in Exchange area
- 3,280 hectares in Corio area
- 209 hectares in Intertidal area
- 123 hectares in Hobsons area
- 1 hectare in Central area

Condition

A condition measure for seagrass heath is currently not available

Services

Provisioning

Uncultivated marine plants, algae and animals for food

Nutrients and natural feed for cultivated biological resources (aquaculture)

Regulating

Climate regulation - carbon sequestration and storage (280,700 tonnes of carbon stored)

Water cycle regulation - nutrient cycling, oxygenisation

Water flows regulation, mass flow regulation

Maintenance of habitat and nursery populations (minimum 343 tonnes of fish stock enhancement)

Cultural

Recreation

Information and knowledge

Spirtitual and symbolic

Non-use - existence and ecosystem capital for future generations

Benefits

Seafood

Climate change mitigation ($2.9-16.0 million carbon stored; up to $0.06-$0.35 million sequestered per year)

Clean water

Coastal erosion prevention

Fish stock enhancement (minimum $6.1 million per year)

Recreational fishing, diving, snorkling

5.1 Seagrass Extent

Figure 12 outlines how seagrass is classified under the Combined Biotope Classification Scheme (CBiCS). This allows seagrass to be consistently defined, mapped and aggregated into higher classifications.

Figure 12 – Seagrass classification

Level 1 - Environment: Marine

Level 2 - Broad habitat type: Sublittoral rock, sublittoral sediment

Level 3 - Habitat complex: Seagrass

Level 4 - Biotope complexes: Amphibolis stands, Halophila beds, Zostera and Ruppia beds

The five areas used in this study are Central, Corio, Exchange, Hobsons and Intertidal. These are illustrated in Figure 4. Table 11 presents an ecosystem asset account for Port Phillip Bay. It includes seagrass assets across Port Phillip Bay areas. Around 7,350 hectares of seagrass beds were recorded in Port Phillip Bay. This is 3.7 per cent of Port Phillip Bay's total area, with Corio Bay and the Exchange areas accounting for the majority of seagrass.

An important caveat is that the newly classified seagrass data builds on datasets from the year 2000. Past studies on the extent of seagrass indicate a pattern of frequent, localised and small-scale fluctuations across Port Phillip Bay.[34] It is not clear what is causing the fluctuations and how it may be impacting on condition and ecosystem services.

Table 11 – Ecosystem assets in Port Phillip Bay (hectares)

Broad habitat	Habitat complex	Central	Corio	Exchange	Hobsons	Intertidal	Total
Littoral sediment	Mangrove				0	4	4
	Mud		0			274	275
	Saltmarsh coastal vegetation		87	475	5	1,868	2,435
Littoral sediment total			87	475	5	2,147	2,714
Sublittoral rock	Ravine			798		11	809
	Rock (unclassed)	299	471	760	902	48	2,481
	Seagrass			209			209
	Seaweed		298	64	3	5	369
Sublittoral rock total		299	769	1,832	904	63	3,868
Sublittoral sediment	Mud	69,923	3,391	7,393	3,922	234	84,863
	Muddy sand	8,935	5,898	10,656	3,872	8	29,369
	Sand	5,800	11,064	23,458	6,921	312	47,555
	Seagrass	1	3,280	3,524	123	209	7,138
	Seaweed		7,087	352	431	14	7,884
	Silty mud	141	9,737	2,113	905	28	12,925
Sublittoral sediment total		84,800	40,457	47,498	16,175	804	189,734
Total		**85,099**	**41,313**	**49,804**	**17,085**	**3,014**	**196,315**

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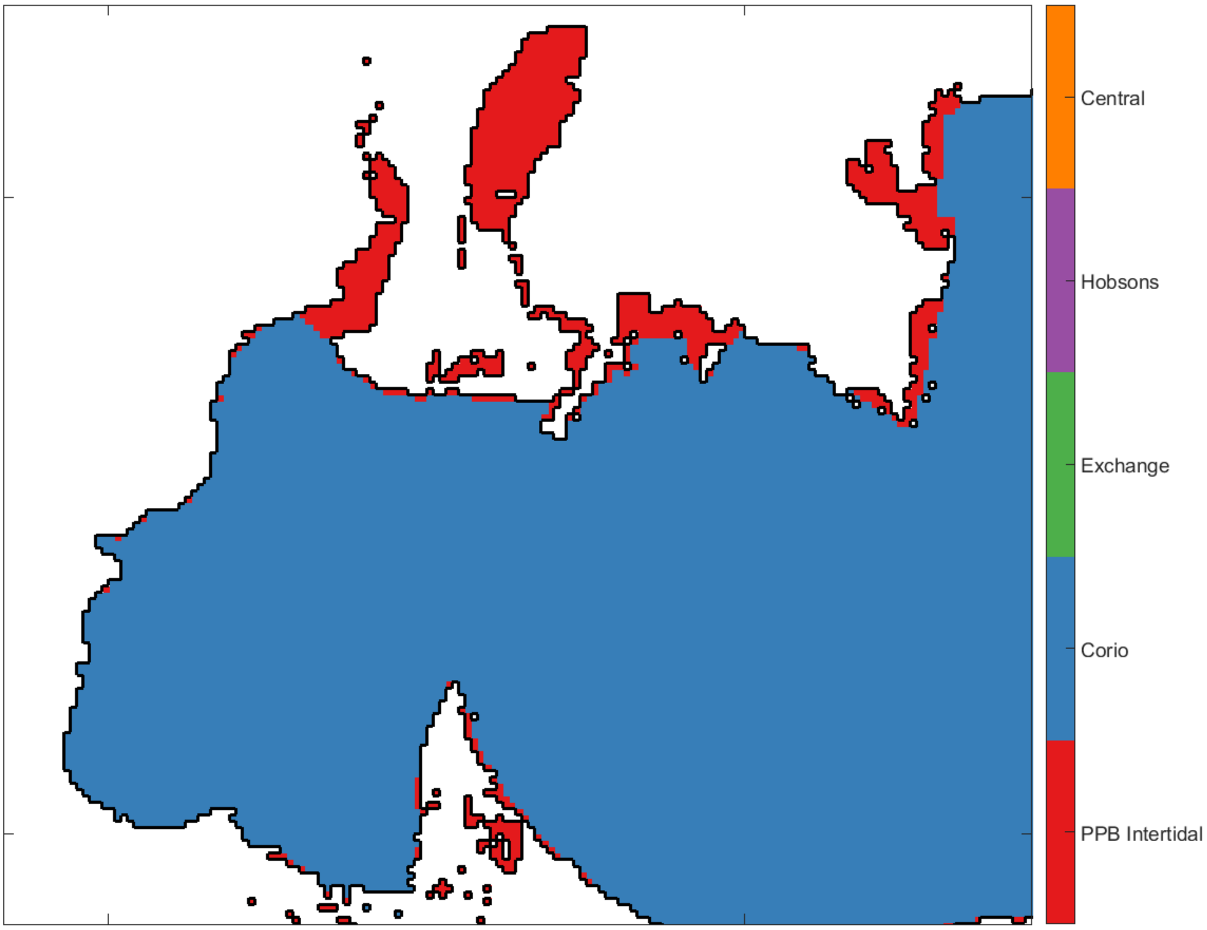
[34] Warry, F.Y. and Hindell, J. S. (2009) *Review of Victorian seagrass research, with emphasis on Port Phillip Bay*, Department of Sustainability and Environment Victoria, p. 1.

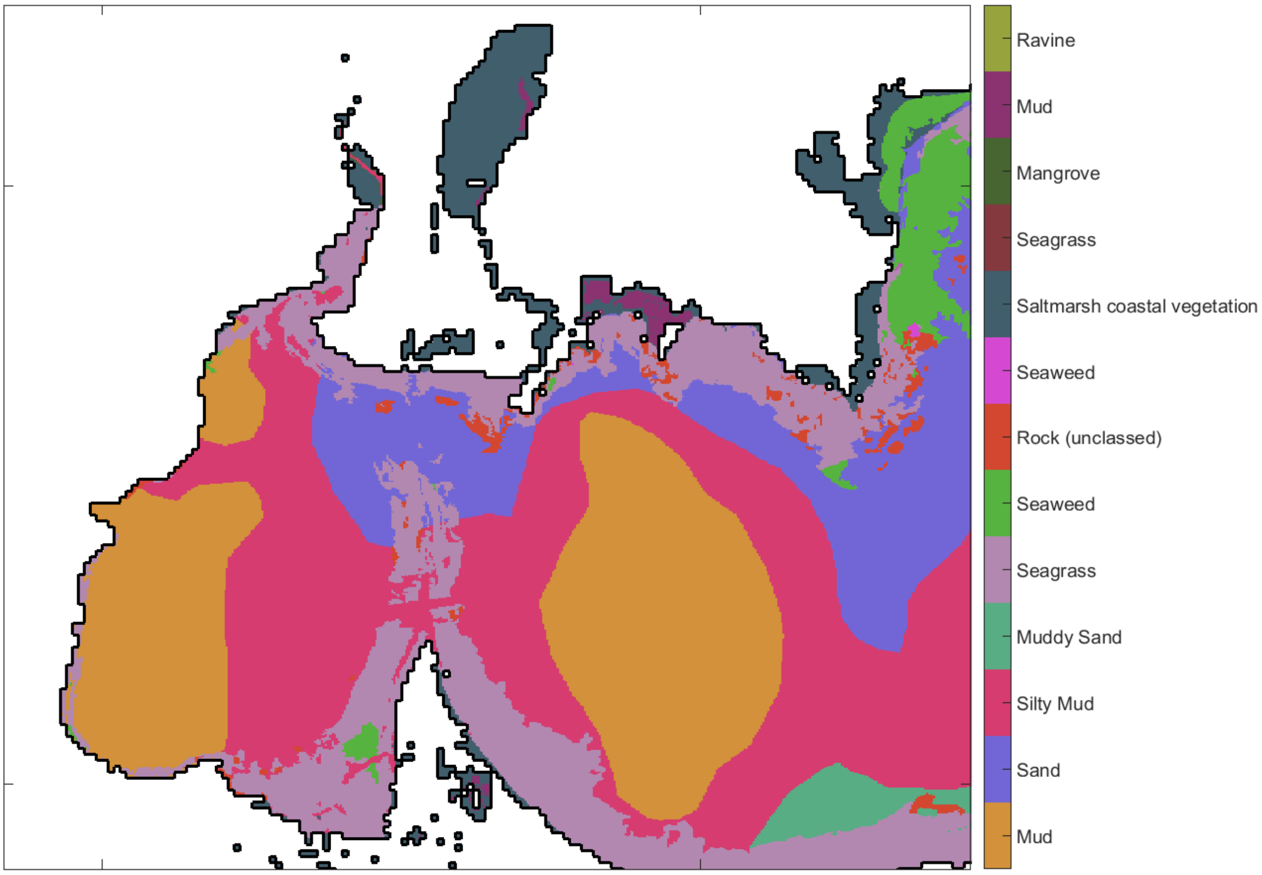
Figure 13 shows a map of Corio Bay, with blue representing the ‘Corio’ area and red representing the ‘Intertidal’ area. Figure 14 shows the same Corio Bay zone but ecosystem assets are spatially mapped. Large areas of mud and silty mud are evident in the centre of Corio Bay, with significant areas of seagrass along the southern and northern shores. This seagrass stock aligns with the account presented in Table 11 – there is 3,280 hectares of seagrass in the Corio area. Table 11 also indicates that the bulk of saltmarsh is in the Intertidal area (depicted in red in Figure 13). This can be seen in Figure 14 where there are significant areas of saltmarsh to the north of Corio Bay.

Figure 13 – Geographic aggregations – Corio and Intertidal in the Corio Bay area



Source: DELWP EnSym

Figure 14 – Ecosystem assets in the Corio Bay area



Source: DELWP EnSym

5.2 Seagrass Condition

As previously discussed, ecosystem condition accounts require spatial data on the condition of ecosystem assets. This can be a single metric or a composite of several metrics to create a condition score. Condition data for seagrass ecosystems has emerged as a key gap.

At the biotope level the spatial data available provides some information on the density of seagrass coverage – eg dense, medium or sparse. However, the impact of the seagrass density on ecological processes such as carbon and nutrient cycling remains unclear.[35] This means that seagrass density could not be used as a clear condition indicator linking seagrass beds with the flow of ecosystem services they deliver.

A noted previously (Section 4.2) seagrass contributes to the oxygenation of oceans by generating oxygen through photosynthesis and it would be useful to combine information on dissolved oxygen levels with nutrient inflows and seagrass extent and condition to understand the overall condition of the Bay. Further work is required in this area to understand the links between each.

5.3 Ecosystem Services

Ecosystem services provide the link between ecosystem assets and the benefits derived and enjoyed by people. They are generated through ecosystem processes reflecting the combination of assets characteristics, intra-ecosystem and inter-ecosystem flows.

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[35] Warry, F.Y. and Hindell, J. S. (2009) *Review of Victorian seagrass research, with emphasis on Port Phillip Bay*, Department of Sustainability and Environment Victoria, p. 1.

Seagrass beds deliver a number of ecosystem services that are of significant benefit to people. Table 12 provides on overview of key ecosystem services. Note that this is a summary of key ecosystem services identified for this study. It is not necessarily an exhaustive list of ecosystem services provided by seagrass assets.

Table 12 – Qualitative list of ecosystem services from seagrass ecosystems

Ecosystem service	Description
Provisioning	
Uncultivated marine plants, algae and animals for food	Seagrass ecosystems provide fish and shellfish which can be taken up for food (commercially or recreationally), providing a benefit to people.
Nutrients and natural feed for cultivated biological resources	Nutrient resources for aquaculture products.
Regulating	
Climate regulation	Seagrass ecosystems sequester and store carbon dioxide. This reduces greenhouse gases in the atmosphere, mitigating the impact of climate change.
Water cycle regulation	Seagrass ecosystems contribute to the oxygenation of oceans by generating oxygen through photosynthesis. Seagrass ecosystems also absorb nutrients, slow the flow of water and stabilise sediments with their roots. Combined, this provides a benefit to people and the environment by improving water quality.
Water flow regulation, mass flow regulation	Seagrass ecosystems trap sediments with their roots which helps stabilise the sediment, prevent coastal erosion and buffer coastlines against storm events. This provides coastal protection benefits to communities and infrastructure.
Maintenance of nursery populations and habitat	Seagrass ecosystems provide habitat and nutrients to support spawning and recruitment of species. Some organisms are permanent residents of seagrass ecosystems, while others are temporary visitors.
Cultural	
Recreation	Seagrass ecosystems contribute to seascape character and biodiversity of species for recreation (eg snorkelling, diving, and fishing).
Aesthetic	Seagrass ecosystems contribute to seascape character and biodiversity of species for aesthetic enjoyment.
Information and knowledge	Seagrass ecosystems contribute to seascape character and biodiversity of species for scientific research and education.
Spiritual and symbolic	Seagrass ecosystems contribute to seascape character and biodiversity of species that have cultural heritage values, provide a sense of personal and group identity (sense of place), or have spiritual and religious function.
Non-use (existence and for future generations)	Seagrass ecosystems provide ecosystem capital for future generation of ecosystem services.

5.4 Valuing Ecosystem Services

This study has valued the flow of two ecosystem services provided by seagrass ecosystems – the maintenance of nursery populations and the provision of habitat. Both the maintenance of nursery populations and the provision of habitat services are intermediate ecosystem services. These services are ultimately of benefit to recreational and commercial fisheries along with passive recreation activities such as snorkelling and diving. Any assessment of the value of services should avoid double counting by recognising these are inputs that result in benefits, such as the benefits earned from commercial fishing.

A study on fish enhancement by seagrass habitat in southern Australia estimates total annual enhancement across a number of species that are commercially fished in Port Phillip Bay, including Australian anchovy, southern sea garfish and King George whiting.[36] The estimated total enhancement (across all age classes) provided by a hectare of seagrass each year is 46.4 kilograms for King George whiting, 0.2 kilograms for Australian anchovy, and just 2 grams for southern sea garfish. This suggests that the enhancement across 7,350 hectares of seagrass in Port Phillip Bay is estimated at around 343 tonnes for these species. The full list of species included in the study is provided in Table 13.

The value of this service can be estimated using market prices for seafood. As outlined in Table 13, the market value of fish stock enhancement has been calculated at $824 per hectare for King George whiting, almost $2 per hectare for Australian anchovy and less than $0.1 per hectare for southern sea garfish. As these species are observed in Port Phillip Bay, the value of fish stock enhancement has been estimated at $826 per hectare. This suggests that the total value of the service across 7,350 hectares of seagrass in Port Phillip Bay is $6.1 million per year for these species.

This represents the change in fish stock attributable to the seagrass habitat, as opposed to realised catch in Port Phillip Bay. It is limited to the value of commercial species taken from a study of southern Australia and not specific to Port Phillip Bay seagrass. For example, snapper was not included, however most of the snapper found west of Wilsons Promontory are spawned and raised in Port Phillip Bay. This means that $6.1 million per year represents the minimum value of the service.

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[36] Blandon, A. and zu Ermgassen, P.S.E. (2014) ‘Quantitative estimate of commercial fish enhancement by seagrass habitat in southern Australia’, *Estuarine, coastal and shelf science*, Volume 141, p. 108.

Table 13 – Recruitment enhancement by seagrass habitat

Species	Common name	Mean enhancement (individuals/m^2)	Total annual enhancement (g/m^{-2})	Annual enhancement age classes > r (g/m^2)	Price ($/kg)	Economic enhancement ($/ha)
Engraulis australis	Australian anchovy	0.01	0.02	0.012	1.58	1.91
Girella tricuspidata	Luderick	0.052	15.54	4.333	2	866.59
Haletta semifasciata	Blue weed whiting	0.012	0.49	0.702	4.33	15.93
Hyperlophus vittatus	Sandy sprat	0.126	0.294	0.053	4.03	21.19
Hyporhamphus melanochir	Southern sea garfish	0.002	0.02×10^{-2}	0.008×10^{-2}	7.27	6.00×10^{-2}
Liza argentea	Flat-tail mullet	0.122	33.06	4.026	3.33	1340.71
Meuschenia freycineti	Six-spined leatherjacket	0.014	20.76	8.674	5.74	4978.66
Meuschenia trachylepis	Yellowfin leatherjacket	0.095	38.86	11.152	5.74	6401.09
Mugil cephalus	Flathead grey mullet	0.926	350.16	34.979	1.78	6226.23
Pelates sexlineatus	Six-lined trumpeter	0.802	6.46	1.675	1.53	256.31
Rhabdosargus sarba	Tarwhine	0.618	514.36	416.912	4.95	206,371.22
Sillaginodes punctata	King George whiting	0.026	4.64	0.507	16.24	824.07

r = age at which fish enter the fishery

Source: A. Blandon, P.S.E. zu Ermgassen (2014)

5.5 Benefits

Over the past few decades there have been a number attempts to value to benefits from seagrass ecosystem services around the world. A global assessment of the ecosystem services provided by seagrass estimated an annual benefit value of US$19,004 per hectare in 1994 dollars, along with a global value of US$3,801 billion.[37] This is around AUD$30,000 per hectare in 2016 dollars. While research has been done on the economic value of ecosystems globally, there is no peer-reviewed work that has been conducted that is specific to Victoria. This part of the study attempts to estimate some site-specific values of the benefits from seagrass ecosystem services in Port Phillip Bay.

5.5.1 Recreational Fishing

Port Phillip Bay is a popular destination for recreational fishers. On an annual basis, recreational fishing catch may exceed that of the commercial sector. For example, the recreational harvest of snapper is four times larger than the commercial catch.[38]

Recreational fishing is a benefit provided by seagrass ecosystem services, as seagrass provides habitat that supports fish species that are recreationally caught. However, the benefits provided by seagrass cannot be

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[37] Costanza, R., d'Arge, R., de Groots, R. et al (1997) 'The value of the world's ecosystem services and natural capital', *Nature,* Volume 387, pp 253-260.
[38] Fisheries Victoria (2013) *Overview of the Port Phillip Bay commercial wild catch fishery*.

explicitly quantified and valued, as there are no data or surveys for relevant fishing locations and therefore the benefits cannot be isolated from other fishing determinants.

Queenscliff Pier and Cunningham Pier in Geelong are two main fishing locations in the south-western area of Port Phillip Bay with surrounding seagrass ecosystems. Fish species found in these areas include: squid, yellow-eye mullet, Australian salmon, flathead, silver trevally, garfish, King George whiting, snapper and leatherjacket.

Results from the Victorian Recreational Fishing Survey 2014 indicate that the average adult fisher in Victoria spends $326 per trip (excluding boat purchase), with the majority of this expenditure going to food, accommodation and transport to and from the fishing location.

5.5.2 Commercial Fishing and Aquaculture

Wild seafood is commercially caught in Port Phillip Bay, providing benefits to producers and consumers. Major species taken include snapper, King George whiting, southern calamari, Australian salmon and flathead. However, the Victorian government has committed to phasing out commercial netting in Port Phillip Bay as part of the Target One Million plan which aims to improve recreational fishing opportunities and contribute to the government’s aim of increasing the number of anglers in Victoria to one million by 2020.

Seafood is produced in aquaculture farms in Port Phillip Bay, providing benefits to producers and consumers. Longline culture of blue mussels is the predominant aquaculture activity in the Bay. Mussel farms can be found near Geelong and the Mornington Peninsula. Currently reserve locations include Pinnace Channel, Clifton Springs, Grassy Point, Kirk Point, Bates Point, Mount Martha, Beaumaris and Dromana. While the exact relationship between seagrass and aquaculture farms is unknown, seagrass ecosystems provide important water filtration services and stabilise sediments through their root systems. This provides improved water quality required for aquaculture farms.

Maintenance of nursery populations and habitat (discussed above) is an intermediate service to the provision of fish for commercial fishing. In any assessment care should be taken to ensure that benefits are not double counted.

5.5.3 Recreation

Port Phillip Bay provides opportunities for recreation experiences. The direct benefit to Victorians and visitors is the personal enjoyment gained while undertaking activity in and around the Bay, which then provides additional health and economic benefits. Whilst information on Bay recreation and tourism is available from a range of sources, it is difficult to define and quantify the relationship between seagrass assets and recreation.

Parks Victoria data indicate an increase in total visitation of Bays from 73.5 million visits in 2008-09 to 76.5 million visits in 2012-13. Visitation to Marine National Parks has also increased from 2.7 million visits in 2003-04 to 3.8 million visits in 2012-13.[39] The Port Phillip Heads Marine National Park is a well-known marine park with seagrass beds in the Bay (particularly in the Mud Islands and Swan Bay sections). Survey data from Parks Victoria estimate about 123,600 visits to this park every year and 25 licensed tourist operators.[40]

A 1999 study on the recreational value of Victorian parks included seven piers and jetties around the Bay and estimated the willingness to pay to visit the Queenscliff Pier at $3.83 per visit (around $6 in 2016 dollars).[41] This value could be applied to the Port Phillip Heads Marine National Park to derive a rough estimate of recreational benefit of $741,600 per year. However, to determine the benefit provided by seagrass assets, a survey would need to be conducted to understand the proportion of visitors for which seagrass is a key motivation for visiting.

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[39] Newspoll (2013) *Parks Visitation Monitor Quarter 1-4 – 2012/2013*, report prepared for Parks Victoria.
[40] Unpublished data provided by Parks Victoria to DELWP for the 2015 Valuing Victoria’s Parks study.
[41] Read Sturgess (1999) *Economic assessment of the recreational values of Victorian parks*.

5.5.4 Climate Change Mitigation

Carbon sequestration

Seagrass removes carbon dioxide from the atmosphere and stores it in organic-rich sediments. There is an increasing body of evidence that coastal and marine ecosystems sequester and store large volumes of carbon.[42] However, the sequestration rates in Port Phillip Bay are unknown.[43] Estimates from some parts of the world indicate a rate of up to 0.83 tonnes per hectare per year.[44]

Carbon sequestration provides a benefit to the economy and society by reducing the amount of carbon dioxide in the atmosphere and reducing the impact of climate change. This benefit is received by the Victorian community as well as broader Australian and global communities.

There are a range of values that can be applied to value the benefit people receive from carbon sequestration, some of which are outlined in Table 14. With the repeal of the Commonwealth Government's carbon pricing mechanism there is no legislated carbon market in Australia. The cost of purchasing emissions reductions in some international markets is less than $1 per tonne of CO2-e. The European Union trading scheme is currently around $9 per tonne of CO2-e. Prices in different markets can vary significantly as they are driven by policy ambition in the jurisdiction.

In the absence of a carbon price in Australia, the Commonwealth's Emissions Reduction Fund (ERF) auctions provides broadly an indication of the average cost of purchasing a set amount of abatement in Australia. Under the third ERF auction held by the Clean Energy Regulator in April 2016 the average price per tonne of abatement was $10.23.

Based on a lower bound of the average cost of abatement in the Australian Emissions Reduction Fund (average price of $10.23 per tonne of CO_2-e) and an upper bound of the social cost[45] of carbon ($57 per tonne of CO2-e), carbon sequestration benefits are valued at up to $0.06-0.35 million per year. Note that other ecosystems in the Bay, such as mangroves and saltmarsh, also provide significant climate regulation services.

Table 14 – Mechanisms for valuing carbon sequestration and storage

Description		Value
Social cost of carbon	Represents the global benefit of reducing emissions (ie avoided damages associated with changes in agricultural productivity, human health, flood risk, ecosystem services and other factors).	$57 per tonne of CO2-e (adapted from United States EPA)
European Union Emissions Trading Scheme	European Union-wide cap and trade system. Accounts for over three quarters of international carbon trading.	Currently $9 per tonne of CO2-e
United Nation's Clean Development Mechanism	Under the Kyoto Protocol certain projects generate tradeable certified emission reduction (CER) credits. CER prices are currently very low as they are driven by global policy ambition rather than the value of abatement.	Currently $0.70 per tonne of CO2-e
Commonwealth Emissions Reduction Fund (ERF)	The ERF operates via a series of auctions, managed by the Clean Energy Regulator. Emissions reduction projects bid into the auction and funds are awarded to the projects that can deliver the lowest cost abatement.	$10.23 per tonne of CO2-e in April 2016

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[42] See http://www.thebluecarboninitiative.org; Fourqurean, J.W. et al (2012) 'Seagrass ecosystems as a globally significant carbon stock', *Nature Geoscience*, Volume 5, pp 505-509.

[43] Department of Sustainability and Environment (2009) *Review of Victorian seagrass research, with emphasis on Port Phillip Bay*, p. 18.

[44] Port Phillip and Westernport Catchment Management Authority (2015) *The distribution and abundance of 'blue carbon' within Port Phillip and Westernport*, p. 4.

[45] The social cost of carbon is used in this study however, it is not an exchange value which is the value recommended for use in the SEEA.

Carbon storage

A study has found that 38.2 tonnes of carbon is stored per hectare of seagrass.[46] This is below ground carbon stored in sediment, not carbon stored in the living plant biomass. Within habitats carbon is stored in living plant biomass for relatively short timescales (years to decades), while carbon stored in sediment can remain for very long time periods (centuries to millennia).[47] This suggests that around 280,700 tonnes of CO2-e is stored in seagrass ecosystems in Port Phillip Bay. Using the same carbon prices outlined above, the value of this stock would be $2.9-16.0 million. It should be noted that this is not an annual benefit received but rather the value of the total stock held in Port Phillip Bay seagrass which could be seen as an insurance value (insurance against the loss of carbon stocks).

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[46] Port Phillip and Westernport Catchment Management Authority (2015) *The distribution and abundance of 'blue carbon' within Port Phillip and Westernport*.

[47] Port Phillip and Westernport Catchment Management Authority (2015) *The distribution and abundance of 'blue carbon' within Port Phillip and Westernport,* p. 7.

6. Conclusion

Marine and Coastal Ecosystem Accounting: Port Phillip Bay builds on previous environmental-economic accounting undertaken by the Victorian Government to demonstrate the relationship between healthy bays and economic and societal wellbeing in Victoria. The study has used available data to produce a draft set of ecosystem extent accounts for the Bay. This approach allows for the integration of terrestrial accounting with marine and coastal accounting to provide a more complete picture of both the economic and environmental relationships. The application of an integrated accounting framework across all environmental dimensions would provide a set of information that can be used to make decisions involving tradeoffs between the use and management of ecosystems in a transparent and consistent manner.

The key findings and recommendations of this study are:

- Robust, comprehensive and fit-for-purpose data is core to decision making. A lack of ecosystem health and spatially referenced data was a key issue in populating accounts for Port Phillip Bay. The development of marine ecosystem condition indicators is a key priority which should continue to be addressed by the Department of Environment, Land, Water and Planning and portfolio partners.
- Due to the absence of time series data, the change over time in the extent of ecosystems in the Bay was not assessed in this study. Measuring and reporting changes in marine ecosystems is a key objective to support the evaluation of the management of ecosystem assets to inform decision-making. If marine accounts were to be produced on an ongoing basis the collection of consistent time series data on ecosystem assets should be a priority.
- Pilot accounts developed for Port Phillip Bay illustrate the extent of ecosystem assets in five geographic areas. The reported areas are only indicative because the extent was derived from different studies using different methods over the last 15 years, rather than a single point in time. This study used new and historical data which have been newly classified under the Combined Biotope Classification Scheme (CBiCS), which is being adopted in Victoria. The Victorian Government's EnSym tool was used to produce the accounts and can be used to report on different geographic areas within the Bay including swimming, aquaculture, local government and river outlet areas to support targeted policy and decision making.
- The Bay is providing water filtration services to Melbourne and the catchments by processing nitrogen that enters the Bay as catchment runoff or from the sewage treatment plant at Werribee. It is estimated that the Bay can processes over 5,000 tonnes of nitrogen per year and the value of this service is estimated at around $11 billion per year, which represents the costs that would be incurred to achieve equivalent denitrification through alterative means, such as upgrading infrastructure or wetland enhancement.
- Although seagrass makes up only four per cent of Bay ecosystems it delivers a diverse range of ecosystem services that provide benefits to the economy and the community – particularly water filtration, sediment stabilisation, maintenance of nursery populations and habitat, and carbon sequestration and storage, with recreation more indirectly linked. This case study is the first attempt in a Victorian context to use seagrass extent information to value benefits from key ecosystem services. It highlights the relationship between the state of ecosystems and the socio-economic benefits they provide.
- Seagrass ecosystems in the Bay provide important habitat services for a number of fish species including Australian anchovy, southern sea garfish and King George whiting. The value of these habitat services is reflected in the enhancement of fish stocks that has been estimated at a minimum of $6 million per year across the 7,350 hectares of seagrass in Port Phillip Bay.
- The Bay also provides benefits such as climate change mitigation through carbon sequestration, which is valued at up to $350,000 per year from seagrass ecosystems. A number of benefits are yet to be quantified, including recreational fishing, aquaculture, recreation and amenity.
- The process of producing accounts for the Bay has revealed opportunities for the further application of the System of Environmental Economic Accounting (SEEA) in the areas of water and waste (emission) accounts. These accounts are important for providing an understanding of inflows to the Bay as a result of economic activity in surrounding catchments. By linking economic activity in the catchments via the water

and waste accounts to the condition of the Bay it is possible to build a more comprehensive picture of the impact on Bay ecosystems and the services and benefits they provide.

This is the first time marine and coastal environmental-economic accounting has been undertaken in Australia.[48] The findings of the report are preliminary however they provide useful insights into areas for further research. The core accounting model used in this study can be used as a guide to focus future research to improve the understanding of the relationships between the marine and coastal environment and the social and economic wellbeing of Victorians.

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[48] The Australian Bureau of Statistics is investigating an expansion of their Great Barrier Reef accounts to include marine and coastal assets.

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