Coast, Estuaries and the Sea

Introduction

Key Findings

- The Victorian coast is an environment with naturally high diversity that is also subject to intensive human use. It features landscapes, plants and animals that are highly valued by Victorians, and as a result it is subject to significant human-induced pressures.
- The coast is highly modified. This is characterised by removal of vegetation and a decline in estuarine condition, especially in closed embayments and close to large settlements. However, in many cases the current rate and extent of modification is not well monitored.
- The coast continues to be a popular place to live and to visit, with a coastal population growth rate of almost 1.4% - faster than the State average. This has resulted in the urbanisation of 16.5% of Victoria's total coastline by 2004.
- What we do on land affects the sea: Water quality is inversely related to land use intensity in the adjacent catchment. As a result, water quality in Port Phillip Bay, Western Port and the Gippsland Lakes is likely to be poorer than in the open ocean, which is characterised by high levels of mixing and flushing, and is further removed from high intensity land use.
- Reduced water quality has a negative impact on both human use of the marine environment, and marine biodiversity. However, in many cases (e.g. extent of seagrass), inadequate baseline data makes it very difficult to determine the scale and significance of the effects.
- Human use of marine species can change marine ecology. Certain species of fin fish have been historically over-harvested, and this has had repercussions on the structure of marine ecosystems. An example of this is the removal of top predators, leading to the formation of urchin barrens, a degraded form of marine habitat.
- Prevention is better than cure: introduced species are a constant threat to Victorian marine systems. There are now 161 introduced species in Port Phillip Bay, considered to be one of the most invaded marine ecosystems in the southern hemisphere, and these are changing its ecosystems. In the vast majority of cases, preventing the incursion of marine pests is cheaper than attempting to remove them once established.
- The establishment of marine parks and reserves that cover more than 11.7% of Victorian waters is a progressive step in the protection of Victoria's marine biodiversity. However, because of the interactions between coasts and the oceans, our marine biodiversity continues to be subject to exogenous pressures.
- As part of an interconnected global system, climate change applies ongoing pressure to Victoria's coastal and marine environments. For example, the projected increase in ocean acidity will have fundamental consequences for marine ecosystems and the industries that rely on them.
- Coastal settlements will be increasingly vulnerable to damaging weather due to climate change. Modelling shows that storm surges of up to 2.3 metres above sea level could be expected by 2070. Victoria must be prepared for these.
- Victoria's marine and coastal biodiversity, already threatened by a range of development and industry pressures, faces significant challenges as a result of climate change. Effects have already been observed and include alteration of breeding patterns and reduced distribution, including commercially important species.
- For several coastal and marine issues, data collection programs and levels of scientific understanding are inadequate for comprehensive environmental assessments. This is particularly the case for coastal vegetation and marine biodiversity.

Victorian coastal and marine assets

The southern coast of Australia is one of the most significant south-facing sections of coast in the southern hemisphere and contributes to the unique status of Victoria's coastal and marine flora and fauna. Ninety to ninety-five percent of species in most taxonomic groups occurring in southern waters occur nowhere else on earth[1]. The Victorian coast contains approximately 120 bays, inlets and estuaries[2], ranging in water area from 1 km^2 to 2,000 km^2. The character of the Victorian coastline ranges from dynamic and continually eroding landforms as a result of exposure to wind and waves from the Southern Ocean, to gentle beaches and quiet inlets.

The range of climatic, geological and oceanographic regimes and the interaction of terrestrial, estuarine and marine ecosystems combine to ensure that this relatively compact and accessible environment is amongst the richest and most diverse in Australia. The coastal environment is the interface between catchments, rivers and the sea; the condition of coasts and estuaries can reflect the condition and management of the whole catchment[3].

Victorian residents and visitors clearly value the State's coastal environment. It was the location of the first European settlements in Victoria and also contains thousands of Indigenous cultural heritage places[4]. The ongoing presence of Indigenous communities along the coast is testament to a long association with the area. A significant and growing proportion of the Victorian population now lives within the coastal zone, which attracts 70 million visits each year by Victorians alone - more than any other recreational area in the State[5].

Great economic value is associated with the State's coastal environment. It contributes to Victoria's economy through natural resource industries such as fishing, oil and gas extraction, and through activities that prosper from operating in a specifically coastal environment, such as tourism, ports and trade activity. Some of the increasing stresses on the coast are due to these industrial and population pressures. Other stressors are due to exogenous factors such as nutrient inputs from catchments, the introduction of marine pests and, most significantly, climate change.

Despite the value of the coastal environment and the significance of the processes impacting upon it, our knowledge and understanding, especially in regard to marine environments, is less developed than for terrestrial areas. The effects of pressures such as urbanisation on coastal biodiversity are clear. Generally, however, information about the coast is far more extensive where it relates to industry, demographics, and tourism. For example, data on the condition of coastal land and water resources is not gathered in a comprehensive manner, making assessment of the condition of coastal and marine systems difficult.

While predominantly focusing on the natural coastal environment, it is the combination of environmental, social and economic values attributable to the coast and adjacent marine systems that make this region of Victoria worthy of a section of this Report in its own right.

Despite its linearity, it is often difficult to exactly define 'the coast' due to its large area and the number of processes that have an influence on it. As a result, a number of different terms are used to describe particular parts of the natural environment that come together to form the coast, including:

- The marine environment: the near shore environment, the seabed and marine waters out to the State limit of 5.5 km[6].
- The foreshore: coastal Crown land 200m from the high water mark.
- Coastal hinterland: public and private land next to and within critical views of the foreshore and near-shore marine environment.
- Coastal catchments: up to the top of catchments that drain directly to the ocean.

Some sections of this part of the Report focus on specific parts of the coast, according to the nature of the issue being discussed. In general, however, references to the coast are intended to include all parts listed above, including the marine environment.

Objectives

- To protect and enhance the environmental, social, economic and cultural values of Victoria's coastal and marine environment.
- To improve and integrate the planning and management of Victoria's coastal zone with the areas and factors influencing it.
- To provide for the sustainable use and development of coastal and marine resources.
- To prevent disturbance of acid sulfate soils along the Victorian coast.
- To improve knowledge and understanding of the coastal and marine environment and factors influencing it.

Overall condition

While 96% of the Victorian coast is in public ownership, and mostly protected in parks and reserves, much of it has been impacted by the human pressures of population growth, tourism and urbanisation. Most Victorian estuaries have been modified to some extent, with only a few remaining in near-pristine condition, and it is likely that the condition of coastal vegetation has been degraded significantly. While significant progress has been made in improving planning for growth and development along the coast, these pressures are predicted to increase in the future. The effects of climate change, particularly increased storm surges in the short term and permanent sea level rise in the longer term, will also have a significant impact on coastal form, coastal vegetation and the built environment.

Compared to many other marine environments around the world, water quality along Victoria's coastline is generally thought to be good. A range of parameters (risk of eutrophication, concentration of industrial pollutants, suspended solids and risk to human health) are measured using key indicators. These parameters can vary depending on location, with semi-enclosed and highly urbanised embayments such as Port Phillip Bay and Western Port being more at risk of reduced water quality. Dredging and reduced flushing as a result of decreased environmental flows associated with climate change can reduce water quality in such areas. The environmental pressure of maritime industries is generally well managed, with the number of pollution events declining. However, the expected increase in ship size, particularly as it relates to the effects of channel deepening on water quality in Port Phillip Bay, should continue to be closely monitored.

Generally, there is a lack of suitable data to adequately measure the condition and trends of Victoria's coastal and marine environments and the key resources they support. For example, no recent trend data exists to allow tracking of changes in coastal ecological vegetation classes, water quality monitoring outside the main estuaries is uncoordinated and disparate, and knowledge of the linkages between key issues (such as tourism) and environmental impacts is limited.

A similar situation exists in regard to marine biodiversity, with information about the condition of marine plants and animals predominantly gathered in the context of maritime industries that depend on them, or in response to activities with likely impacts such as dredging. Where data do exist, they generally show that the condition of fisheries is depleted, particularly for high value species such as the Southern Rock Lobster.

Pressures on coasts, estuaries and the sea

There are a number of pressures acting on coastal and marine environments, each ultimately originating with humans. These pressures also interact and accumulate to cause degradation of natural coastal and marine environments. Coastal landscapes, the animals and plants that reside there, and, in turn, the characteristics that Victorians themselves value are all affected to a greater or lesser extent (see Figure CES0.1).

The anthropogenic conversion of coastal land to intensive uses places pressures on the marine environment. While certain mitigating practices can reduce the effects, the increasing size of the Victorian population. Particular in urban centres close to the sea, constitutes a direct pressure on water quality. Water quality is negatively affected by the inflow of toxins, pathogens and excess nutrients that originate within urban and agricultural landscapes.

The maritime activities of shipping and dredging also place pressure on water quality. The more intensive the pressure (size and number of ships), the greater the implications for marine water quality. An example of this occurs when demand for increased shipping leads in turn to a requirement for channel deepening. Shipping also exerts pressure on marine biodiversity through the risk of pest plant and animal incursion.

Reduced water quality itself constitutes a pressure on both marine biodiversity and human use of the marine environment. For example, eutrophication presents a pressure on marine life through reduced dissolved oxygen and the presence of toxic algae. Other water quality issues that can put pressure on marine systems and human uses of marine systems are toxicity, turbidity and the presence of harmful bacteria.

Fishing also constitutes a pressure on marine biodiversity. Fishing throughout the 20th century resulted in a decline in the stocks of certain key species. In addition, fishing is likely to be responsible for altered trophic relationships, although as is the case for much of Victoria's marine biodiversity, the extent of the effects is largely unknown.

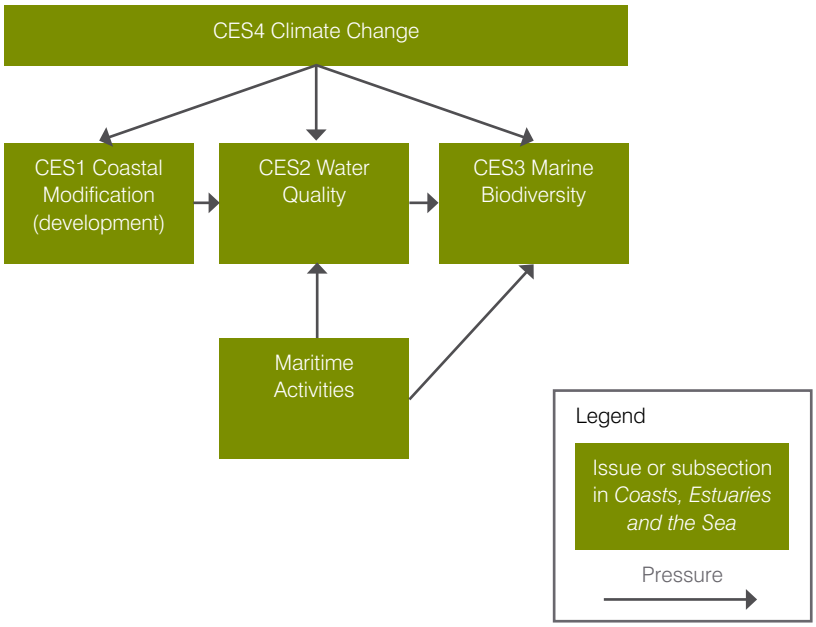
But it is clear that several marine species, particularly those of economic importance such as Southern Rock Lobster, are 'fully exploited'. This means that any further exploitation or an increase in other exogenous pressures would constitute a serious threat to the continuity of the fishery. Management plans to return populations to more sustainable numbers are in place, but continued demand, and factors such as marine pest incursions and climate change, will continue to put pressure on such species.

Exacerbating these localised pressures is the suite of climate change effects, the full implications of which are unknown. These range from changing ocean chemistry to altered distribution of marine animals, some of which now exhibit clear trends. For marine and coastal systems already under pressure, these effects represent additional and potentially confounding impacts. Such impacts are likely to have major implications for coastal development, water quality and marine species, including economic implications.

Recommendation

CES0.1 Ensure that non-climate related stressors are minimised in regions identified as particularly vulnerable to compounding pressures associated with climate change.

Figure CES0.1 Relationships between key pressures acting on coastal & marine systems (simplified) as covered by issues reported in this section.



Management responses

Victoria is fortunate to have 96% of coastal Crown land in public ownership, providing the opportunity for various levels of environmental management. As part of this management system, one third of the State's coastal Crown land is reserved as national park, coastal park, marine national park or marine sanctuary under the *National Parks Act 1975*. Much of the remaining public land on the coast is managed and generally protected by Committees of Management, appointed under the *Crown Land (Reserves) Act 1978*[7]. The *Coastal Management Act 1995* is also important for protecting the State's coastal and marine environment, as it provides a framework for the coordinated management of the Victorian coast. The Victorian Coastal Council has been established to deliver on the objectives of the Act. Any use or development of coastal Crown land also requires written consent under the *Coastal Management Act 1995* from the responsible minister. While the legislation provides a sound basis for the management of pressures on the Victorian coast, additional factors such as resource support for coastal managers needs to be considered to enable effective enactment of the legislation.

Development pressure on coastal settlements is one of the pressures on the State's coastal and marine environment that can result in the significant disturbance or loss of coastal ecosystems and biodiversity. The *Planning and Environment Act 1987* and *State Planning Policy Framework* set the framework for the sustainable use and development of land to minimise these pressures. With the population growth rate of coastal Victoria increasing faster than the Victorian average (Indicator CES1.5), it was recognised that coastal municipalities required assistance to appropriately manage development whilst protecting coastal values. The *Coastal Spaces* initiative was established in 2004 to improve strategic planning for coastal development and develop planning tools for coastal municipalities, such as providing support to develop settlement plans and settlement boundaries. This initiative has made a positive contribution to managing coastal development, but it is uncertain whether the initiative has made a similar contribution to maintaining and protecting the coastal and marine environment.

The management responses for managing marine water quality have been well-developed by the EPA. Historically, the identification of point source pollution and impacts on water quality has influenced appropriate management responses to marine water quality. The *State Environment Protection Policy (Waters of Victoria)* (SEPP (WoV)) provides the framework for the protection and monitoring of Victoria's marine waters. The SEPP (WoV) establishes a series of targets to maintain the health of marine water quality and sets the standards for various other water quality programs (e.g. Beach Report program). In some cases there is scope for tightening water quality objectives and for a greater level of monitoring.

The realisation that Victoria's coastal and marine environments are vulnerable to the effects of climate change led to the *Future Coasts* project, which assesses the vulnerability of Victoria's coast and marine environment to storm surges and sea level rise. The initiative includes digital mapping, and modelling the erodibility of the entire Victorian coast. The information collected needs to be used in conjunction with the most recent climate modelling to develop adaptation policy for coastal communities. It is also important that adaptation strategies are supported with sufficient resources to ensure that action is taken.

Response Name

Coastal Management Act 1995

Responsible Authority

Department of Sustainability & Environment

Response Type

Legislation

The *Coastal Management Act 1995* (the Act) aims to provide a co-ordinated approach to strategic planning and management of the Victorian coast. The Act establishes the Victorian Coastal Council (VCC) to oversee this. The direction and responsibilities of the VCC are established under the Act, with the Council required to submit annual reports to the minister to monitor the effectiveness of the Act. The VCC Annual Report provides an update on various actions associated with achieving the objectives of the Act, including the status of actions in the Victorian Coastal Strategy and Coastal Action Plans. But without any clear indicators to measure successful coastal and marine management, it is difficult to determine whether these actions are effective. The Act defines coastal Crown land, and its use and development for the purpose of consent under the Act.

To ensure a regional perspective for coastal management and strategic planning, the Act also establishes Regional Coastal Boards. Three Regional Coastal Boards have been established to date: the Western, Central and Gippsland Coastal Boards. A key function of the Boards is to develop Coastal Action Plans (CAPs) within their region. CAPs provide direction for coastal management and planning issues at a regional level. To date, 18 CAPs guiding management of coastal development, boating activities, estuaries and water quality protection have been developed by the Regional Coastal Boards.

At a local level, the Act also establishes the option to develop management plans for any area of coastal Crown land. Local management plans set priorities for funding and provide direction for conservation and development at a local level. The 2004 Victorian Coast report recorded that 68 foreshore management plans had been completed[8].

Under the Act, any use or development on coastal Crown land requires written consent from the minister. The consent process applies to all development on coastal Crown land and ensures that the broader public interest for public land use is maintained[9]. In 2006/07, 247 applications were made for consent under the Act, with 239 applications featuring works in the order of $35 million[10] approved. Since 2003/04 the number of applications for consent under the Act has increased by 32%.

Response Name
Victorian Coastal Strategy

Responsible Authority
Victorian Coastal Council

Response Type
Policy/strategy

The Victorian Coastal Strategy is prepared every five years by the Victorian Coastal Council and aims to establish long-term planning for the Victorian coast by:

- ensuring the protection of significant environmental features of the coast
- providing clear direction for the future use of the coast and marine environment
- identifying suitable development areas and development opportunities on the coast
- ensuring the sustainable use of natural coastal resources.

The requirement to develop and review the *Strategy* is outlined in the *Coastal Management Act 1995*. The Strategy provides a vision for coastal and marine management for the next five years and outlines actions to meet this. The Act outlines that land managers, including ministers, local government and committees of management, must take all reasonable steps to 'give effect' to the Strategy. The latest Strategy is currently in draft stage and is due to be launched in October 2008, following amendment to incorporate new sea level rise projections.

This Strategy builds upon the previous two Strategies published in 1997 and 2002, and outlines new key areas of adaptation to climate change and improving management of the marine environment. A key achievement supported in previous iterations of the Strategy includes the establishment of the Coastal Spaces initiative, which describes on-the-ground projects to protect the open spaces of Victoria's coastline from development (see CES1 Coastal Modification responses).

It is not known whether the final Strategy, which will be implemented through the Victorian Planning Provisions, will provide local governments with a strong basis for accepting or rejecting developments in low-lying coastal areas that may be subject to future innundation as a result of sea-level rise and/or storm surges. At present there is uncertainty around the likely extent of sea-level rise and future flooding risk, which is impeding the timely resolution of coastal development proposals. Amendment of the Victorian Planning Provisions to consider climate change impacts is required to provide local governments with strong grounds for decision making regarding planning.

Evaluation of management responses

The *Coastal Management Act 1995* provides an effective framework for coordinated coastal management in Victoria. The objectives of the Act are appropriate to this task and meeting them will provide sufficient protection of coastal assets. However, to ensure that Victoria is working towards this, a review of the effectiveness of Victoria's coastal planning and management arrangements established under the Act is needed. The review should focus primarily on the capacity of management bodies to fulfil their legislative responsibilities while examining the effectiveness of the Act's planning mechanisms to appropriately manage coastal modification pressures. Strengthening of the Act should also take into account the action in the draft Victorian Coastal Strategy, which calls for 'consideration of improvements to Victoria's coastal planning and management arrangement'.

Recommendation

CES0.2 Coordination of the monitoring and management of Victoria's coastal and marine environment should be improved. Review the governance arrangements and strategic planning processes established under the *Coastal Management Act 1995*. A major focus should be on the capacity of coastal management bodies to successfully fulfil their legislative responsibilities and examine opportunities for improving coordination. State Government should provide appropriate funding to expedite the implementation of the review's recommendations into planning law.

The *Coastal Management Act 1995* established the Victorian Coastal Council as the peak body for achieving the objectives of the Act, primarily through the development and implementation of the Victorian Coastal Strategy. The Strategy is an important management response to coastal modification pressures, as it sets out actions for appropriately managing the coastal and marine environment into the future. However, any strategy will have minimal effect if the actions lack support from the management bodies or are not implemented. Implementation of the actions arising from the Victorian Coastal Strategy has often lacked co-ordination and accountability, a shortcoming highlighted in DSE's feedback on the draft Strategy. There is a need to develop an interagency committee to coordinate and progress actions outlined in the Victorian Coastal Strategy.

Recommendation

CES0.3 As the key strategic plan for Victoria's coastal and marine environment, ensure that the actions outlined in the Victoria Coastal Strategy are implemented. The Department of Sustainability and Environment establishes and leads an interagency committee to coordinate and progress actions outlined in the Victorian Coastal Strategy.

The Victorian Coastal Strategy identifies the need to develop key indicators and targets to provide a measure of successful coastal management. For example, indicators should be developed in the context of establishing performance measures for Committees of Management under the *Crown Land (Reserves) Act 1978*. While the need for indicators has been identified, little work has yet been done to develop the indicators, limiting the ability to make strong assessments of the efficacy of coastal management actions.

Recommendation

CES0.4 Develop a set of indicators to provide coastal managers with a measure for successful coastal management.

CES1 Coastal Modification

Key findings

- The population of coastal Victoria is growing faster than the State average, particularly in areas close to Melbourne.
- While generally the planning processes to accommodate growth and development pressures in coastal towns is improving, the amount of subdivision and rate of urbanisation along the coast continues to increase.
- The number of tourists visiting the Victorian coast is decreasing, largely due to a significant decrease in day-trippers.
- Extensive modification of vegetation and estuaries has occurred, with land within or in closest proximity to large coastal settlements most affected.
- The condition of most estuaries has been degraded, particularly those around the more populated and developed coastal centres, to the extent that only a few, mainly in the far east of the State, remain in near-pristine condition.
- While the coast has undergone significant modification from the natural state, it remains difficult to determine the status and trends of the natural coastal environment due to a lack of consistent, reliable data.
- Victoria has at least 55,000 ha of potential coastal acid sulfate soils, disturbance of which can cause the generation of sulfuric acid that can pollute, soil water, waterways, wetlands and estuaries.

Description

The coast is valued for its unique and diverse attributes. Yet in many cases it is *the use and enjoyment of these values* which puts pressure on coastal environments. Victoria's coastal environment has been significantly modified since European settlement, with the rate of modification increasing over time as the State's population has grown and more people want to use and access the coast. Various scales and types of industrial, commercial and residential developments have been constructed along the length of the coast. Infrastructure, such as roads, has been installed and water has been extracted from both estuaries and the rivers leading to them to support the growing level of human activity.

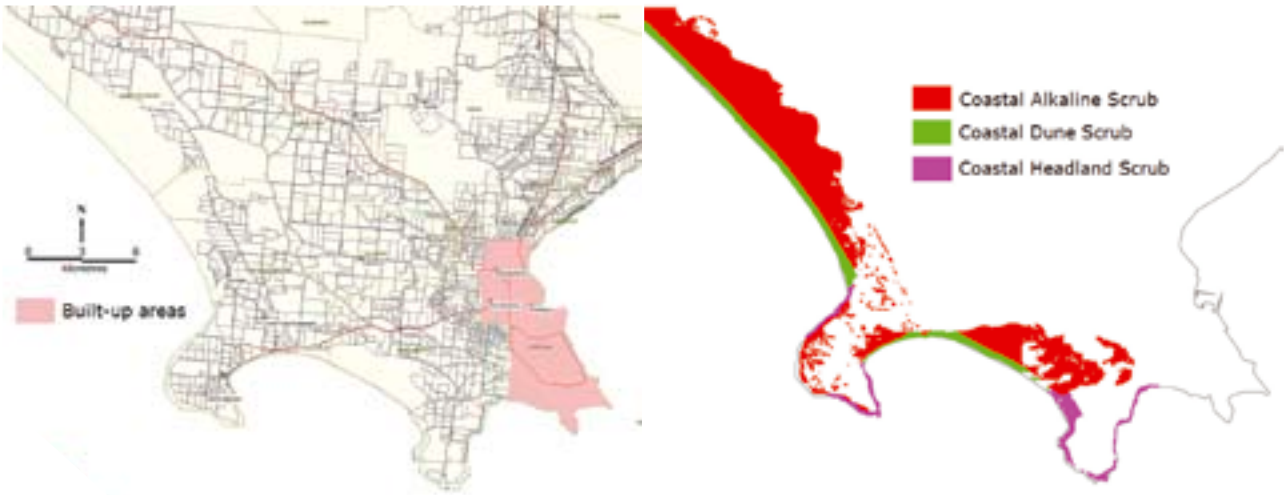
The effects of this increased modification of the coastal environment have been wide ranging, with the state of the natural coastal environment closely related to the intensity of human interaction. Highly intensive human activities such as those that occur in towns and cities usually result in a high degree of modification of the natural environment from its original state. Lower intensity activities such as agriculture can allow some natural values and processes to persist, while in the absence of any human uses, the natural environment is more likely to retain high natural values. This is well illustrated by Figure CES1.1, which shows the inverse relationship between the intensity of human land use (left) and the extent of coastal native vegetation (right) for the Portland area of western Victoria.

As a result of extensive coastal modification of this kind, the distribution and condition of native coastal vegetation across Victoria has been impacted or depleted significantly from pre-1750 conditions. In turn, the subsequent loss of habitat has reduced the number and range of fauna species. In addition, the condition of most estuaries, particularly those around the more populated coastal centres, has been degraded to the extent that only a few, in the far east of the State, remain in near-pristine condition.

A number of mechanisms are now being used to help prevent further modification of the Victorian coast and to prevent further degradation of coastal values. Nearly the entire coast is in public ownership, in various types of parks and reserves (including those that protect marine habitats). However, the level of management varies significantly, depending on reservation size and status, with national parks generally the best protected. For urban areas, improved planning processes have been developed with the intention of creating clear guidelines for the protection of coastal townships and surrounding environmental values, and also to provide a degree of certainty for residents and developers.

Within this context, the extent of subdivision and urbanisation in coastal Victoria continues to increase in response to a growing population. Projected population growth also follows this trend and will likely mean that without stronger mechanisms of protection, modification of coastal natural environments will continue.

Figure CES1.1 Comparison of the intensity of human land use (built up areas & road density) and extent of indigenous vegetation cover (coastal EVCs) in the Portland area, Victoria
Source: Victorian Government[11]



Objectives

- To improve the condition of the coastal environment.
- To encourage sustainable use and development of coastal areas.
- To improve understanding of the coastal environment and the processes impacting upon it, particularly modification.

State

Indicator CES1 Amount of coastline urbanised

Urbanisation is the process of converting the use of land to develop urban centres. Whether urbanisation is the result of a new tourist resort, dredging for a marina or the creation of a rural subdivision, it inevitably involves modifying the natural environment[12]. As one of the most intensive human uses of the coastal environment, the extent of the urbanised coast is an important indicator of the degree to which coastal environments are modified away from the pristine state.

All of Australia's coastal regions are experiencing growth and pressure from urbanisation. The causes of this vary, but in Victoria it generally reflects an overall increase in population through migration and natural increase, changes in household types which increase the demand for housing, and a general trend to retire to coastal centres (see Pressures, below). Added to this has been a buoyant property market with greater investment in coastal property as a lifestyle choice or simply as a financial investment (see Part 2 Driving Forces). The age and family structure of coastal populations is also changing, which, apart from having impacts on human services provision[13], can also have impacts on the natural environment.

As a result, many coastal urban areas, particularly those around and within a few hours drive of Melbourne, are experiencing unprecedented levels of development. This development is in the form of uptake of existing residential land, rapid transformation of building stock through redevelopment, and increasing use of rural allotments for residential living[14].

Many of the environmental effects of activities that occur in urban areas will be detected through environmental indicators (e.g. water quality, vegetation cover). However, assessing the change over time in the amount of the Victorian coastline that is urbanised (see Figure CES1.2) provides information on the likely scale of pressures on the natural coastal environment attributable to development.

While approximately 270 km of the current extent of Victorian coastal urbanisation took place prior to 1980, between 1980 and 2004 a further 41 km of the Victorian coastline was urbanised, an increase of 15%. Victoria has consistently had the second highest percentage of urbanised coastline after New South Wales. Tasmania recorded the fastest rate of urbanisation, where 119 km of coast was developed between 1980 and 2004.

Indicator CES2 Amount of coast in protected area system

The total Victorian coastline, excluding islands, is approximately 1800 km long[16]. Approximately 55% falls under the highest level of protection under the *National Parks Act 1975* (consisting of national and state parks). A further 35% falls under the next level of protection (consisting of coastal parks and reserves).

In addition, there are sections of public land that do not fall under these protections. In total it is estimated that almost 96% of Victoria's coastal land is in public ownership[17]. While much of this protection is linear, taking the form of reserves that have been specifically designed to protect coastal features, in some cases protection extends far inland, to areas that are less commonly regarded as coastal[18]. Examples include the Great Otway and Croajingolong National Parks. This extended area of protection provides additional benefits beyond those that are provided by linear reserves. For example, vegetation is maintained in a better condition within these national parks than within freehold land and this helps to maintain water quality in the local estuaries (see Indicator CES 4; see also Figure CES3.8 for marine areas under protection).

Indicator CES3 Condition of coastal vegetation communities

There are approximately 300 ecological vegetation classes (EVCs) in Victoria, including a large variety of coastal EVCs. Coastal ecological vegetation classes vary in size and range, but each is characterised by assemblages of plants that are specifically adapted to coastal environments. While the effect of urbanisation on indigenous vegetation is difficult to quantify, it is likely that it and other anthropogenic pressures have exerted significant pressure over the past 200 years. As a result, the extent and condition of several coastal EVCs, as described by conservation status (which takes into account the original extent of the EVC, the current level of depletion and the quality of remaining stands) is now significantly decreased.

A sample of EVCs selected as representative of Victorian coastal vegetation types is shown in Table CES1.1. The conservation status for each, according to the coastal bioregions in which it occurs, is also listed. The distribution of these EVCs is shown in Figure CES1.3. For a full description of Bioregions, Victorian EVCs and their distribution, see Part 4.2 Land & Biodiversity.

Figure CES1.2 Urban development along Victoria's coastline, total kilometres and percentage of total coastline, 1980-2004
Source: Australian Government[15]

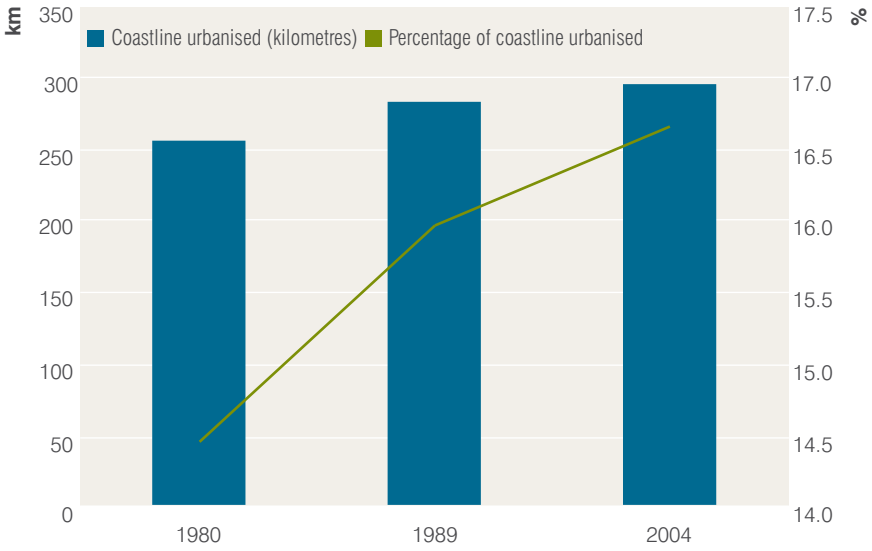


Table CES1.1 Extent and conservation status of selected Victorian coastal EVCs.
Source: DSE[19]

EVC Name	Area (Ha)	Description	Bioregions	Bioregional Conservation Status[i]
Coastal Dune Scrub/ Coastal Dune Grassland Mosaic	15,310	A mapping unit that covers the vegetation succession from the grasses and the salt-tolerant vegetation of the foredune to the closed scrubs on the secondary dunes along ocean and bay beaches and lake shores. Closed scrub or grassland on siliceous and calcareous sands that are subject to high levels of saltspray and continuous disturbance from onshore winds. Usually, this mosaic can be separated into its component EVCs at the site scale.	Otway Plain Otway Ranges Victoria Volcanic Plan East Gippsland Lowlands Wilsons Promontory Warrnambool Plain	Depleted Depleted Depleted Least concern Least concern Vulnerable
Coastal Dune Scrub	2,607	Coastal dune scrub occupies the secondary dunes along ocean and bay beaches and lake shores. Closed scrub with occasional emergent trees on siliceous and calcareous sands that are subject to high levels of saltspray and continuous disturbance from onshore winds.	Gippsland Plain Warrnambool Plain Bridgewater	Depleted Depleted Least concern
Coastal Headland Scrub	5,207	A scrub or low shrubland on steep, rocky coastal headlands often associated with cliffs exposed to the stresses of extreme salt-laden winds and salt spray from the south-west.	Gippsland Plain Otway Ranges Glenelg Plain Bridgewater Otway Plain Strezlecki Ranges Victorian Volcanic Plain Warrnambool Volcanic Plan Wilsons Promontory	Depleted Depleted Endangered Vulnerable Vulnerable Vulnerable Vulnerable Vulnerable Vulnerable
Coastal Tussock Grassland	1,004	A tussock grassland that may contain emergent shrubs. Occurs on exposed coastal cliffs and bluffs. Soils are saline and the strong, salt-laden winds preclude tree growth.	Strzelecki Ranges Wilsons Promontory Gippsland Plain Otway Plain Otway Ranges Victorian Volcanic Plain Warrnambool Plain	Depleted Rare Vulnerable Vulnerable Vulnerable Vulnerable Vulnerable
Coastal Alkaline Scrub	14,603	Occurs near coastal, deep calcareous (alkaline) sand dunes and swales, and commonly on the landward side of primary dunes. Elevation is low (20-60m ASL) and average annual rainfall is approximately 550-950mm. A shrubland, typically with a medium shrub layer, small shrub layer and sedges, grasses and herbs in the ground layer.	Wilsons Promontory Glenelg Plain Otway Plain Victorian Volcanic Plain Bridgewater Gippsland Plain	Depleted Endangered Endangered Endangered Least Concern Vulnerable

i See glossary for definition of conservation status terms.

Figure CES1.3 Current distribution of selected coastal EVCs in Victoria
Source DSE[20]

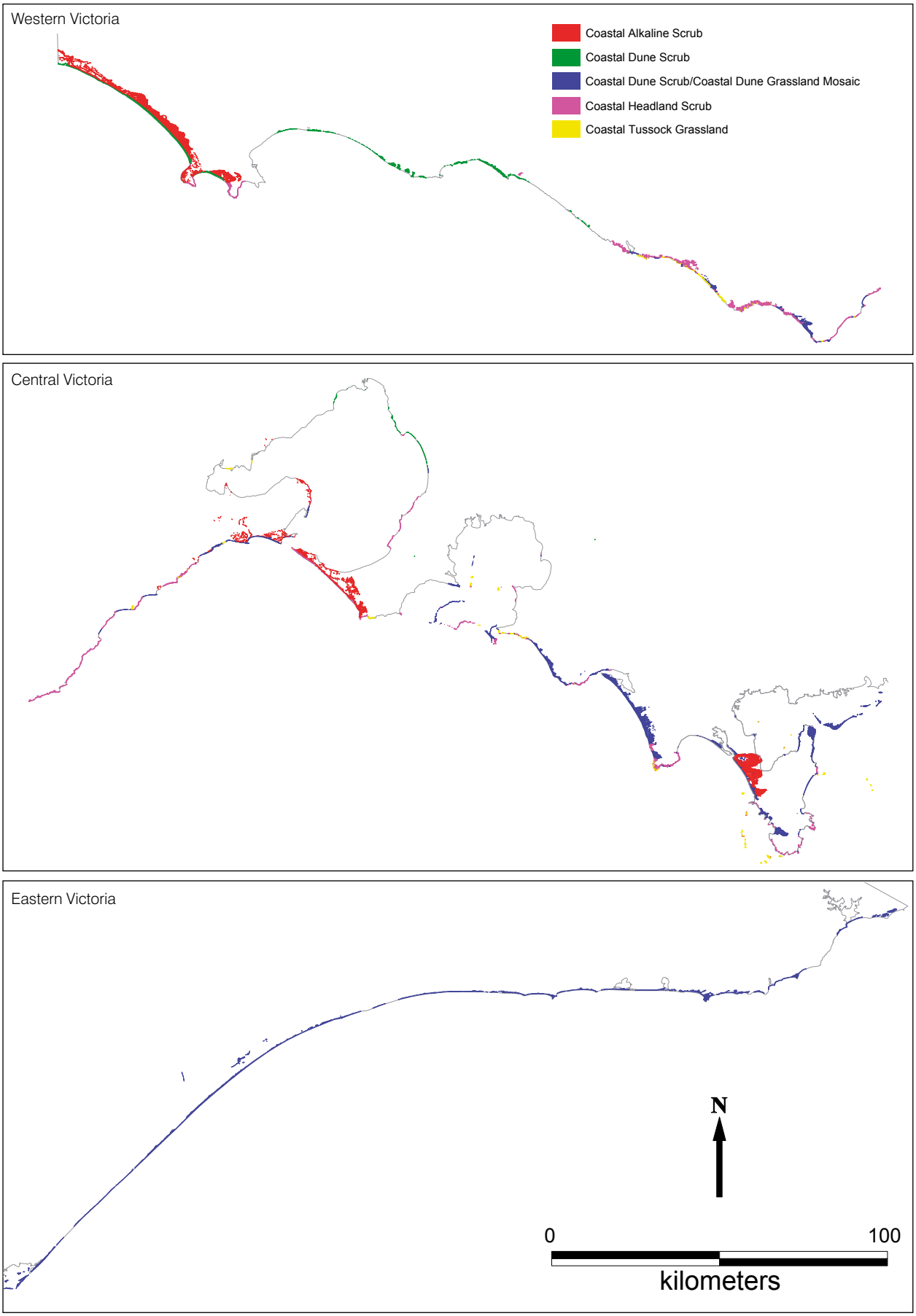


Figure CES1.3 shows that there is high diversity in vegetation across coastal Victoria. *Coastal Dune Scrub/Coastal Dune Grassland Mosaic* currently covers the largest area (15,310 ha) and is predominantly found east of Port Phillip Bay. It is also the least degraded of the EVCs analysed. *Coastal Alkaline Scrub* has the second largest area of distribution (14,603 ha) and is mainly found around Wilsons Promontory, the Mornington and Bellarine Peninsulas as well as Cape Bridgewater and Discovery Bay near Portland. Of the EVCs analysed, *Coastal Headland Scrub* and *Coastal Alkaline Scrub* are the most degraded, followed by *Coastal Tussock Grassland*.

It is not possible to show recent trends in the distribution or status of these EVCs, as no time series data is recorded. However, as discussed in Part 4.2 Land & Biodiversity, the extent and condition of nearly all vegetation types in Victoria has deteriorated over the last 200 years, and it is likely that coastal vegetation has experienced a similar change.

Recommendation

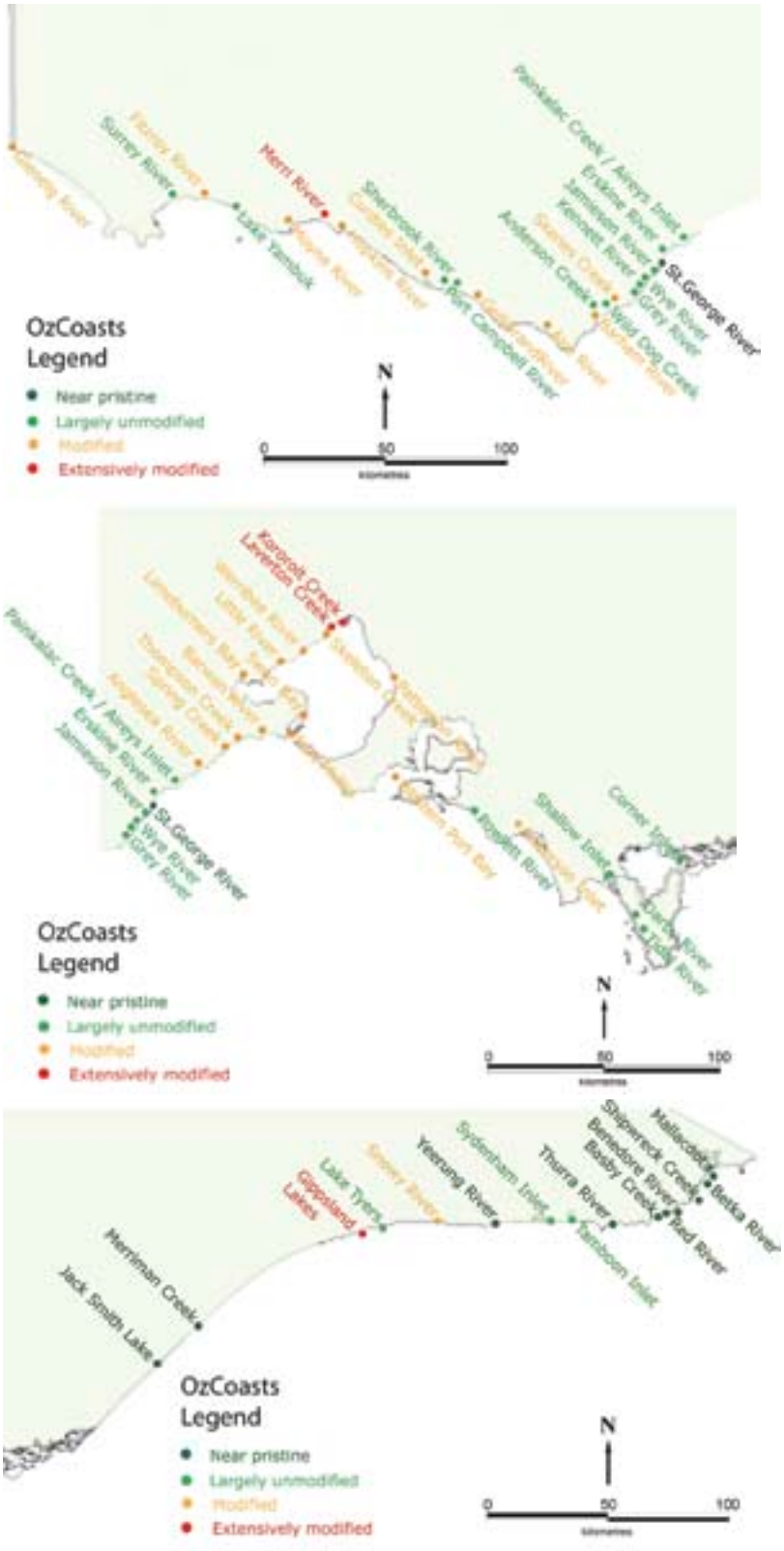
CES1.1 The Victorian Government should allocate funds for and undertake five-yearly estimates of coastal native vegetation cover in Victoria, based on high quality aerial photography or satellite imagery (As per recommendation in LB1: Vegetation loss and modification).

Indicator CES4 Estuarine condition

In recent years, there has been an increasing focus on estuaries and their management in Victoria. This has helped to provide a better understanding of the contributions to estuaries from catchments, and has led to a sharp increase in the perception of estuaries as important parts of coastal management[21].

Port Phillip Bay and Western Port, two large, permanently open estuaries in the central coast, are considered highly modified. The Gippsland Lakes are also considered extensively modified, while Corner Inlet retains greater natural values. The west and east coasts are characterised by many small estuaries that can be closed for much of the time. Smaller estuaries are the dominant estuary types in Victoria and as such are more prone to the effects of catchment modification such as land-use change and streamflow change[22].

Figure CES1.4 Condition of Victoria's estuaries, 2008
Source: OzCoasts and OzEstuaries[25]



There is limited data available on the ecological condition of estuaries[23] and so the degree to which they are modified from a 'near pristine state'[24] is used as an indicator of the state of the coastal environment (see Figure CES1.4).

Victoria's most modified estuaries occur around the more populated and developed coastal centres such as Lakes Entrance, Warrnambool and around Laverton/Altona in Melbourne (Laverton Creek and Kororoit Creek). Victoria's only near-pristine estuaries are located in the far east, where there is minimal modification and development, and where the catchments retain a good cover of native vegetation. Other largely unmodified estuaries occur around South Gippsland, along the Great Ocean Road and along the south-west coast. For more information on the condition of catchments, see Part 4.3 Inland Waters.

Pressures

There are many human-induced activities that can threaten coastal areas, particularly estuarine environments. Increasing population and development pressures are key drivers of processes leading to environmental change in coastal Victoria. These have effects as diverse as loss of important coastal and nearshore habitat, loss of open space and natural landscapes, increased nutrient loads to estuaries, and increased stormwater runoff into coastal waters.

In addition, the provision of infrastructure to support industrial activities, shipping and tourism ventures, and expanding human settlements has both environmental and physical effects. Given that the population growth in coastal areas of Victoria is projected to continue, the quality of our coastal and marine environments will continue to be placed under pressure[26]. This will also be exacerbated by the impacts of predicted climate change (See Part 4.1 Atmosphere: Climate Change).

Indicator CES5 Coastal population growth

Population growth is recognised as a driving force that has a significant impact on the environment (see Part 2: Driving Forces). The population growth rate of coastal Victoria (as defined by statistical local areas (SLAs)) was 1.4% between 1996 and 2006. This was more than the Victorian average of 1.2%, a trend that is expected to continue into the future (see Figure CES1.5)[27].

Particularly strong population growth rates in Victoria in recent years have been in coastal areas close to Melbourne, with bayside municipalities (e.g. Bass Coast, Cardinia, Casey, Surf Coast & Wyndham) all recording average annual growth rates higher than the State average between 1996 and 2006[29]. Much of this is related to the growth of Melbourne and Geelong and the subsequent expansion of the commuter belt. Coastal areas further from Melbourne have generally had lower population growth rates, with the exception of the Gippsland Lakes region, which remains a popular retirement destination. Larger towns such as Warrnambool and Bairnsdale are also expected to grow as they fulfil roles as regional service centres for smaller coastal areas[30].

While actual numbers may not seem significant, the percentage *growth rates* experienced by coastal areas are significant when compared with the State average. For example, the population of Surf Coast Shire increased by 3.2% per year between 1996 and 2001, while Victoria's population increased by 1.1% per year over the same period. The Surf Coast Shire population increased by a further 1.8% between 2001 and 2006. For small towns, this relatively large proportional change can present challenges for coastal planning and the protection of coastal values.

Indicator CES6 Coastal recreation and tourism

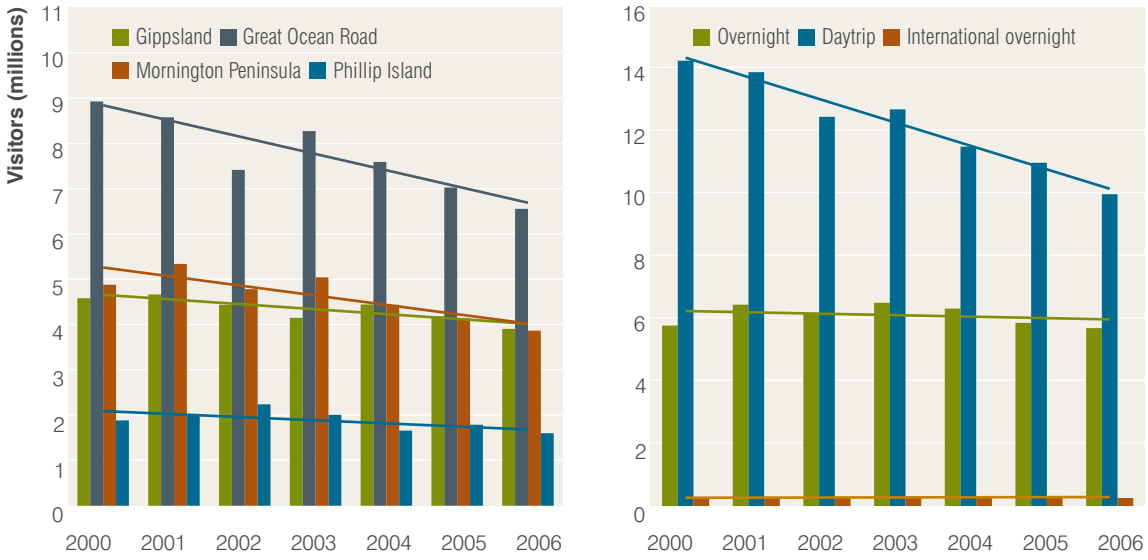
Tourism is a major economic activity in Victoria, providing benefits to the local economy and community in many regional areas, particularly the coast[31]. Eighty-seven percent of Victorians have visited the coast at least once in the last 12 months[32]. 'Going to the beach' is the most popular nature-based activity for all domestic and international visitors, representing about half of visits[33]. Coastal infrastructure can be costly, partly because it is underutilised in off-peak periods. For coastal municipalities this can be an economic burden that has unintended environmental impacts.

More research is needed to accurately characterise the relationship between tourist numbers and environmental impacts in coastal areas. Nevertheless, it is generally accepted that the level of tourism, as measured by visitor numbers and accommodation capacity, is indicative of the pressure that it exerts on the natural environment (see Box CES1)[34]. Also, the types of activities that tourists engage in and the way that tourism is managed are highly relevant to the way that tourism impacts the coast[35]. For better environmental outcomes, coastal land use planning should include consideration of the likely effects of the population's activities, both resident and peak (i.e. tourist), at the outset.

Figure CES1.6 shows the number and type of visits to Victoria's coast between 2000 and 2006[36].

Figure CES1.5 Historic and projected population growth for coastal Victoria 1991-2016 compared to rest of Victoria and whole of Victoria
Source: DPCD[28]

Figure CES1.6 Total visits to Victoria's coast by region (left) and by type of visit (right)
Source: Tourism Victoria[37]



All of the coastal tourism regions experienced a reduction in total visitors during the period, with the greatest reduction occurring in the Great Ocean Road region (26.6%); however, this region retains its position as the most popular on the coast.

Overall, there has been a decrease of 21.4% in total visits to the Victorian coast between 1999 and 2006 (see Box CES1 and Figure CES1.7). Daytrips, while still the most popular type of visit, fell 30%, from over 14 million in 2000 to fewer than 10 million in 2006. Overnight visits remained relatively stable, while the number of international overnight visits increased 3.8% from a relatively low base of approximately 247,000 in 2000, to 256,000 in 2006. These extra international visits were to the Great Ocean Road and Mornington Peninsula regions.

Box CES1 Coastal population fluctuations in Phillip Island and Torquay

Figure CES1.7 highlights coastal population fluctuations along the Victorian coast. Coastal destinations close to Melbourne are changing in character, with some now functioning as dormitory suburbs of larger cities, such as Torquay is for Geelong. Nevertheless, Phillip Island and Torquay still show significant population fluctuations over the year as a result of increased visitation in peak periods. For example, the population on Phillip Island increases to almost four times the resident population during weekends over summer. The total population doubles during weekends over summer in Torquay[38].

An increase in population during peak visitation periods can adversely affect the health of the coastal and marine environment. In Torquay, litter and coastal erosion have been highlighted as two environmental impacts associated with population fluctuations[40]. Beach cleaning and foreshore management costs peak during the summer months. There is no firm evidence to confirm who is responsible for the increase in litter on the beach during this period, but it is considered to be the result of the additional visitation to the area.

Figure CES1.7 Peak (visitor) population estimates for selected Victorian coastal towns, 2007
Source: DPCD[39]

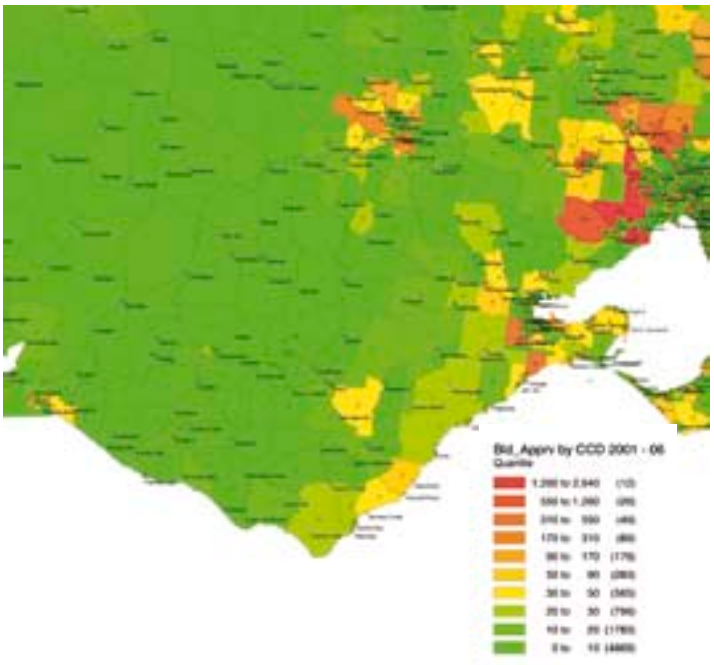
Indicator CES7 Coastal subdivision

Subdivision within township boundaries is commonly undertaken to divide an existing larger block of land with a single dwelling into multiple blocks ('allotments') for dwellings. A large proportion of development on the coast occurs within towns, and most of this is within Melbourne, Victoria's largest coastal settlement[41].

There has also been significant growth in coastal areas close to Melbourne, some of which is outside town boundaries. This growth continues to follow historic patterns of land use transition from productive to rural amenity uses[42]. The areas particularly affected are between Cape Otway and Wilsons Promontory. Figure CES 1.8 shows the extent of this type of development between Geelong and Lorne.

Further from Melbourne, the areas subject to a higher level of development are generally associated with established towns and include Portland, Port Fairy, Warrnambool, Port Albert, Marlo, The Gippsland Lakes and Mallacoota. Except where such developments are subject to specifically coastal issues (see Box CES2), the environmental pressures of development in coastal towns are similar to urban development pressures that occur elsewhere in the State.

Figure CES1.8 Building approvals by census collection district (CCD) Warrnambool to Geelong, 2001-2006
Source: DSE[43]



The coastal non-urban landscape provides important social, economic and environmental benefits at a local, regional and state level. It protects rural land use, holds aesthetic landscape value, provides a diversity of open spaces and experiences, gives individual settlements a sense of identity and helps to maintain biodiversity values[47]. Subdivision of coastal land outside existing urban zones and settlement boundaries (see *Management Responses*) involves transforming land used for rural purposes, such as farming, into residential developments of various scales.

Subdivision within and between towns constitutes pressure on coastal environments. The latter, however, is of particular relevance as it is more likely to exert pressure on distinctively coastal values. For example, the sorts of developments that are being built and that can go largely unnoticed in coastal towns can detract from the coast when they are built between towns[48]. Protecting the agriculturally and aesthetically valuable non-urban spaces between Victoria's coastal settlements is of key concern to many Victorians[49]. While Victorian coastal environments are subject to this pressure, it is generally acknowledged that the current absolute extent of - and therefore impact of - linear urban sprawl in coastal Victoria is not as great as that in Queensland or New South Wales.

Box CES2 Subdivision application at East Beach, Port Fairy

In February 2008, the Minister for Planning called in an application for a 28-lot residential subdivision at East Beach in Port Fairy[44]. The proposed subdivision comprises an area of approximately 4 hectares of coastal primary sand dunes located on the eastern fringe of Port Fairy. Under the *Planning and Environment Act 1987*, the minister may call in a planning permit application if the proposal raises a major issue of policy. Concern was raised because of the potential conflict of policy outlined in the State Planning Policy Framework and in the Victorian Coastal Strategy.

The site is sandwiched between eroding sand dunes and low-lying, flood-prone land. East Beach has been subject to ongoing coastal erosion, which may pose a risk to development on the site. The construction of the Moyne River training walls (to direct and confine river flow) in the late 1800s was undertaken to ensure access to the port of Port Fairy, with the port located on the banks of the Moyne River. While the training walls allow access to the port, the walls restrict the natural movement of sand towards East Beach and erosion occurs[45]. Coastal erosion has already threatened existing properties on the primary dune at East Beach, with a rock seawall installed along sections of the beach to protect the properties from further erosion. While the seawall does provide some protection from coastal erosion, it has reduced the beach width available for public use. This erosion problem may be accelerated in the future, with climate change anticipated to cause continuing rising sea levels and increased storm surge activity. On the landward side of the site, there may be exposure to an increased risk of flooding from the Moyne River, with extreme heavy rainfall events expected to become more intense due to climate change[46].

The proposed subdivision at East Beach highlights the importance of understanding coastal processes in managing development on the coast. This issue also highlights the need to better understand the potential impacts of climate change on the coast so as to ensure that appropriate mitigation and adaptation strategies can be implemented. The minister has appointed an advisory committee to provide advice on the most appropriate long-term outcome for this site. (see also Climate Change, Box CES12)

Recommendations

CES1.2 Develop strong and consistent indicators of coastal urbanisation to measure the impact of coastal development pressures on the coastal and marine environment.

CES1.3 Strengthen strategic and statutory tools for managing urban growth on the coast.

Implications

The majority of the Victorian coast is in public ownership, with most of it recognised and protected in parks and reserves (see *Management Responses*). Nevertheless, the implication of the continued demand for use and access to coastal environments means that they will continue to be placed under pressure. Despite the protections, the Victorian coast has been impacted by human pressures, and this is well illustrated by the indicators above. With strong residential growth and associated urban development projected to continue, these pressures are also likely to continue.

The impact of these trends will vary across coastal Victoria. In some instances, ample land is available, services are provided, and development is well managed. In other cases, whilst land is subdivided, only limited services are available and increased development has created issues such as pollution hotspots, and impacts on heritage values[50]. Without active and close management, projected development for some coastal environments, is likely to mean that there will be several significant direct effects. These are explored here.

Acid sulfate soils

Coastal acid sulfate soils (CASS) arise under different conditions to agriculture-related soil-acidifying processes (see 4.2 Land & Biodiversity). Potential coastal acid sulfate soils were formed within the last 10,000 years, when sea levels were higher than today. Metal sulfides, usually iron sulfides such as pyrite, form in natural environments which are anaerobic, rich in sulfate, metal oxides and organic matter. Such sites typically exist in estuaries, lakes, lagoons, morasses, swamps, marshlands and flood plains, and so coastal environments often have potential acid sulfate soils[ii]. Such soils are known as *potential acid sulfate soils*, which pose no threat unless disturbed. However, due to coastal urbanisation, they can be at risk of disturbance. If disturbed and exposed to oxygen, sulfuric acid is produced and soil pH can drop below 4. In this way *potential acid sulfate soils* become *actual acid sulfate soils*. This reaction is irreversible, constituting the crossing of an ecological threshold.

Disturbed acid sulfate soils have severe environmental impacts. Acidic discharge from acid sulfate soils changes soil structure, resulting in irreversible shrinking and permanent lowering of the ground surface. Acidification of waterways leads to fish kills and deoxygenation of the water, which in turn leads to algal blooms[51]. Acidification is also associated with reduced hatchling survival and low growth rates in a range of species. At acidity levels of pH 4, iron, manganese, arsenic and aluminium can be mobilised into waterways and reach toxic levels. Acidification and the associated heavy metal toxicity affect aquatic vegetation, which provides food and shelter for aquatic animals, and can have adverse effects on fisheries and waterbird habitats. In addition to its environmental impacts, sulfuric acid is highly corrosive of concrete and steel structures, potentially damaging coastal infrastructure. Australia-wide, the economic impact of acid sulfate soils is estimated at $10 billion due to the need to abandon developments and the cost of land rehabilitation.

Indicator CES8 Occurrence of acid sulfate soils

Acid sulfate soils occur both inland and along the coast. Victoria-wide, there is little information about the distribution of acid sulfate soils. The information that does exist is predominantly for coastal areas where acid sulfate soils are found in low lying coastal plains. A pilot study composed of a field survey and preliminary spatial mapping of potential coastal acid sulfate soils was undertaken in Victoria in 2003[52]. This study estimated a total area of 55,000 hectares of potential acid sulfate soils. The extent of this is shown in Figure CES1.9 and the estimated distribution among CMA regions is shown in Table CES1.1. Due to the high incidence of CASS in the sampled area, it is likely that the total area of land with coastal acid sulfate soils in Victoria may be significantly under-estimated.

Actual acid sulfate soils have been found at Dowd's Morass near Sale and the Coode Island silts in the Yarra River. Elsewhere, potential coastal acid sulfate soils have been found underlying parts of Port Albert, Patterson Lakes in Carrum, Frankston, Apollo Bay, in the flood plains of the Powlett River and the Nicholson River.

Figure CES1.9 Distribution of potential acid sulfate soils along the Victorian coast.
Source: Rampant et al. 2003.

Table CES.1.2 Occurrence of potential acid sulfate soils in Victorian CMA regions
Source: Rampant et al. 2003

CMA region (west to east)	Total area of potential acid sulfate soil (ha)
Glenelg Hopkins	7,106
Corangamite	13,845
Port Phillip	11,628
West Gippsland	19,666
East Gippsland	2,651

ii Acid sulfate soils can also be found in inland environments if suitable conditions occur, e.g. at salt discharge sites, saline waterways, saline waterbodies, waters polluted with contaminants that supply sufficient organic matter, sulfate or iron oxides (see Part 4.2 land and Biodiversity)

As well as acid sulfate soils and the erosion of community values identified as distinctly 'coastal' (see also Part 4, Coast, Estuaries & the Sea, Climate Change, Box CES12), there are a number of other implications of coastal modification

- the displacement of coastal terrestrial, aquatic and marine ecosystems due to land clearing for infrastructure. In addition to the impact on biodiversity, removal of coastal vegetation renders coastal communities more vulnerable to storm surges and erosion (see CES4; Climate Change)
- a number of issues attributed to roads; increased stormwater run-off, input of toxicants to waterways, reduced access for wildlife and induced recreational use of undeveloped areas
- the effect of unmanaged recreation on coastal land close to developments. This can result in potential impacts on biodiversity (for example, harming species that use particular coastal habitats, such as dune- or beach-nesting birds). As well as impacting on biodiversity, this can also impact on the utility of the coastal zone, particularly for activities such as fisheries, tourism and recreation
- the creation of new point and non-point source pollution (see CES2: Water Quality) due to development, farming and peak tourist populations, thus placing extra demands on sediment and nutrient management programs
- the transport of pest species due to recreational activities, and by both marine and terrestrial vehicles with associated effects on biodiversity values and local fisheries, aquaculture or agriculture.

In turn, these impacts may have flow-on effects for people living in or visiting coastal regions. With significant growth projected for a number of coastal areas, urban development and human activity present major ongoing challenges. A failure to manage growth sustainably in the long term will result in a reduction of the values that make the coast special. Some important values at risk include:

- reduced visitor satisfaction as a result of environmental damage and loss of natural assets
- increased fire risk and the need for emergency management
- loss of township character and reduced quality of life for residents and visitors[53].

Management Responses

Response Name
Crown Land (Reserves) Act 1978

Responsible Authority
Department of Sustainability and Environment

Response Type
Legislation

Of the 2000 kilometres of Victorian coastline, approximately 1920 kilometres (or 96% of the Victorian coast) is in public ownership in parks and reserves[54]. The *Crown Land (Reserves) Act 1978* stipulates the management requirements of all Crown land protected in reserves in Victoria. Under the Act, Victoria's Minister for Planning can appoint a Committee of Management to manage the reserve. Committees of Management can include members of the community, representatives of Local Governments, Parks Victoria and DSE. As the appointed land manager, the Committee has responsibility to manage, improve, maintain and control that reserve.

Approximately 58% of the entire Victorian coastline is managed by public or Local Government Committees of Management[55]. A review of coastal management in 2003 identified 56 Committees of Management appointed under the Act to manage the 400 Crown land reserves along the coast[56]. With over half of the State's coastline managed in this way, it is important that these Committees of Management are provided with an appropriate level of support from the State Government to fulfil their responsibilities under the Act so that as a group they can provide coordinated conservation programs throughout coastal Victoria.

Response Name
Coastal Spaces

Responsible Authorities
Department of Planning and Community Development / Department of Sustainability and Environment

Response Type
Policy/strategy

The Coastal Spaces initiative was developed in 2004 to provide a framework for the development and protection of the open spaces between towns along Victoria's coastline. The Coastal Spaces Inception Report (May 2005) identified some key themes including protecting open spaces between coastal towns, managing development 'hotspots' along the Victorian coast and capacity building within coastal local government. The Coastal Spaces Recommendation Report (April 2006), led to over $2 million in funding allocations from the State Government to implement local strategic projects addressing development on the coast.

Coastal Spaces projects and recommendations must be developed with reference to the *Planning and Environment Act 1987*, which sets the legislative framework for the planning and the basis for the sustainable use and development of land in Victoria. The State Planning Policy Framework (SPPF) developed under the Act outlines Statewide planning policies and practices that need to be considered in local planning schemes. The Coastal Spaces initiative aims to influence both the Act and the SPPF by providing actions to encourage sustainable development along the coast such as the development of settlement plans and settlement boundaries for coastal municipalities (see Indicator CES 9). The recommendations of the Coastal Spaces initiative were included in the SPPF in September 2007. Coastal planning decisions must now be consistent with these requirements.

Indicator CES9 Townships with settlement plans and boundaries

Settlement plans are a tool used by local governments to manage growth and development of townships, and to provide a guide to the long-term planning and development of coastal towns. They give consideration to a range of issues including projected population growth, township character and amenity; they provide residents and planners a degree of certainty that the values of the town and surrounding coastal area will be protected in the longer term.

A settlement boundary may be included as part of a settlement plan. This sets an outer boundary for a town and defines the allowable extent of urban use and development, although it can be reviewed and shifted. In this way a settlement boundary can help to protect the values of the open spaces between coastal settlements, although it should only be considered as one component in a suite of initiatives.

The Coastal Spaces initiative provides legislative, financial and skills support to coastal municipalities to implement settlement plans and boundaries. Coastal Victoria is generally well progressed with settlement planning (see Figure CES1.10), indicating some good uptake of Coastal Spaces initiatives. In 2007, of the 87 settlements along Victoria's coast, 77% had a detailed settlement plan and 19% of settlements had integrated their settlement plan into the planning scheme[57]. More towns had settlement boundaries developed in 2007 than in 2006. In 2007 a greater proportion of LGAs had integrated settlement boundaries into the planning scheme, an important step in ensuring that settlement boundaries are supported by statutory direction and weight in decision making.

Response Name
Coast Action/Coastcare

Responsible Authority
Department of Sustainability & Environment / Department of Environment, Water, Heritage and the Arts

Response Type
Program

Coast Action/Coastcare is a community program that supports coastal and marine-based volunteer groups. Coast Action/Coastcare is jointly funded by the State and Commonwealth Governments. The Coast Action program was initiated in Victoria in 1994, with the national Coastcare program commencing in 1996. The program engages and educates members of the public in protection and rehabilitation of coastal environments.

The Coast Action/Coastcare Strategy 2004-2010 outlines the objectives and future direction of the program. The Strategy aims to increase understanding and awareness of coastal and marine environments through training programs for community groups, 'Summer by the Sea' activities, programs, and supporting research and monitoring programs.

The Coast Action/Coastcare program is just one education and community awareness service for the coastal and marine environment. Other programs include ReefWatch, Fishcare, Parks Victoria Education and the Marine Discovery Centre at Queenscliff.

Response Name
Victorian Strategy for Coastal Acid Sulfate Soils

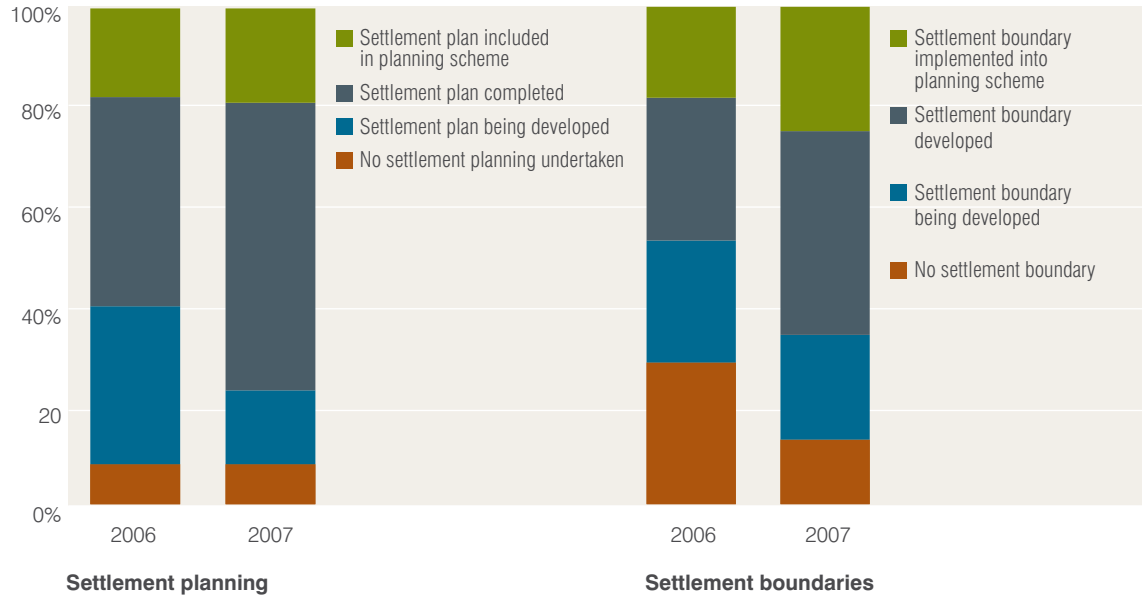
Responsible Authority
Department of Sustainability and Environment

Response Type
Strategy/policy

A draft strategy for coastal acid sulfate soils in Victoria was released in June 2008. The objective of the strategy is to protect the environment, humans and infrastructure from the harmful impacts of disturbing coastal acid sulfate soils. A first principle is to avoid disturbing coastal acid sulfate soils, the most environmentally and economically responsible option and preferred management strategy. The draft strategy proposes a risk management approach to guide decision makers and draft best practice guidelines for the assessment and management of coastal acid sulfate soils have also been developed. The draft strategy also outlines policy requiring any development on or near potential acid sulfate soils to show that disturbance will be avoided.

In development of the *Victorian Strategy for Coastal Acid Sulfate Soils,* site investigations are being undertaken to increase the accuracy and quality of coastal acid sulfate soils information along the Victorian coast. The investigations are focusing on priority areas determined by pressure for land-use development and where coastal acid sulfate soils issues are occurring.

Figure CES1.10 Proportion of settlements with each stage of coastal settlement planning in 2006 and 2007
Source: Data derived from DPCD[58]



Evaluation of coastal modification responses

The *Coastal Management Act 1995 and Crown Land (Reserves) Act 1978* provide the basis for the management of modification pressures along the Victorian coast. As outlined earlier, it is recommended that a review of the *Coastal Management Act 1995* is conducted to determine the effectiveness of Victoria's coastal planning and management arrangements established under the Act. This review should also consider the management arrangements for coastal Crown land established under the *Crown Land (Reserves) Act 1978*. The legislative process under this Act for appointing a Committee of Management for Crown land reserves is effective, but consideration should be given to the support and direction provided to Committees to undertake their legislative responsibilities. Opportunities for Committees to seek funding from both State and Commonwealth Government grant programs to improve the condition of the coastal environment have increased in recent years but many Committees are likely to struggle due to a lack of funding and human resources. DSE supports Committees of Management through 'training, policy, planning and sustainable management advice' and it is important that this support continues and is enhanced where possible[59].

Recommendation

CES1.4 The State Government should better value and support the Committees of Management responsible for managing coastal Crown land. Review arrangements and level of support for Committees of Management to manage coastal Crown land under the Crown Land (Reserves) Act 1978. At the conclusion of the review, State Government should fund and resource any critical recommendations.

Despite the significance of coastal development in Victoria and the range of management tools in place to address it, over half of the Victorian population still lack confidence in Government planning and building guidelines to protect the character and feel of coastal towns[60]. The Coastal Spaces initiative aims to address this issue. While some positive progress has been made to manage coastal growth (see Figure CES1.10), the primary focus of the initiative was not to monitor the condition of the coastal and marine environment, and in the absence of robust indicators it is therefore difficult to assess the nexus between the effectiveness of Coastal Spaces and the condition of the coastal environment. Provision of strong data on coastal condition would ensure that decision-makers and planners have access to the necessary information to make informed decisions. Improvements in the ongoing monitoring of coastal processes and incorporation of this knowledge into the planning system should also occur.

Recommendation

CES1.5 Develop indicators to monitor the impacts of urbanisation on the coastal and marine environment. Develop a program for ongoing monitoring of key coastal processes, ensuring that knowledge is utilised to inform coastal management decisions.

While education programs increase the community's knowledge and awareness of the coastal and marine environment and the impacts of coastal modification, these programs are often resource-limited, may not be informed by the most recent science, and lack a coordinated approach. Coordination of research effort and volunteer input would also assist in translating knowledge gained into the development of more robust management responses.

Recommendation

CES1.6 Identify a central agency to provide support and to coordinate coastal and marine education programs. Use this central agency to identify critical knowledge gaps and develop initiatives to improve connections between policy-makers, coastal managers and researchers.

The *Victorian Strategy for Coastal Acid Sulfate Soils* is currently in draft form, as is the revised Victorian Coastal Strategy, which identifies the disturbance of coastal acid sulfate soils during coastal development as a significant risk. It is too early to evaluate the effectiveness of these responses to the threats posed by coastal acid sulfate soils.

Recommendation

CES1.7 The Victorian Government should continue the current CASS survey, along with development and implementation of the Coastal Acid Sulfate Soil strategy, which identifies risk areas.

For further information

Coastcare
http://www.coastcare.com.au/

DSE, Coasts
http://www.dse.vic.gov.au/dse/nrencm.nsf/Home+Page/DSE+Coasts%7EHome+Page?open

CoastLinks
http://www.coastlinks.vic.gov.au/index.htm

CES2 Water quality

Key findings

- Activities on land affect water quality. Semi-enclosed embayments, especially adjacent to urbanised areas such as Port Phillip Bay, Western Port and Gippsland Lakes can be impacted by point and non-point sources of pollution that can reduce water quality.
- Locations within Victoria's estuarine environments that are directly impacted by inputs such as increased nutrient and suspended solid loadings have historically displayed the poorest water quality. Such sites include Long Reef and Hobson's Bay in Port Phillip Bay, and Corinella in Western Port.
- Due to the anticipated increasing pressures of climate change, dredging and inflow of nutrients, and the interactions between these pressures, there is an increased risk that bays and estuaries, particularly those close to human settlements, will experience reduced water quality in the future.
- While maritime activity is increasing and is projected to further increase, the number of reported marine pollution events in Victoria is declining.
- Most of the dredging in Port Phillip Bay and other Victorian ports over the last six years has been undertaken for maintenance purposes. In 2008 a significant dredging program was commenced that increased the amount of dredged material removed to more than 150 times the average annual dredge. This program is likely to have implications for water quality and water quality monitoring in Port Phillip Bay.

Objectives

- To maintain Victoria's marine water quality within State Environment Protection Policy objectives and to further improve marine water quality
- To reduce the impacts of maritime activities on the coastal and marine environment
- Increase compliance with marine environmental protection rules through relevant legislation and regulations
- To raise awareness of ways of improving marine water quality
- To improve understanding and management of marine ecosystems

Description

As described in CES1: Coastal Modification, a large and growing proportion of Victorians live on or close to the coast. In addition to the implications this has for the coastal terrestrial environment there are also implications for estuarine and marine water quality, principally due to urban stormwater run-off, treated effluent discharge, and, to a minor extent, aquaculture. Port Phillip Bay and Western Port are the two largest and most densely populated areas of Victoria's coastline and are home to many industries. The location of these heavily urbanised centres in close proximity to the marine and estuarine environment means that activities which occur within the catchments can also have implications for the adjacent marine environment. Other settlements along the Victorian coast are also associated with local water quality issues, particular those on the Gippsland Lakes.

As well as land-based pressures, Victorian marine waters are subject to pressures from a number of economically beneficial maritime industrial activities including shipping, fishing, and oil and gas extraction. Maritime activity, particularly in terms of the size of ships calling into Victorian ports, has increased since 2002 and is projected to increase further. Dredging is undertaken periodically in most ports on the Victorian coast to maintain navigable shipping channels. Depending upon how it is managed, dredging can have implications for marine processes, water quality and, in turn, marine biodiversity (see CES3 Marine Biodiversity). In particular, there are environmental implications of the Port Phillip Bay channel deepening project that should continue to be closely monitored.

In addition to dredging, other maritime activities have the potential to cause pollution in the coastal and marine environment. While the number of reported shipping-related marine pollution events in Victoria has decreased in recent years, the sources of most such events have been not been identified.

Potentially polluting discharges from terrestrial-based urban and industrial systems are classified as *point* and *non-point*. Point source discharges are direct discharges into the receiving environment from the pipes of industrial facilities and municipal sewage treatment plants. Point source discharges usually introduce water from the source into a single location, are close to large population centres, and most are licensed by the EPA. Non-point source discharges are diffuse in nature, often delivered to the marine environment through pulses, and are the result of non-specific sources as water moves across the land and through the ground. Agricultural and urban stormwater runoff that reaches the marine environment via streams and rivers is the major component of non-point pollution and is likely to constitute the greatest proportion of pollution to marine and estuarine systems overall.

The management of water quality is governed by both Commonwealth and State legislation. Within these policies and related guidelines, objectives for water quality are specifically defined for several sites for a range of parameters including physiochemical (salinity, temperature, turbidity and dissolved oxygen), nutrients (particularly nitrogen), contaminants (including heavy metals) and pathogens (specifically *Enterococci)* in the marine waters of Victoria. The health and utility of the marine environment can be directly influenced when variables fail to meet these objectives.

Monitoring by EPA Victoria indicates that Victoria generally has good marine water quality. At key locations within embayments such as Port Phillip Bay, Western Port and the Gippsland Lakes[61] however, periods of reduced water quality for parameters such as concentrations of nutrients, suspended solids and chlorophyll-a have been observed. Generally when water quality indicators fall outside of State Environment Protection Policy (SEPP) guidelines (see also *Management Responses*), this is due to episodic discharges from rivers and drains and reduced mixing and flushing of water.

The pressure of reduced water quality can have implications on the health of marine flora and fauna at these sites, and also the beneficial uses of these waters for human activities such as swimming, boating, and recreational and commercial fishing.

State

Marine and estuarine water quality around the State varies according to site. Although the open waters on the continental shelf of Bass Strait experience a slower rate of mixing than the adjacent open ocean[62], water quality there is generally believed to be good, although it is rarely monitored. Water quality in the open ocean can be negatively affected by sediment plumes from rivers after storm events. Such local effects are usually rapidly dispersed, only briefly affecting recreational and commercial fisheries.

Victorian estuarine and bay systems, however, are subject to reduced water quality. This is due both to the high level of human activity in and around Victorian bays and estuaries and the lower rates of water mixing with open waters. In order to monitor the condition of waters in bays and estuaries, the EPA measures water quality at a number of sites in Port Phillip Bay and Western Port according to State Environment Protection Policy (SEPP) *Waters of Victoria* (WoV)[63] guidelines, which in turn are based on nationally agreed standards. These monitoring sites are shown in Figure CES2.1

The EPA also measures water quality in the Gippsland Lakes at Lake Wellington, Lake Victoria, Lake King (2 sites) and Shaving Point (Figure CES2.2).

Figure CES2.1 Spatial marine segments and fixed site sampling locations in Port Phillip Bay and Western Port
Source: EPA[64]

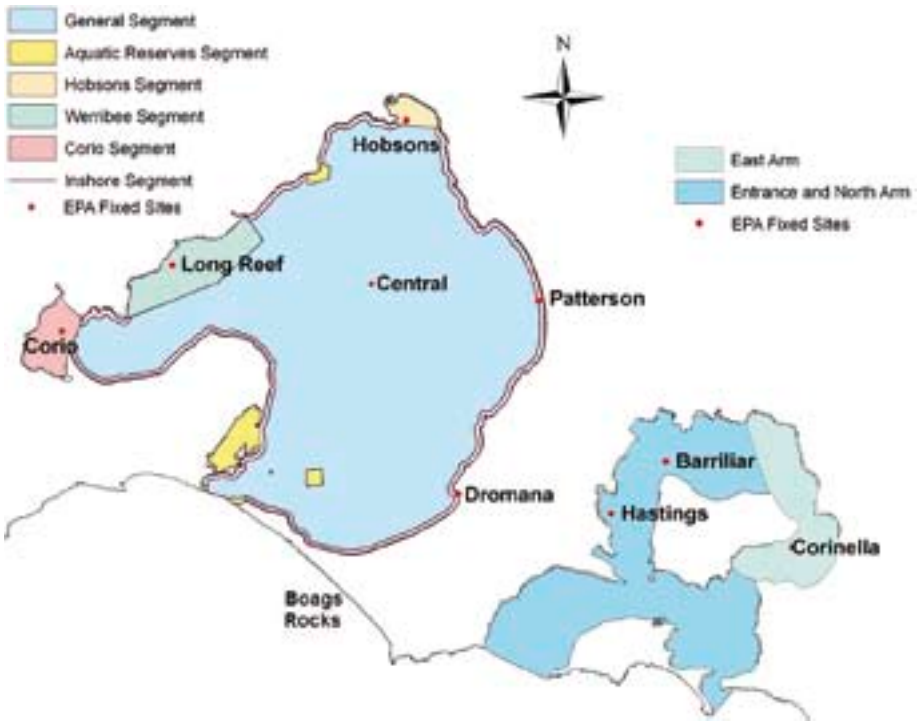


Figure CES2.2 Fixed site sampling locations in the Gippsland Lakes
Source: Adapted from EPA[65].

The SEPP (WOV) provides objectives for water quality indicators measured at these sites. The objectives are based on an *ecological risk assessment approach*[66] and vary among sites as they are set to protect the most sensitive designated beneficial use. Generally this is ecosystem health, although it can be recreational or aquacultural use as in the case for bacteria. The SEPP states that the objectives are 'set to protect and maintain aquatic ecosystem health. The suggested use of the recommended objectives is that their exceedence indicates a potential risk of adverse ecological effects'[67]. As more is learnt about water quality under natural conditions, and as is the case for toxins, as targets are met, the objectives set by the SEPP standards should be reviewed and made more stringent where appropriate.

Recommendation

CES2.1 SEPP standards should be reviewed and strengthened as understanding of water quality under natural conditions increases and as existing targets are met.

There are a number of parameters that are important for marine water quality and in most cases there are interactions between these parameters. These issues and the key indicators used to describe them in this report are shown in Table CES 2.1.

Generally, Victoria's estuarine waters are in a good condition as measured by these indicators, with most indicators for most sites falling within objectives over the period monitored[68]. For certain indicators and in certain locations, however, these objectives have been exceeded.

Eutrophication

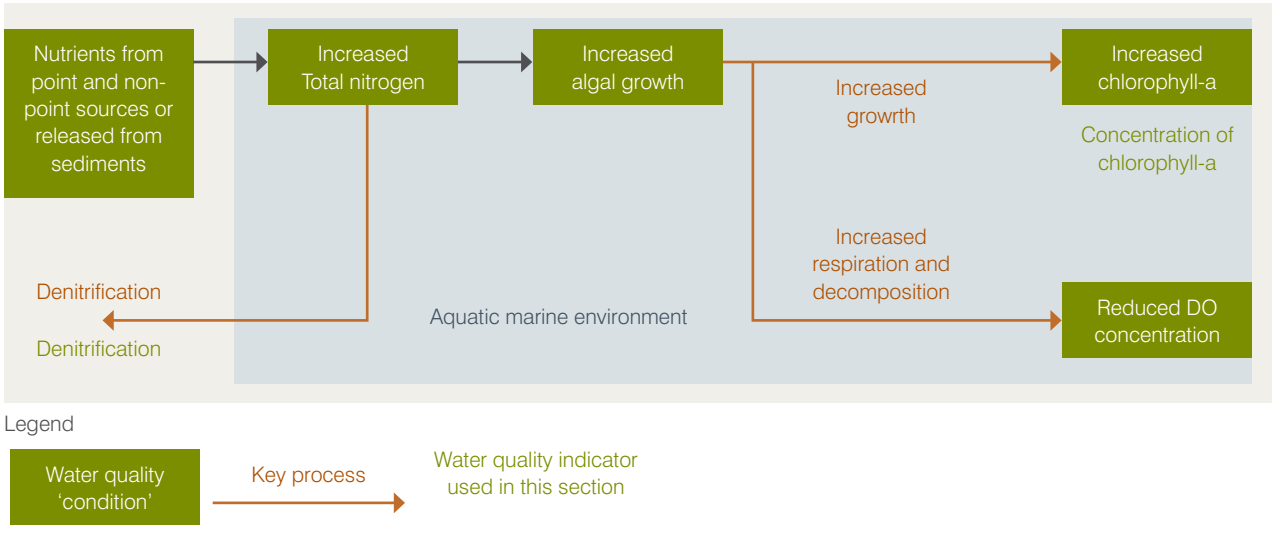
Nitrogen and phosphorous are nutrients that are critical for plant growth. In healthy marine ecosystems, nitrogen is generally much less abundant than phosphorous, and it is generally the lack of nitrogen rather than phosphorous that limits the growth of algae and other plants. Anthropogenic nitrogen loads are introduced to the marine environment via point and non-point sources and can stimulate algal growth, especially when the efficiency of natural *denitrification* processes is reduced.

Two significant point sources of nitrogen into Victoria's waters are the outfalls associated with the Western Treatment Plant in Port Phillip Bay and the Eastern Treatment Plant at Boags Rocks near Gunnamatta Beach on the Mornington Peninsula (Figure CES2.1) (see also *Pressures,* below). There is a risk that the introduction of nitrogen can reach levels that can lead to eutrophication, especially in waters in close proximity to such sites, and when mixing is reduced. Most eutrophic conditions are characterised by increased concentrations of chlorophyll-a, and fluctuations in dissolved oxygen (DO) levels. Reduced DO is harmful to marine and estuarine animals (See CES 3 Marine Biodiversity).

Table CES2.1 Water quality issues and key indicators used in this report.

Water quality issue	Indicators	
Eutrophication	Concentration of chlorophyll-a	Denitrification efficiency
Toxicity	Concentration of lead	
Water clarity	Secchi Depth	
Recreational water quality	Concentration of Enterococci	

Figure CES2.3 Interactions between aspects of eutrophication and use of key indicators



Indicator CES10 Denitrification efficiency

Nitrogen is naturally removed from marine and estuarine system through sequential microbial processes known as nitrification and denitrification[69]. It assists in ensuring that nutrients (specifically nitrogen) are kept in a healthy state of equilibrium, limiting the likelihood of eutrophication. Nitrification, is the conversion of ammonium produced by the decomposition of organic matter to nitrate ions. Nitrification rates are improved by high concentrations of dissolved oxygen (DO), itself facilitated by mixing of the water column. DO can be reduced when the sea bed sediments are disturbed, which typically occurs during dredging (see Box CES3). Denitrification converts the bio-available nitrate ions to nitrogen gas which escapes to the atmosphere. Bacteria at the bottom of marine ecosystem and are disturbed during any process that impacts the benthic layer, including dredging, perform the denitrification process.

There is currently limited information available for quantifying the denitrification processes in most of Victoria's marine and estuarine waters, although it is likely that the Gippsland Lakes were subject to reduced denitrification efficiency as a result of the 2007 floods. Nitrogen cycling is of particular importance to Port Phillip Bay, due to nutrient loading from rivers, drains and the Western Treament Plant. The long residence time (slow mixing with Bass Strait) of water in Port Phillip Bay allows time for nitrogen to be removed by various micro- and macroscopic communities in the sea bed (see Figure CES2.4)[71,72] and as a result the low concentrations of nitrogen in Port Phillip Bay are believed to be a result of high, natural denitrification efficiencies of this water body. If nitrogen loads are in excess of nitrogen cycling capacity, the long residence time would exacerbate water quality impacts.

A recent study of denitrification in Port Phillip Bay estimates that of the combined input sources at least 60% of the total nitrogen is removed from the marine environment through denitrification[73]. resulting in a high level of efficiency compared to similar estuaries internationally[74]. This indicates the importance of this process in reducing the risk of eutrophication. Figure CES2.5 indicates there has not been a significant change in seasonal average denitrification efficiency within sites assessed in Port Phillip Bay.

Figure CES2.4 Schematic of ecological nitrogen cycling in Port Phillip Bay
Source: Adapted from Port of Melbourne Corporation [70].

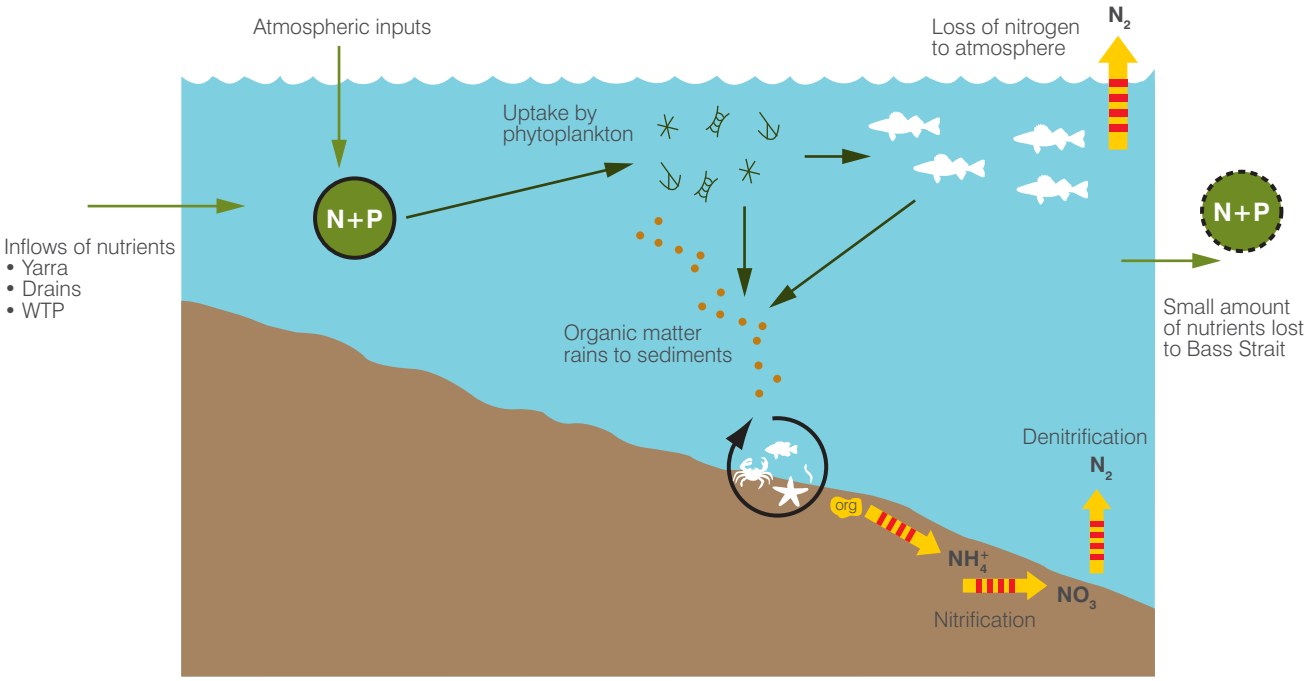
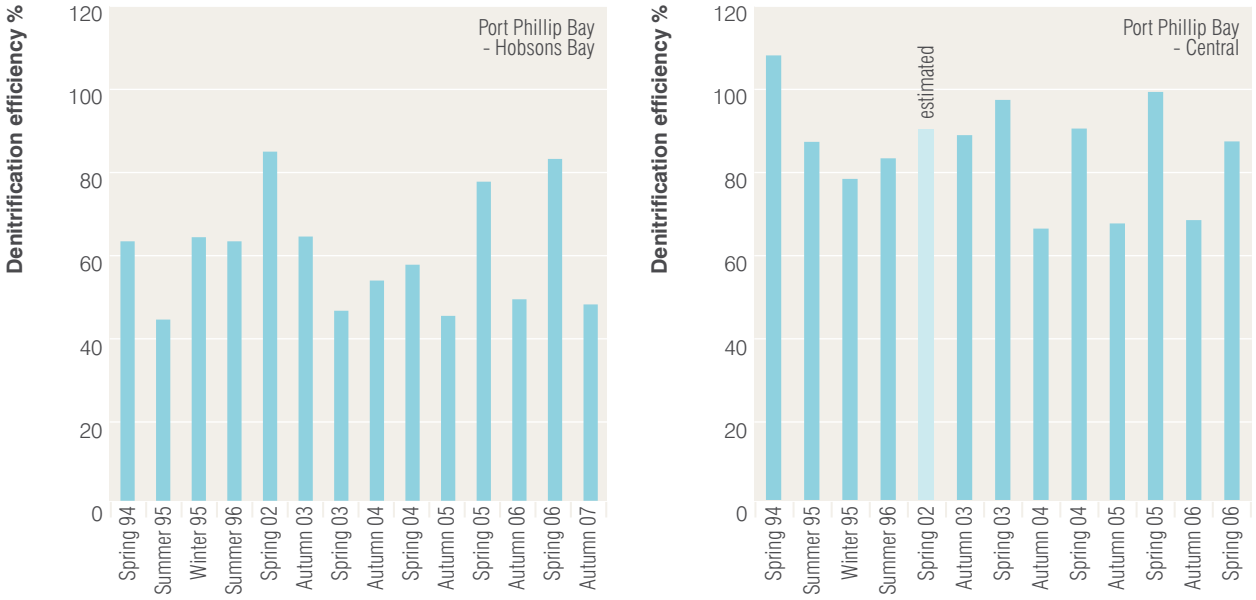


Figure CES2.5 Seasonal variation in mean denitrification efficiency in sediments measured in the centre of Port Phillip Bay
Source: Longmore 2007[75].



Due to the importance of the denitrification process and its vulnerability during dredging, it is essential that denitrification is monitored throughout the dredging program in Port Phillip Bay.

Recommendation

CES2.2 Continue to monitor the efficiency of denitrification in Port Phillip Bay, with more frequent monitoring under conditions of likely denitrification stress, such as after significant storm events and during dredging.

Indicator CES11 Concentration of chlorophyll-a

Chlorophyll-a is the green pigment found in plants and is a crucial component of photosynthesis. The concentration of chlorophyll-a in water is commonly used as a measure of water quality as it provides an indication of the abundance of phytoplankton in the marine environment. Increases in chlorophyll-a concentrations within a marine environment are usually due to seasonal increase in temperature, increased nutrient and sediment levels, decreased flushing or increased residence times and can be influenced by a reduction in nitrogen cycling (denitrification efficiency)[76]. For example, elevated chlorophyll-a levels are more common during the summer months when water temperatures and light levels increase[77], High levels of chlorophyll-a are often indicative of poor water quality. High levels of phytoplankton may also reduce dissolved oxygen. Certain species of phytoplankton may produce toxins in water, with implications for the health of fish, other animals and humans that come into contact with the water.

In particular, increased residence times and decreased flushing in the marine environment lead to an increase in the presence of nutrients such as nitrogen and phosphorus. As described previously, nitrogen and phosphorus must be maintained in healthy concentrations to avoid the risk of eutrophication and algal blooms.

The SEPP (WOV) specifies objectives for chlorophyll-a concentrations in Victoria's marine waters. Objectives for chlorophyll-a are either specified in SEPP(WoV) itself (for example the objective for open coasts is <1 µg/L or is set by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality[78]). Chlorophyll-a objectives are higher for Port Phillip Bay and Western Port than for open waters to allow for the naturally higher level of nutrient inputs from catchments that can feed into these bays. Where SEPP(WoV) does not specify an objective, for example, at Lake King South, the policy defaults to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Figure CES2.6 Chlorophyll-a levels objectives at Long Reef, Hobsons Bay, Corinella and Lake King South 1983 – 2008
Source: Unpublished EPA data[79].

Chlorophyll-a concentrations measured at the four sites generally meet specified objectives and are at a level below that thought to be necessary to protect the Ramsar wetlands on the Bay shore, although at sites in Port Philip Bay they have on occasion exceeded the objectives specified in the SEPP (WoV)[80]. Increasing use of water sensitive urban design, (see *Non-point sources of marine pollutants* below), and the levels of water treatment and water recycling, such as that which is occuring for the Eastern Treatment Plant (see Point source discharges below), would help to reduce the flow of nutrient concentrations at these sites.

Generally, chlorophyll-a concentrations measured in Western Port are good. However, at Corinella, frequent exceedance of the objectives reflects the naturally elevated nutrient levels and reduced flushing conditions that are characteristic of this location in the Bay.

Lake King South in the Gippsland Lakes periodically experiences higher chlorophyll-a levels than the other sites reported. This is the result of algal blooms associated with nitrogen and phosphorus loadings, a common occurrence in the Gippsland Lakes (see also Part 4.3 Inland Waters). The SEPP for total nitrogen, an important precursor of chlorophyll-a concentration, is also often exceeded at this site[81].

Recommendation

* For other recommendations targetting non-point sources of nutrients, see 4.3 Inland Waters

CES2.3 Reduce nutrient loads to meet ecological objectives. Set stretch standards for eliminating nutrient flows for the Western Treatment Plant and Boags Rocks (Gunnammata) outfalls.

Industrial contamination

There are a number of potentially toxic substances from industrial and urban processes that can affect water quality and, as a result, the health of animals and humans that use the marine environment (see Figure CES2.7). Implicated substances include heavy metals such as copper, arsenic, mercury, lead and cadmium; organic compounds such as pesticides and polychlorinated biphenyls (PCBs), which can be concentrated in estuaries due to the interaction between fresh and salt water. The influx of industrial contamination can be particularly harmful in estuarine environments where flushing is limited, and when historic deposits containing such substances are re-suspended, as can occur during storms or dredging (see Pressures).

In most cases, the presence of industrial toxins in the marine environment is the result of activities that occur or historically occurred upstream within catchments, and is attributable to non-point sources. As is the case for other marine water quality issues, a highly modified catchment such as the Yarra or Maribyrnong is often attributed with increased influx of toxic pollutants compared to more pristine catchments. Intensive uses such as the industrial and urban activities that occur within these catchments are responsible for many substances, although in many cases substances move through the air (see Part 4.1 Atmosphere, Air Quality) and surface or ground water (see Part 4.3 Inland Waters) before reaching the marine environment. In some cases, toxic substances can also enter marine environments as a result of maritime activities. If poorly managed, antifouling paints used to prevent the growth of organisms on ships and the spread of marine pests[82] (see CES3 Marine Biodiversity) can also be a source of marine toxicity.

Indicator CES12 Lead concentration

Lead is one of a suite of metals emitted by industrial processes. It is a pervasive industrial pollutant that can be toxic at relatively low concentrations, although others such as copper are more so. As well as industrial point sources, the weathering of paint and roofing materials and emissions from motor vehicles have historically been common diffuse sources of lead. Due to major programs to reduce sources of lead, trends may not be directly representative of all industrial toxicants in the marine environment, although its concentration is thought to be typical of the generally declining level of heavy metal contamination[83]. Figure CES2.8 shows the concentrations of lead in three Victorian estuaries.

Figure CES2.7 Interactions between aspects of toxicity and use of the key indicator

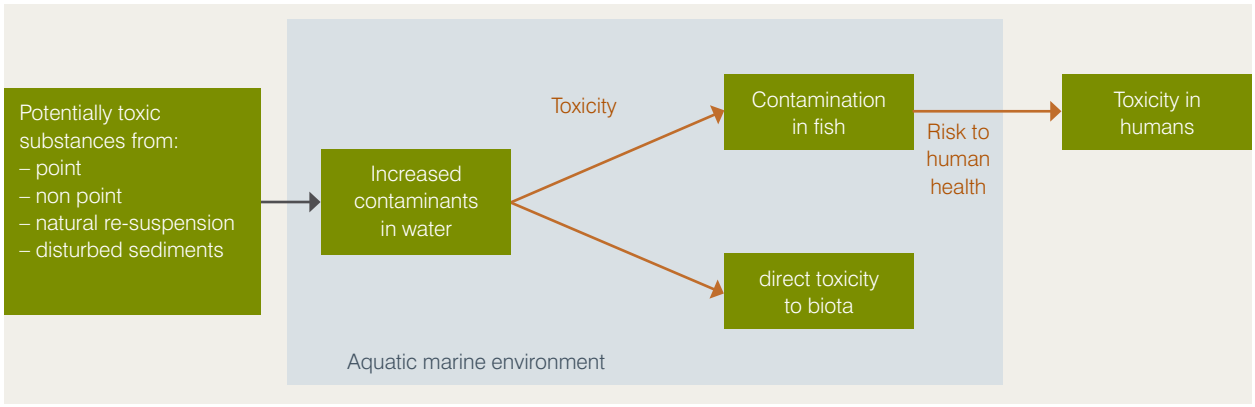
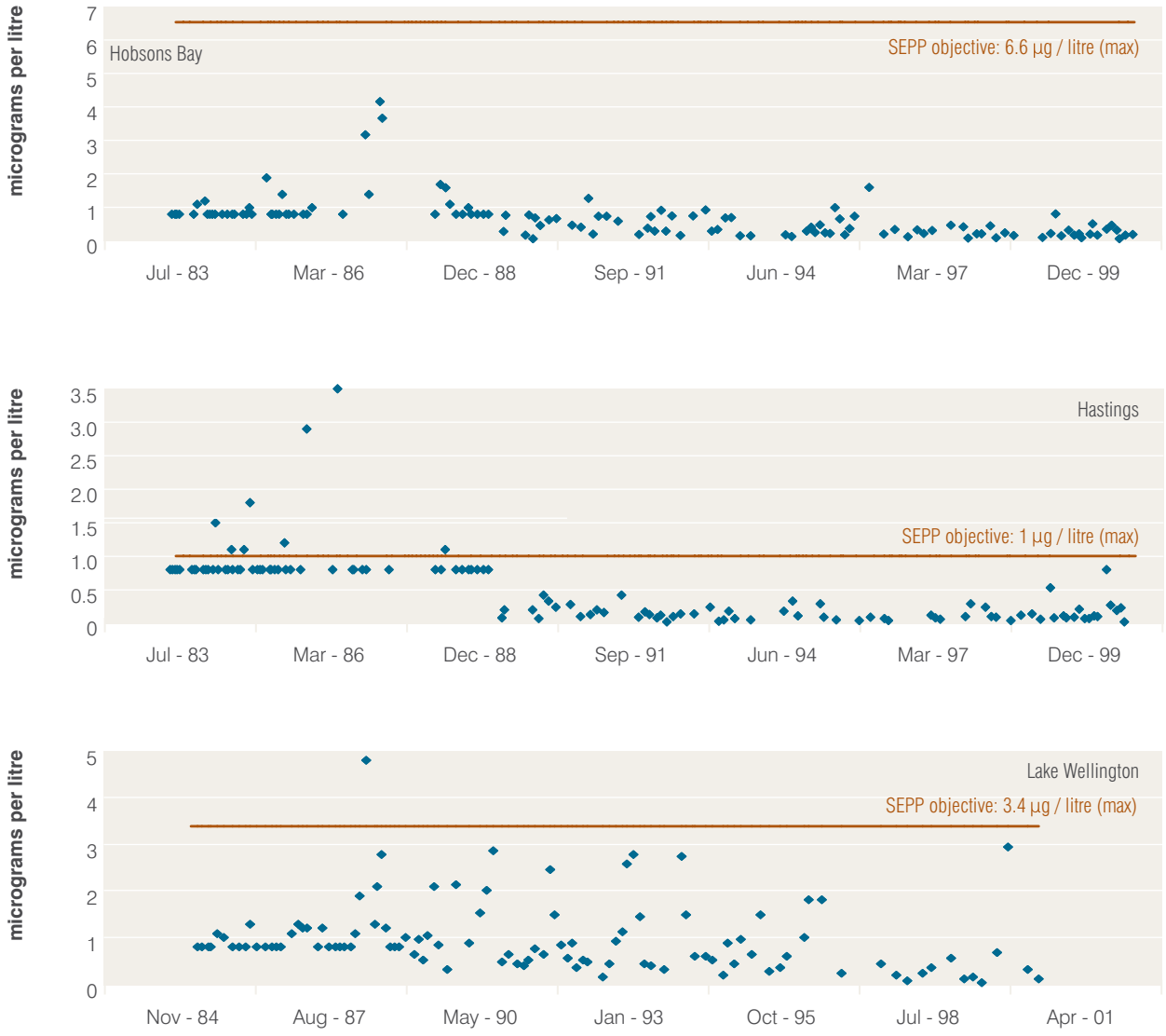


Figure CES2.8 Lead levels and SEPP objectives at Hobsons Bay 1983-2008, Hastings 1983-1999 and Lake Wellington 1983-2001
Source: Unpublished EPA data[84].



Lead concentrations at the three sites generally meet SEPP objectives. Transport of pollution from land-based sources has progressively declined since the 1980's and by the late 1990's lead in Port Phillip Bay waters was at the limits of detection, although at Hobsons Bay the slightly elevated levels suggest that the Yarra River continues to be a source[85]. The reduction in lead across other sites in Victoria is attributed to the phasing out of lead in petrol (in 1999, the date the data collection ended), paint and other formerly common uses. For Hastings in Western Port, levels also show a downward trend and appear to be approaching background levels. Lake King in the Gippsland Lakes also recorded downward trends but other sites, including Lake Wellington, recorded consistently higher levels which, although seasonal, may be attributed to the natural re-suspension of lead from sediments rather than to new inputs from the associated rivers and streams[86]. This site is thought to be characteristic of the way that the legacy of poor management of industrial wastes continues to affect water quality and raises the importance of testing for toxins in sediments and in indicator species, in addition to testing in the water column.

Recommendation

CES2.4 Establish a regular program of testing for toxicants in sediments and in key indicator species as well as in the water column.

Water clarity

Water clarity is affected by the amount of particulate matter (suspended solids, such as clay and silt particles, and planktonic organisms such as algae and zooplankton) in the water column. At most sites a small amount of suspended solids in the form of nutrients is essential to the survival of microscopic plants and animals. However, turbidity in marine waters can increase when there is a large inflow of suspended solids from non-point sources such as rivers, for example during a storm event, during tidal and seasonal variation such as strong winds, and during activities such as dredging. Shallow waters are more susceptible to increased suspended solids because of the ease with which sediments are re-suspended in the water.

High turbidity can reduce light penetration (a condition that can also result from increased algal growth), making it difficult for marine plants to grow. High turbidity can also result in the settling of suspended solids and the smothering of plants and seaweeds that grow on the sea floor (see Figure CES2.9). High turbidity also reduces the aesthetic value of estuaries and beaches, making them less attractive for recreational activites.

Indicators of the transparency (Secchi depth, see Indicator CES13) of water provide an approximation of light penetration and are used to measure turbidity relevant to human use. A different measure of turbidity; PAR (Photosynthetically Active Radiation) attenuation, is the usual measure required to assess light penetration for ecosystem function. Turbidity indicators such as these provide information on the amount of light that is available for marine organisms, particularly plants and benthic species (those on the floor of the marine environment) or an indication of whether turbidity levels are acceptable for human beneficial uses. There are ongoing programs in Port Phillip Bay, Western Port and the Gippsland Lakes, using both Secchi depth and PAR that measure water clarity.

Indicator CES13 Secchi depth

Secchi depth is measured by lowering a high contrast black and white disk (a *Secchi disk)* into the water and noting the depth at which it is no longer visible. A high result for Secchi depth usually indicates better water quality.

State Environment Protection Policies for Victoria's coastal waters specify objectives for suspended solids and turbidity based on each site's natural variations. With the exception of isolated areas usually subject to point source discharges and heavy rain, Victoria's open coast is not prone to excessive suspended solids. However, Victorian bays and estuaries can be subject to periodic increases in turbidity and so Secchi depth is measured at a number of sites, three of which are shown in Figure CES2.10.

Figure CES2.9: Interactions between aspects of water clarity (turbidity) and use of the key indicator.

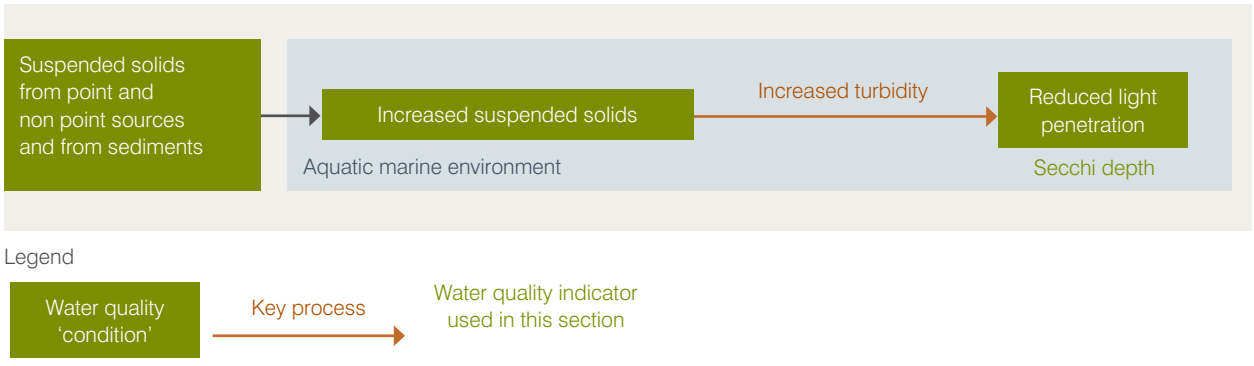
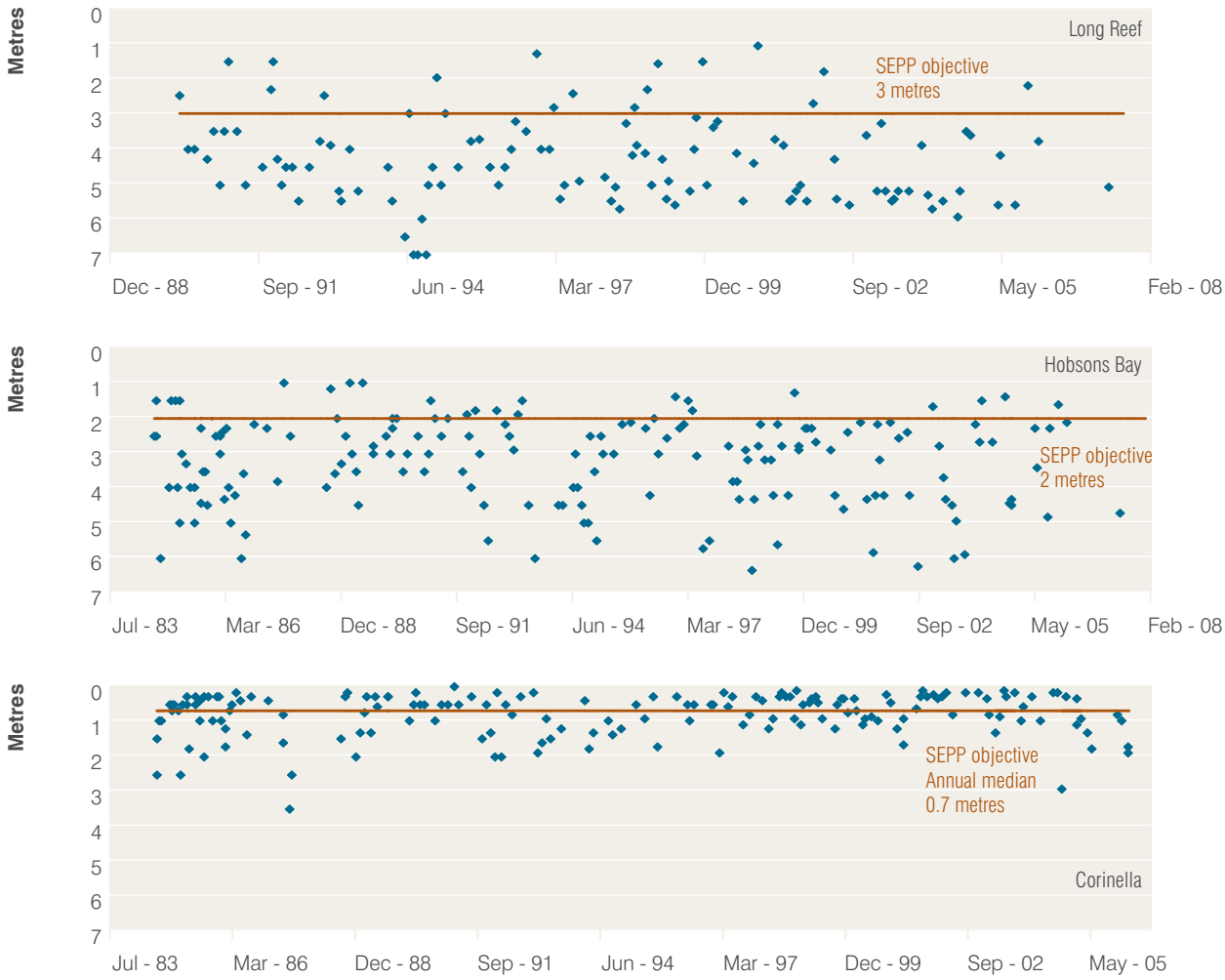


Figure CES2.10 Secchi depth and SEPP objectives, for Long Reef, Hobsons Bay and Corinella, 1983-2007
Source: EPA unpublished data[87]



The waters of Port Phillip Bay are generally not considered to have high concentrations of suspended solids except during flood from the Yarra River following heavy rain and during dredging (see *Pressures* below). Elevated suspended solids have been measured consistently since at Corinella in Western Port since the current monitoring program began in 1984. This has been attributed to the highly mobile sediments in the form of muds characteristic of the area, hence the lower SEPP objective for this site. The Gippsland Lakes have also historically been affected by suspended solids from the large freshwater catchment loadings into these estuarine systems.

Melbourne Water and the EPA have initiated studies to determine the impact of contamination from these estuarine systems on edible fish species that can inhabit the surrounding waters. Preliminary investigations have determined that concentrations of contaminants in fish were below the maximum residue limits (MRL) for food, yet the tissues of some eels sampled contained levels of a chemical of concern above the specified MRL[88].

Recreational water quality

Recreational water quality refers to the suitability of water for swimming and other activities that involve direct contact with the water[89]. EPA Victoria has been monitoring the health of popular swimming beaches in Port Phillip Bay and more recently, Western Port during the warmer summer months, when demand for recreational use is high, by testing for the presence of indicator bacteria. Testing of recreational water quality has also occurred at beaches along Victoria's western coastline[90]. The testing sites in Port Phillip Bay and Western Port are shown in Figure CES2.11.

Prior to 2002, EPA used the bacteria species *Escherichia coli* (known as *E.coli*) as the principal water quality indicator for recreational marine waters. In recent years, The World Health Organisation and the National Health and Medical Research Council have recognised that Enterococci bacteria are the best indicator for marine recreational water quality[92] and the EPA has adopted this indicaor.

Enterococci are bacteria commonly found in the gastro-intestinal tracts of warm blooded animals and may be present in marine waters. Animal faeces (including dogs), which are washed into the sea via rivers and stormwater drains after rain events is thought to be the principle source of *Enterococci*[93]. Poorly managed sewage is also likely to play a lesser role. Ingestion of these bacterial pathogens can lead to gastrointestinal illnesses such as diarrhoea.

Indicator CES14 Enterococci concentration

Routine sampling of the concentration of *Enterococci* in water is performed by the EPA from November to March each year. Each Summer the results are assessed against objectives for primary contact recreation outlined in the SEPP (Waters of Victoria) 2003. For Enterococci, the SEPP sets an objective median of 35 *Enterococci* per 100ml and a 75th percentile of 150 *Enterococci* per 100ml[94]. Figure CES2.13 shows 75th percentile *Enterococci* levels for thirty-five beach sites around Port Phillip Bay.

Figure CES2.11 Recreational beach quality sample locations in Port Phillip Bay and Western Port
Source: EPA[91]

Figure CES2.12: Interactions between aspects of recreational water quality and use of the key indicator

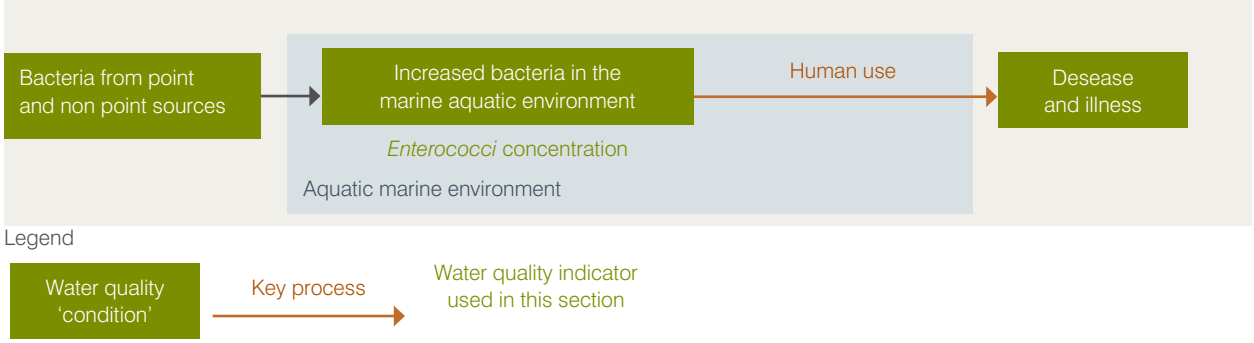
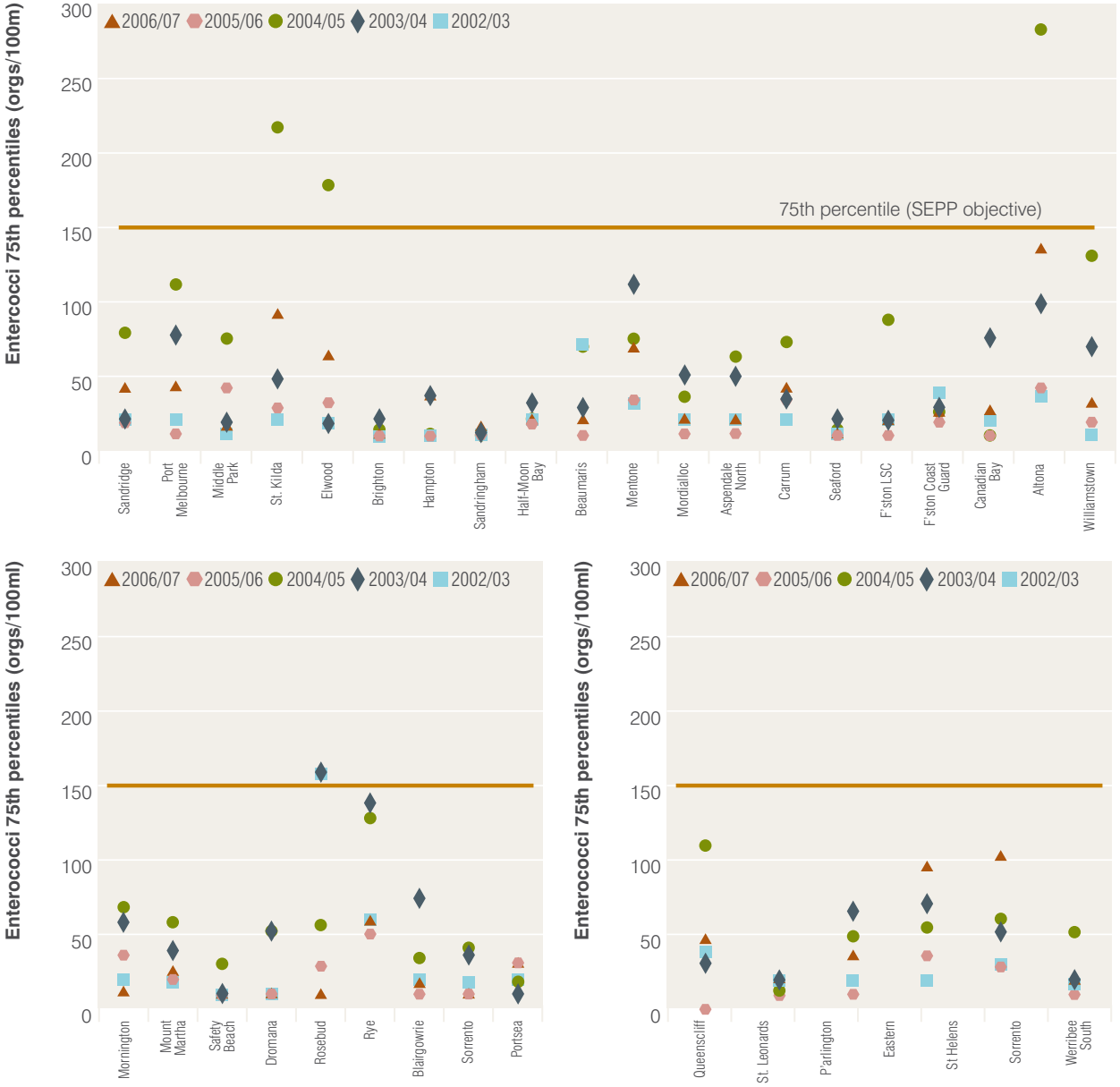


Figure CES 2.13 Enterococci readings for Port Phillip Bay, Summers 2002-2007
Source: EPA data[95]



Of all sites shown, the majority of beaches comply with the SEPP objective (75th percentile). A number of sites (including St. Kilda Beach, Elwood and Altona) returned elevated *Enterococci* levels during 2004-2005[96]. As is the case for most incidents of elevated *Enterococci* levels, this was due to a large rain event in February 2005[97].

Elevated levels of *Enterococci* are likely to be due to both point and non-point sources, particularly stormwater drains that discharge water at these sites on Port Phillip Bay. These stormwater inputs contribute to reduced recreational water quality at times of elevated input loadings. EPA recommends against swimming near stormwater drains, rivers, streams and other outlets into Port Phillip Bay during and 24 hours after rain.

As with Port Phillip Bay, rainfall events around Western Port often result in elevated bacterial numbers. However, overall results for recreational water quality in Western Port indicate that bacterial numbers are generally better than in Port Phillip Bay. This is likely to be because of the smaller population and lower density of impervious surfaces in this catchment.

The recreational water quality of beaches along the western coastline of Victoria has been found to be very good with the exception of some estuarine sites such as Wye River and Kennett River. Elevated bacterial levels in these estuaries appeared to be associated with localised stressors on river catchments partly as a result of the increased population, pressures on the townships' septic and sewerage infrastructure, and stormwater drainage[98].

Recommendations

CES2.5 Enhance catchment and stormwater education programs that highlight the risks of poor urban waste management to flora, fauna and human beneficial use of the marine environment.

CES2.6 Increase incentives for municipalities, communities and businesses to retro-fit water sensitive urban design into existing infrastructure.

Pressures

Pressures on marine water quality have two distinct origins: those originating from maritime activities and those originating from terrestrial activities.

Maritime pressures

Maritime activities such as commercial and recreational shipping, and port activity are all vital and legitimate uses of our seas and coast, but they can present environmental costs and risks. In the first instance, the more ships that enter Victorian waters, the greater the risk of pollution from ships. There is also and greater chance of contamination by marine pests (see CES3 Marine Biodiversity). Similarly, the larger the ships that seek entry to the Port of Melbourne, the greater the demand for dredging, which itself can affect marine water quality (Figure CES2.14).

Because these issues are interrelated, the indicators *Commercial Shipping, Dredging and Marine Pollution* are included here to illustrate the extent of these maritime pressures on water quality.

Indicator CES15 Commercial shipping

The Port of Melbourne is the busiest container and general cargo port in Australia, handling 37% of the nation's container trade[99]. The other major Victorian ports of Hastings, Geelong and Portland cater for more general cargo. There are also over a dozen smaller ports which service the commercial fishing, recreational boating and other offshore industries such as the gas and the petroleum sector.

Almost 85% of Victoria's traded goods (by customs value) are exported from Victoria's commercial trading ports, and almost 80% are imported through them. The ports and their related businesses form part of an estimated 16,000 businesses that operate primarily within the freight and logistics sector in Victoria, providing more than 100,000 jobs. The Victorian shipping profile, in terms of tonnage and number of visits, is shown in Figure CES2.15.

Figure CES2.14 Relationships between maritime pressures and water quality (simplified)

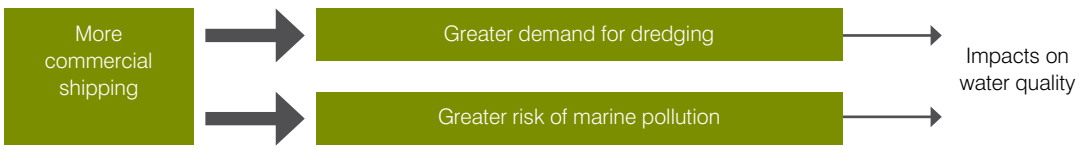
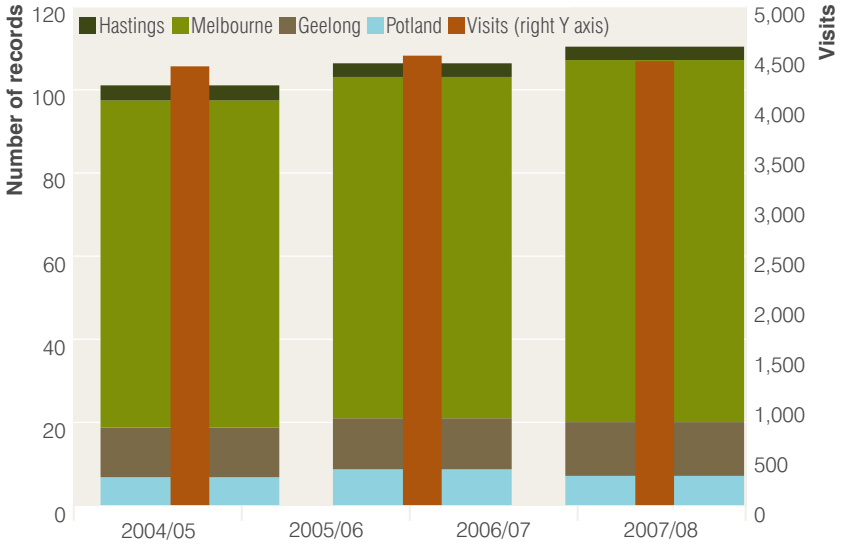


Figure CES2.15 Gross registered tonnage (GRT) and total visits to Victoria's commercial ports between 2004/05 and 2006/07
Source: DoI[100] 2007-08 data was not available at time of publication



While the total number of visits by ships to Victoria's four main commercial ports has remained relatively stable over the last three years, at approximately 4,500 visits per year, the weight of commercial ships has been increasing over the last three years. The greatest increase in average gross registered tonnage (GRT) over the three years was for ships visiting Geelong (15% - from 23,128 to 26,510 tonnes). The GRT of all shipping visits to Victoria increased from approximately 101 million tonnes in 2004/05 to over 110 million tonnes in 2006/07 (an 8.9% increase).

In contrast to both Geelong and Portland, which predominantly handle bulk goods, a significant amount of the trade currently handled by the Port of Melbourne is in the form of containers. By 2035, the number of containers handled at the Melbourne Port, under a business-as-usual scenario, is projected to increase 500%. This is the main driver of the Channel Deepening Project (see Box CES3). Trade in all of Victoria's commercial ports is forecast to grow in coming years, with the highest relative increases expected at the Port of Melbourne and Port of Hastings[101].

Apart from the impacts of dredging, the implications of increased shipping on water quality include the effects of antifouling paints in ports and off-shore, the introduction of exotic species into ports, harbours and coastal waters, oil or hazardous cargo spills in ports and coastal waters, and ship waste in ports.

Indicator CES16 Dredging in Port Phillip Bay and Western Port

Dredging refers to the removal of sediment, rocks and other material from the bed of shipping channels to maintain or deepen them. All dredging requires approval under the *Coastal Management Act 1995*. Some dredging programs have ongoing approval under the Act (eg maintenance dredging based on an approved management plan), others are a single dredge so get temporary approvals, and others are capital dredging on a scale that requires an Environmental Effects Statement (eg the current Channel Deepening project). Dredging can take place for the following reasons:

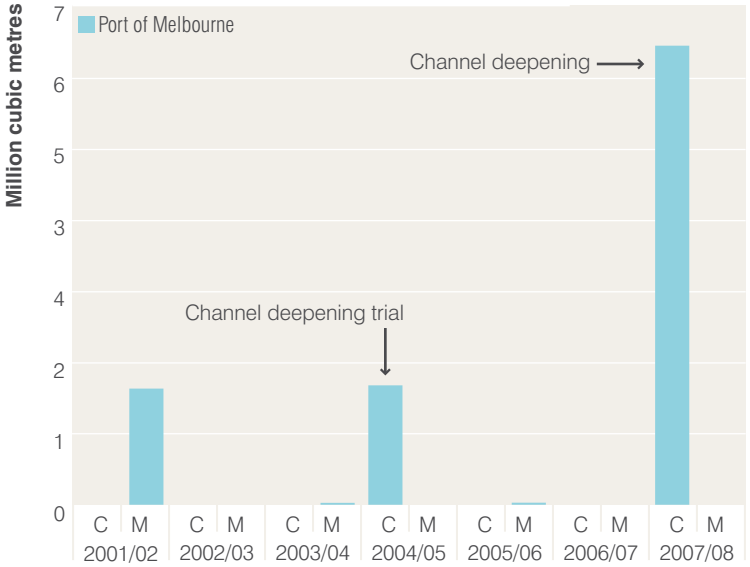
- to maintain the depth in existing ports, harbours and channels to provide ready and safe passage for commercial and recreational vessels (known as maintenance dredging)
- to create new or deeper access or berths for vessels. This may mean the deepening and widening of channels and anchorages as well as the excavation of basins and marinas from areas of previously dry land (known as capital dredging)
- to provide material for specific purposes (e.g. beaches in coastal areas subject to erosion are sometimes 'renourished' with sand from other areas)
- to bypass an artificial structure, such as a breakwater, that is an obstacle to the normal pattern of sediment movement along the coast. Dredging prevents a build-up of material to be deposited downstream of the obstacle to allow the natural sediment transport process to occur.

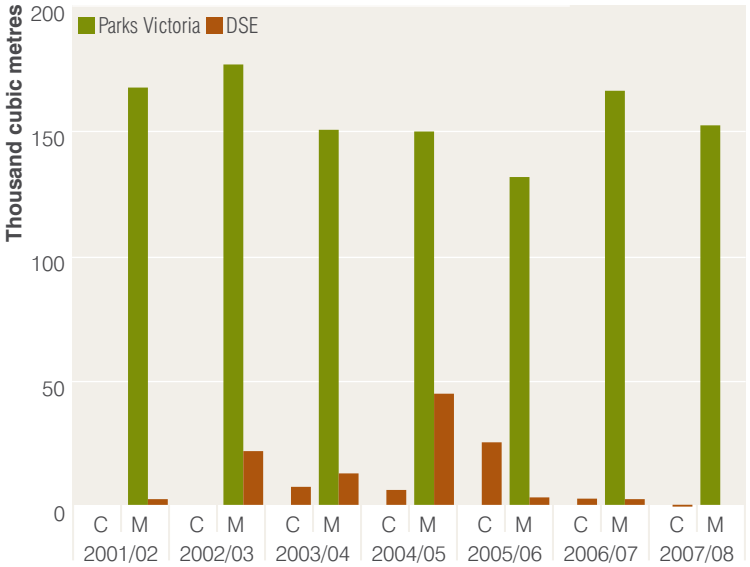
Dredging is performed at a number of sites along the Victorian coast, but most is performed in Port Phillip Bay and at the artificial opening of Lakes Entrance in the Gippsland Lakes. This indicator focuses solely on dredging within Port Phillip Bay, which consists of three types:

- Maintenance dredging conducted by Parks Victoria as waterway manager of the bay to provide safe and navigable access.
- Dredging for specific activities such as to maintain existing boat ramps and for creating access at new boat ramps.
- Shipping channels maintenance dredging undertaken by commercial port authorities.

Figure CES2.16 shows dredging undertaken in Port Phillip Bay each year between 2002 and 2007.

Figure CES2.16 Capital (C) and maintenance (M) dredging in Port Phillip Bay by agency, 2002-2008. *DSE: Department of Sustainability & Environment
Source: Department of Sustainability and Environment [102], Parks Victoria [103] and Port of Melbourne Authority[104]





Dredging by the Port of Melbourne accounts for the greatest amounts of material moved from Port Phillip Bay between 2002 and 2007. In comparison with the channel deepening trial, which removed just over 1.6 million cubic metres of material in 2005, a total of 22.9 million m^3 of material, more than 150 times the annual average, will be dredged from the existing shipping channels within Port Phillip Bay as part of the Channel Deepening Project.

Box CES3 Channel deepening in Port Phillip Bay - turbidity & industrial contamination

The purpose of the Channel Deepening Project (CDP) is to increase vessel accessibility to the Port of Melbourne by deepening some parts of the existing shipping channel in Port Phillip Bay. Given the significant environmental values of Port Phillip Bay and potential impacts of the proposed works, the project required approvals under both State and Commonwealth legislation and the development of the Environmental Management Plan (EMP). Trial dredging of small channels occurred in 2005 to test the adequacy of the environmental management measures established for the project. After these trials, the project was approved by State and Commonwealth Governments to proceed in December 2007.

Dredging activities can result in the re-suspension and mobilisation of sediments and pollutants on the seafloor. When sediment is disturbed and becomes suspended in the water, a visible 'plume' can be created. Suspended sediment has the ability to clog the gills and membranes of marine organisms, reduce visibility and light within the water column and smother organisms on the sea floor105. As a result of dredging, re-suspended or 'mobilised' pollutants, including the heavy metals that are a legacy of industrial activities in the Port Phillip catchment, can potentially contaminate marine organisms and lead to biomagnification through the food web (see *Industrial contamination* above). Human health can be affected through the consumption of contaminated marine organisms or by direct contact during recreational activities (e.g. swimming).

The EMP establishes 'rules' to minimise the intensity of the plume from the CDP at sensitive locations in Port Phillip Bay, such as areas containing important seagrass habitat. The EMP outlines the performance standards, monitoring programs and control requirements to minimise the potential impact on the coastal and marine environment (including plume intensity). The intensity of the plume is measured at 20 locations around the bay, with limits applying to 11 of these locations. Trigger levels at these locations provide an early warning system to alert the port manager that plume intensity is increasing. Dredged contaminated sediment from the north of Port Phillip Bay will be transported to an underwater clay-bunded containment site. Monitoring will also take place in the north of the bay for three months after the dredging of contaminated sediment is completed and will test the concentration of contaminants in fish tissue. To date there have been only three environmental incidents, each of a relative minor nature, associated with the channel deepening project; a failure to clean up in a dredged area, a small (less than 900 litres) oil spill from a dredging vessel and the temporary malfunction of a turbidity monitoring buoy[106].

Dredging can have implications for marine ecological processes when it directly disturbs species that live in benthic sediments. Of particular importance is the ecological process of denitrification that these organisms perform (see Indicator CES10 Denitrification). Also of concern is the impact that dredging can have on both turbidity and the ability of light to penetrate to plants for photosynthesis, and the settling of suspended solids onto marine plants and macroalgae (seaweed), which can also reduce their ability to photosynthesise[107]. These effects can flow on and result in changes in species composition, loss of biodiversity and reductions in commercial and recreational fisheries catches.

Dredging programs in ports, harbours and estuaries adjacent to urbanised or industrialised areas are also likely to mobilise contaminated substances in the form of dredge spoil, which can in turn impact on water quality.

Other coastal and marine implications of dredging can be less related to water quality and may not be apparent immediately but may progress over extended periods of time. These include changes in circulation patterns, coastal zone dynamics and coastal morphology from modified coastline and/or seabed[108]. Under climate change conditions, when reduced flows and high rates of water extraction could close off river mouths, dredging to maintain access for recreational and commercial shipping (e.g. Lakes Entrance) is likely to be an issue of future concern

In addition to the coastal and marine implications of dredging, channel deepening in response to shipping demand has implications for road and rail freight networks (see Part 3.1 Energy) in the form of flow-on impacts that were not considered as part of the Environmental Effects Statement. It is also likely to induce demand for increased materials flows (see Part 3.3 Materials). As such, a more strategic assessment of the sustainability implications of major projects such as channel deepening should be undertaken (see Part 5 Living Well).

Recommendation

CES2.7 Undertake strategic environmental assessment (SEA) in Victoria, ensuring that the long-term and flow-on effects of a project are considered to assess high-order concepts, prior to the site-specific assessment via existing EIA and EES.

Indicator CES17 Reported marine pollution

A marine pollution incident is defined as any event that results in a chemical, oil or oily mixture, sewage or garbage entering the marine environment[109]. Most of these occur in or around ports, but some are also of terrestrial origin (see Terrestrial Activities below). Ballast water discharges are not included in this definition of marine pollution (see CES3 Marine Biodiversity).

The Victorian EPA and Marine Safety Victoria (MSV) collect details on the type and location of reported marine pollution incidents in the State. Marine pollution incidents are categorised under a three-tier system: Tier 1 for amounts between 1 and 10 tonnes, Tier 2 for amounts between 11 and 100 tonnes, and Tier 3 for amounts greater than 100 tonnes.

While all spills reported during the period were categorised as Tier 1, most incidents reported in Victoria are thought to be actually less than 100 litres, and 90 per cent of those are less than 20 litres[110]. Figure CES2.17 shows the number of reported marine pollution incidents in Victoria for each year since 1999/00.

Overall there has been a decrease in the number of reported incidents over the nine-year period since 1999/00. The highest number (109) of incidents occurred in 2000/01 and the lowest number (41) in 2007/08, although data for the most recent period is yet to be fully completed and further incidents may be reported.

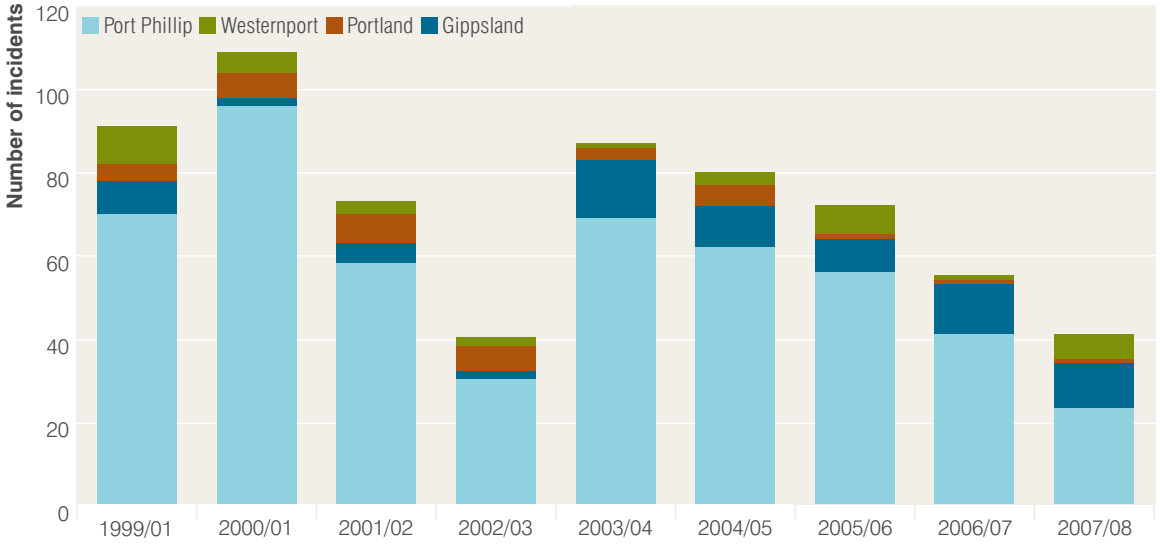
The greatest number of marine pollution incidents reported each year is in Port Phillip Bay (505 incidents over the period 1999-2008), mostly near the mouth of the Yarra River in the northern part of the bay[112]. This is likely due to the higher level of activity associated with the bay and the greater potential for sighting and reporting incidents due to the larger number of people using the area. Gippsland has the next highest number of reported incidents, with 72 incidents over the period 1999-2008.

The cause of most (over 55%) of the reported shipping incidents shown in Figure CES2.17 is classified as either *unknown* or *not set*, although, as noted above, most of these are less than 100 litres. Nevertheless, the fact that there are a large number of unknown sources implies that better strategies for identification of the responsible party are warranted. At 19% of all incidents, *land based discharges* is the next most common category. This category refers to oils, heavy metals and other chemicals that enter waterways from a variety of sources, including urban and agricultural runoff and industrial and mining operations via stormwater, landfill leachate, and transportation or industrial spills (see Terrestrial Activities below). Small stormwater sources constitute the bulk of the load and should continue to be addressed through more effective management of stormwater.

Recommendation

CES2.8 Investigate opportunities for better observation and reporting of marine pollution events, specifically the numerous small events currently classified as unknown or not set.

Figure CES2.17 Reported marine pollution events in Victoria by site 1999/00–2007/08
Source: Marine Safety Victoria[111]



In contrast to the many small marine pollution events shown above, there have been only five major marine pollution events in or near Victorian waters since 1903. These are shown in Table CES2.2.

Maritime pollution spills can result in heavy metals and other toxic substances and chemicals entering the marine environment (see example in Box CES4). These can have drastic impacts on freshwater and marine ecosystems. The effects may vary in severity from reducing growth and reproduction to directly killing plants and animals. As described above, the effects of many toxic chemicals are increased by their ability to remain and build up in the environment over a long period of time. The results can be particularly destructive in wetlands and bays where flushing is limited[114].

Table CES2.2 Significant marine oil spills in Victoria over the 20th Century
Source: Australian Maritime Safety Authority [113],

Year	Ship	Sites affected	Mass
1903	Petriana	Port Phillip Bay	1,300 tonnes
1988	Al Qurain	Portland	184 tonnes
1990	Arthur Phillip	Cape Otway	Unknown
1999	Sylvan Arrow	Wilsons Promontory	Less than 2 tonnes
2003	ANL Pioneer	Woolamai & Kilcunda	≈ 40 tonnes

Box CES4 ANL Pioneer oil spill and EPA's response

In early 2003, the German container ship *ANL Pioneer* discharged 30-40,000 litres of waste oil sludge from its ballast water tank into Bass Strait. The incident occurred outside State waters, about nine nautical miles off the Victorian coast. The spill eventually washed ashore between Woolamai and Kilcunda, covering approximately twelve kilometres of coastline.

The clean-up was coordinated by Marine Safety Victoria under the *Victorian Marine Pollution Contingency Plan*. Under the guidance of the Plan, a number of agencies and volunteers were involved in the clean-up response. In total, 144 tonnes of oily waste was removed from the coastline. Twenty-five oiled Little Penguins were recovered during the clean-up, two of which died. Several species were impacted, including pied cormorants, silver gulls and hooded plovers. Considering the significant impact on the coastal environment, the response to the incident was effective and further environmental damage was minimised.

Under the *Environment Protection Act 1970*, the Environment Protection Authority used its authority to track down the responsible vessel through four ports across four different countries. The shipping company was ordered to pay more than $1 million in fines, clean-up expenses, environmental projects and legal costs, constituting the biggest environmental penalty in Victoria's history[115].

Terrestrial Activities

The majority of Victoria's population resides along the coast, and the human activity in these areas can adversely impact water quality in adjacent marine and estuarine environments. Water quality is directly impacted when discharges from domestic, agricultural and industrial sources enter marine and estuarine water bodies. The EPA classifies terrestrial sources of marine pollution as either point or non-point source. Statewide, point sources account for only a small proportion of polluting substances entering marine and estuarine waters, however point sources can be locally significant. Most point sources are licensed and monitored by the EPA with those that are not usually being temporary and illegal discharges. Non-point sources include urban stormwater and agricultural (rural) runoff which enters marine waters (both bays and open coastal waters) via streams and rivers (although license point sources upstream also contribute to these). Due to their dispersed and ephemeral nature, non-point souces are not licensed and are difficult to quantify but account for the far larger proportion of potentially polluting substances that enter estuarine and marine waters.

Indicator CES18 Point source discharges

Industrial point source discharges introduce chemical loads such as nutrients, various metals, petroleum hydrocarbons and other contaminants into the marine waters surrounding the discharge point. Victoria has 29 EPA-licensed point source discharges that enter marine environments, with the majority located within Port Phillip Bay and Western Port (Table CES2.3). The licences set enforcable limits for nitrogen, dissolved oxygen and pH concentrations and other substances, depending upon the site specific licence that must be maintained to achieve environmental protection. Point source discharges to Victoria's marine environment are classified as either industrial facilities, wastewater treatment plants or aquaculture activities, the latter making up just 0.002% of nitrogen discharged.

Table CES2.3 EPA licensed point source discharges along Victoria's marine coastline
Source: EPA unpublished data,[116]
Note: *See glossary for explanation of treatment techniques

	Plant	Volume (ML/day)	Outfall length (m)	Treatment	Nature of Waste
1	Shell (PPB)	400	0	Oil/water separation	Cooling
2	Boags Rocks	380	10	Secondary+ Cl*	Domestic/Industrial
3	Werribee	361	0	Adv. Secondary+lagoon	Domestic/Industrial
4	Great Southern Waters (Indented Head)	80	0	Lagoon	Aquaculture
5	Black Rock	70	1200	Adv. Secondary	Domestic/Industrial
6	Southern Ocean Mariculture (Port Fairy)	48	0	Lagoon	Aquaculture
7	Ocean-wave Seafoods (Avalon)	48	0	Lagoon	Aquaculture
8	Latrobe Valley	31.8	1267	Secondary+lagoon	Domestic/Industrial
9	Performance Research (Leopold)	24	0	Lagoon	Aquaculture
10	Victorian Mariculture (Narrawong)	24	0	Lagoon	Aquaculture
11	SWOP	20.7	550	Primary	Industrial
12	Altona	16	400	Secondary+lagoon*	Domestic/Industrial
13	Warrnambool	12.9	20	Secondary	Domestic
14	Esso Long Island Point (Western Port)	4.5	600	Secondary	Domestic/Industrial
15	Venus Bay	4.1	0	Primary *	Industrial
16	Wonthaggi	3.7	0	Secondary+lagoon	Domestic
17	Portland	3.6	80	Secondary	Domestic
18	Cowes	2.5	120	Secondary+ Cl	Domestic
19	Port Fairy	2.3	10	Secondary +UV	Domestic/Industrial
20	Bluescope Steel (Western Port)	2.2	0 and 800	Biological and Lagoon	Industrial/Domestic
21	Lorne	1.06	0	Adv. Secondary+UV	Domestic
22	Apollo Bay	0.8	0	Adv. Secondary+UV	Domestic
23	DPI (Queenscliff)	0.8	0		Aquaculture
24	Anglesea	0.51	200	Adv. Secondary+UV	Domestic
25	Foster	0.3	0	Secondary+lagoon	Domestic
26	Toora	0.2	0	Secondary+lagoon	Domestic
27	Port Welshpool	0.1	0	Secondary+lagoon	Domestic
28	Portsea Camp (PPB)	0.08		Secondary + Cl	Domestic

Of the 29 point source discharges, 76% of the total volume of water comes from three sources: a Shell industrial site in Corio Bay and the two treated effluent discharges from the Western Treatment Plant (Werribee) and the Eastern Treatment Plant (near Gunnamatta).

As a result of these, areas of concern in Victoria's marine and estuarine environments include Long Reef (adjacent to Werribee) and Boags Rocks (near Gunnamatta) on the Mornington Peninsula. The point source discharges at these two sites contribute greater than 75% of the point source inputs of nitrogen, phosphorous and suspended solids into Victoria's marine environment In 1996 the Western Treatment Plant alone accounted for around half of the nutrients discharged into the bay[117]. It now represents a much smaller proportion (see *non-point sources of marine pollution* below), and is undergoing an upgrade which will further reduce nutrient discharge[118].

Turnover of water in marine and estuarine environments is critical to reducing the impact of point and non-point discharges. Where a discharge cannot be treated to meet the objectives set by the SEPP, EPA may approve a *mixing zone*. This is an area within which designated environmental quality objectives, as set by SEPP, do not need to be met, and therefore where beneficial uses may not be protected. Mixing zones are usually approved for particular parameters (e.g. nutrients), rather than being zones where no objectives are met. Licence holders are required to periodically review cleaner production and treatment technology to allow reductions in the size of mixing zones.

The proposed desalinisation plant will constitute an additional point source of potentially polluting substances to the site

near Wonthaggi, south-east of Melbourne. Up to 280 gigalitres per year of hyper-saline water will be pumped back into the sea. The impact of this discharge on water quality is not expected to extend beyond the mixing zone, 100 metres from the outlet. By the time the discharge reaches the boundary of the mixing zone it will have been diluted with seawater by a factor of 50. The full Environmental Effects Statement is due for release in late 2008[119]. If the project is approved, it will be essential to conduct ongoing monitoring against baseline water quality objectives at this site. As well as water quality, this project also has potential implications for coastal biodiversity and solid waste management. As with channel deepening (above) the environmental implications of major projects such as these should be assessed using strategic environmental assessment (SEA) to provide a better understanding of all impacts of the project (see Part 5: *Living Well Within Our Environment*).

Non-point sources of marine pollutants

Non-point sources of marine pollutants to Victoria's marine waters are significant. They include diffuse sources such as agricultural discharges not regulated by EPA and stormwater runoff that contains pollutants, nutrients (See Part 4.3 Inland Waters) and litter (See Part 3.3: Materials). Agricultural runoff is typically high in nutrients and constitutes a potential pressure on marine water quality.

Catchments are considered a source of contamination when they introduce water of lower quality to the estuaries and subsequently into marine environment (see Part 4.3 Inland Waters), particularly during episodic storm events and sometimes for several years after wildfire (see Part 4.3 Inland Waters). The urbanised catchments of the Yarra and Maribyrnong Rivers contribute pollutants such as heavy metals from industry and nutrients in stormwater runoff into the receiving environment of Hobsons Bay. The sources of input into these catchments continue to be varied and it is difficult to manage all discharges into, and from these river systems, and so they can make a significant contribution to reduced marine water quality. For example, The Yarra River system itself integrates all the non-point, catchment influences and contributes one of the greatest 'point' sources (unlicensed) of pollutants to the bay (see Part 4.3 Inland Waters: Management Responses).

Heavy metal contamination from non-pouint sources has historically been largely confined to Port Phillip Bay. In particularly, concentrations of metals there have gradually decreased over the years (although it is likely that the Yarra continues to be a source[120]). This reduction is due to reduced inputs of metals into the receiving environment as awareness about their toxicity has increased, and as industrial processes are improved.

Melbourne Water and the EPA have initiated studies to determine the impact of contamination from these estuarine systems on edible fish species. Preliminary investigations have determined that concentrations of contaminants in fish were below the maximum residue limits (MRL) for food, yet the tissues of some eels sampled contained levels of a chemical of concern above the specified MRL[121]. Mussels are routinely used as indicator species to determine the concentrations of chemicals in bays and oceans throughout the world. Consistent with reduced metal input into the marine environment, metal concentrations in mussels collected from Victorian waters have decreased.

Implications

Victoria's marine environment is diverse and varied, and pressures on water quality have been imposed on the many different locations. Where nutrients or other pollutants enter the sea, mixing and dilution of water is essential for the maintenance of water quality. Yet in the populated embayments and other areas that have reduced turnover of water as well as elevated nutrient and toxin input, pathogens and physicochemical stressors can reduce water quality and the utility of the marine ecosystem.

For example, although it is natural for chlorophyll-a concentrations to fluctuate, the Gippsland Lakes have a history of increased chlorophyll-a concentrations due to limited mixing of the water. Eutrophic conditions (increased chlorophyll-a and reduced dissolved oxygen) have at times compromised the beneficial uses of this marine environment[122]. Toxic blue-green algal blooms, in particular, are of ongoing concern due to their effect for local communities that rely on fishing as both an industry and as a recreational activity. In addition, eutrophic conditions can adversely affect water quality for swimming and, as a result, there can be significant flow-on impacts on tourism and local businesses.

The effects of toxic substances vary depending upon the substance and its concentration but can range from reduced growth and reproduction, to diminished abundance or distribution of marine species, to directly killing plants and animals. The effects of many toxic chemicals are increased by their ability to build up within the food web (known as bio-accumulation) over a long period of time. Toxicity is rarely thought to be an issue for Victorian marine species of importance to humans as food. However, a 2005 investigation[123] found that some eels caught in the Yarra estuary contained levels of polychlorinated biphenyls (PCBs) above the Food Standards Australia and New Zealand maximum residue limit. As a result, the Chief Health Officer advised an eel consumption limit that is still in place[124]. In June 2008, high bio-accumulated mercury levels were found in several dolphins (20 living and 8 dead from stranding) in Port Phillip Bay. The mercury is believed to have originated from historic industrial processes and settled in the bay where it may have been more recently disturbed and entered the food web[125]. This case emphasises the importance of sampling for toxins in sediments rather than in the water column alone.

Decreased water clarity and increased sediment concentration can affect benthic organisms such as those that perform the important role of denitrification, and seagrasses. Seagrass at Corinella in Western Port, an area of inter-tidal mudflats, has been shown to be affected by the redistribution of sediment. Seagrass beds are one of the most sensitive marine ecosystems to elevated suspended solids (see CES3 Marine Biodiversity), and this can have flow-on effects for marine fauna, including species of commercial value, that use this habitat[126].

Similar to the effects of eutrophication, a reduction in recreational water quality (i.e. an increase in *Enterococci* concentrations) can have adverse effects on human health if not discovered early. Swimming in pathogen-contaminated waters frequently leads to gastroenteritis. Unsafe concentrations of pathogens in coastal waters may also require restrictions on shellfish harvesting and recreational fishing activities. Economic losses incurred by increased pathogen populations include closure of shellfish fisheries, the costs associated with medical treatment, lost time at work and economic loss to businesses that rely on coastal recreational activities[127].

In addition to these water quality implications, there are other effects of decreased water quality that may be attributable to a changing climate (see also CES4 *Climate Change*); for example, decreased inflow of fresh water to estuarine systems can change their ecology. In the Gippsland Lakes, it is likely that this has led to an increase in salinity levels, which is thought to be having an effect on the breeding and migration patterns of black bream. In turn, this is having an effect on local recreational and commercial fishing[128].

Management responses

Response Name
State Environment Protection Policy (Waters of Victoria)

Responsible Authority
Environment Protection Authority

Response Type
Policy/Strategy

The *State Environment Protection Policy (Waters of Victoria)* 2003 (SEPP (WoV)) aims to protect the beneficial uses and values of the State's water environments by setting objectives for nutrients and other physico-chemical parameters in Victoria's marine waters beyond which management action is triggered. The SEPP (WoV) provides a coordinated approach for the protection and, where required, the rehabilitation of the health of Victoria's water environment. In particular, the SEPP (WoV) identifies roles and responsibilities for environment protection and rehabilitation and identifies strategic actions and tools to address activities that pose a risk to the Victorian water environment.

A series of schedules has been developed under the SEPP (WoV) that relates to specific marine environments, making the policy administratively complex but highly adaptable to Victoria's range of different marine environments. As marine water quality is influenced by runoff from the whole catchment, the schedules deal with individual catchments providing detail on the indicators and actions to manage the associated water bodies. Different schedules that set targets for site-specific parameters, have been developed for the Gippsland Lakes and Catchments, Port Phillip Bay and Western Port and Catchments. Some have been identified as not at risk of water quality decline, while for others, decline in certain variables does not affect the beneficial uses identified as important. If specific objectives are not outlined in the SEPP (WoV), the environmental quality objectives are outlined in the *Australia and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). The standards are considered integral to the maintenance of both marine health and human uses of marine environments.

For example, the SEPP (WoV) schedule *F6 Waters of Port Phillip* recognises the need to develop the Port Phillip Bay Environment Management Plan (EMP). The EMP provides a framework for the identification of issues in Port Phillip Bay and determines priorities and actions to improve and maintain water quality standards. The EMP sets targets for the reduction of nutrients and identifies the risks of marine pests as priorities to be addressed, and various agencies (including DSE, EPA, Melbourne Water) are working towards meeting the targets established in the EMP.

To ensure compliance with the SEPP (WoV), the EPA monitors water quality indicators at 14 fixed sites in the three major Victorian embayments (Indicators CES10 – CES13). As part of the EMP, the EPA also monitors for Enterococci at 36 beaches around Port Phillip Bay during summer (Indicator CES14). However, there is very little water quality monitring outside of the major embayments.

Response Name
Best Practice Environmental Guidelines for Dredging

Responsible Authority
Environment Protection Authority

Response Type
Guidelines

To undertake dredging works in Victorian waters, consent must be obtained from the responsible minister under the *Coastal Management Act 1995. The Best Practice Environmental Guidelines for Dredging* (2001) notes the requirements that coastal managers must meet in order to gain consent for dredging works in Victoria. These address the environmental issues and controls involved in dredging, including water quality objectives in addition to those detailed in the SEPP (WOV), and water quality monitoring requirements. Applications for consent under the *Coastal Management Act 1995* are submitted to DSE but advice may also be sought from the EPA in relation to compliance with the Guidelines.

Dredging works may also be subject to further assessments and approvals. Additional approvals depend on the scale of the works. A planning permit may be required for works that occur in an area subject to a local planning scheme. If the proposal is likely to involve significant environmental, social or economic impact, the works may be subject to an approval under various State and Commonwealth (Cwth) legislation (i.e. *Environment Effects Act 1978, Environment Protection (Sea Dumping) Act 1981, Environment Protection and Biodiversity Conservation Act 1999 (Cwth)*[129]).

Large-scale dredging, such as that currently being undertaken for the Channel Deepening Project (see Box CES3), is not covered by the Guidelines but requires a detailed environmental effects statement that must be signed off by the relevant minister.

Response Name
Victorian Marine Pollution Contingency Plan

Responsible Authority
Marine Safety Victoria

Response Type
Process/function

The Australian Maritime Safety Authority manages the National Plan to Combat Pollution from the Sea by Oil and other Noxious and Hazardous Substances. However, at a state level, Marine Safety Victoria has the responsibility to ensure that there is an effective response to oil pollution incidents in Victorian waters under the *Marine Act 1988*. To fulfil this responsibility, Marine Safety Victoria developed and manages the Victorian Marine Pollution Contingency Plan (VicPlan) in consultation with the EPA.

If an oil spill occurs, VicPlan is immediately activated, initiating a process to confirm the spill and determine the most appropriate response. The response to the spill is managed at a regional level under VicPlan, with a number of agencies responsible for responding to the incident. The VicPlan process has proven to be an effective response in minimising the potential impact of the reported pollution incidents, which have decreased in recent years (See Figure CES2.17).

Response Name
Pollution of Waters by Oil and Noxious Substances Act 1986

Responsible Authority
Environment Protection Authority

Response Type
Legislation

The EPA is responsible for the investigation of pollution in Victorian waters and the prosecution of offenders. The *Pollution of Waters by Oil and Noxious Substances Act 1986* provides the legislative framework to protect the sea and other waters from pollution by oil and other noxious substances. Marine pollution is also considered under the *Environment Protection Act 1970,* which sets whole-of-environment objectives such as preventing pollution and minimising environmental damage. It establishes programs to meet these objectives (i.e. development of State Environment Protection Policies). Both Acts prohibit the discharge of oil and pollution into marine waters and provide a mechanism to take appropriate action against offending vessels and recover costs incurred during clean-up associated with the incident.

To ensure compliance with the Act, the Pollution of Waters by Oil and Noxious Substances Regulations came into operation in 2002. The Regulations outline the timeframe and process of discharging of oil and oily substances. Marine Safety Victoria also has a responsibility under these regulations, and this responsibility ensures the two agencies provide a coordinated approach to responding to marine pollution.

Evaluation of water quality responses

Due to its importance for human health and the survival of marine-based industries, the health of marine waters, particularly embayments and estuaries, has been monitored for many years. The first comprehensive environmental study of Port Phillip Bay and catchment was completed in 1971 and the initial SEPP that addressed pollution sources in the bay was approved by the State Government in 1975[130].

With inland waterways becoming less accessible due to decreasing water availability, and with the coast remaining a popular destination for both recreational and commercial activities[131], pressure on the coastal and marine environment will continue. Current management responses seek to address these increasing pressures to ensure that marine waters retain high levels of quality and, therefore, utility. The *State Environment Protection Policy (Waters of Victoria) 2003* (SEPP (WoV)) provides a detailed framework for the protection and monitoring of Victoria's marine water quality. However, the SEPP objectives do not identify all areas for active managment. In ensure that any reduction in water quality is detected early, monitoring programs must be robust in methodology, continuous and should cover all marine and estuarine environments.

Recommendation

CES2.9 Water quality programs must be methodologically sound, continuous and should provide an indication of water quality in all Victorian marine and estuarine waters. There is a case for regular, low frequency monitoring outside of the major embayments that should be investigated.

As outlined in the SEPP (WoV), dredging activities pose a particular threat to water quality and should be managed to minimise re-suspension and transport of sediments and pollutants that may pose an environment risk. With ships' tonnage increasing (See Figure CES2.15), pressure to undertake further dredging works to enable access to Victoria's bays is expected to remain high. The process for reviewing proposed dredging works ensures critical evaluation of the proposal prior to any works proceeding but does not require that a strategic assessment of all environmental impacts of decisions are considered in the decision-making process.

The current channel deepening project in Port Phillip Bay and the extensive sand management program at Lakes Entrance have significantly increased knowledge of the impacts of dredging works. In addition, the Commonwealth Government developed the *National Ocean Disposal Guidelines for Dredged Material* in 2002, building on the Victorian EPA's *Best Practice Environmental Guidelines for Dredging.* A review of the EPA's Guidelines would ensure that the process remains current and consistent with the current knowledge and dredging management practices.

Recommendation

CES2.10 Review the Best Practice Environmental Guidelines for Dredging to ensure the dredging approval process remains current and consistent with the current knowledge and dredging management practices.

Limited resources and expertise limits the approval process for dredging works. To ensure that the existing framework remains effective, additional support and resources should be focused on providing regional government agencies with a 'tool box' to review and appropriately consider proposed dredging works. For example, a map-based database could be developed to provide DSE and EPA staff with a decision-making tool to help identify issues and potential requirements needed for an applicant.

Recommendation

CES2.11 Support the development of a 'tool box' for State Government agencies to assist in the decision-making process for proposed dredging works.

Given the potential for significant impacts upon the marine and coastal environment, the framework and process for responding to marine pollution is well established under State and Commonwealth legislation. Combined with the legislative responsibilities, the pollution response framework is also considered successful due to the training programs and coordination amongst the agencies (both at a State and regional level).

For further information

EPA, Water Quality
http://www.epa.vic.gov.au/water/coasts/default.asp

OzCoasts
http://www.ozcoasts.org.au/

CES3 Marine biodiversity

Key Findings

- Macroalgal assemblages on shallow subtidal reef habitats appear to be in relatively good condition along Victoria's open coast.
- The area of seagrass habitat in bays and inlets has fluctuated over the last 50 years. Current coverage of seagrass at most locations appears to be within the range of historical (since 1960s) fluctuations.
- Ecological communities on soft sediments in Port Phillip Bay are degraded. The relative condition of open coastal soft-sediment assemblages is unknown.
- Some marine species have been overfished in Victorian waters.
- Introduced species have had a large impact on the ecology of Port Phillip Bay and other sheltered bays and inlets.
- Victoria's bays and inlets are under substantial environmental pressure and so are vulnerable to environmental changes.
- Limited data and understanding, and large natural variability, preclude comprehensive assessment of the condition of marine biodiversity against quantitative indicators. In lieu of adequate data, threat-based management using existing information should be used.
- Port Phillip Bay is considered to be one the most invaded marine ecosystems in the Southern Hemisphere, with 161 introduced species representing up to 13% of all benthic sediment and encrusting species recorded in the bay.

Description

Victorian marine ecosystems are unique. They encompass a wide range of physical environments that have developed in a unique geological and oceanographic context and support representatives of more taxonomic groups than all Victorian terrestrial and freshwater habitats combined. The true extent of Victoria's marine biodiversity is largely unknown, but southern Australia is recognised as a diversity hotspot for several taxa including red and brown algae, lace corals, crustaceans and ascidians (sea squirts). In addition, Victorian marine environments support diverse fish assemblages and provide critical habitat for marine mammals and seabirds, many of which are endangered.

Victorian marine environments are diverse. They encompass sheltered and shallow bays and inlets, long stretches of exposed open coast and deep sea. In many shallow marine environments, marine plants such as seagrass and kelp create habitat structure for other species of algae, fish and invertebrates. In deeper water, the reduction in light allows species such as sponges and corals to thrive.

The diversity of marine habitats and species in Victoria is critical for providing a range of ecosystem services. Marine habitats sustain stocks of fish and invertebrates which form the basis of important commercial and recreational fisheries, including aquaculture. Seagrasses, saltmarsh and mangroves stabilise soft sediments, prevent erosion and provide protection from storm surges. Marine species process and recycle nutrients derived from terrestrial sources and also absorb large amounts of carbon, produce oxygen and help to regulate climate. In addition to these essential services, marine biodiversity creates recreational opportunities and contributes to Victoria's social and cultural amenity.

All marine habitats are strongly linked, with many species spending parts of their lifecycle in different habitats. For example, many juvenile fish use seagrass and kelp beds for shelter but move into open water habitats as they mature. In addition to links within marine environments, there are strong links between marine and terrestrial/freshwater systems. Some species use both systems (fish, birds, seals, humans). Furthermore, marine environments are directly affected by activities in adjacent catchments. Freshwater inputs into the catchment affects water quality in marine systems. Strong links within marine environments and between marine and terrestrial systems create special challenges for the understanding and management of marine biodiversity.

Conservation of marine biodiversity is critical for maintaining ecosystem services and for ensuring the resilience of marine systems into the future. More than 5% of Victorian marine waters are in a system of highly protected Marine National Parks and Sanctuaries. Marine communities in these areas are protected from fishing and other extractive industries. Factors such as poor catchment management practices, fishing pressure and introduced species (among others) have already caused changes in Victoria's marine environments. Improved management of these and other pressures will be necessary to sustain marine ecological communities into the future, particularly given the likely cumulative impacts of climate change.

A lack of knowledge and understanding of marine systems is a major hindrance to our ability to protect marine biodiversity and to report on its current condition. In Victoria, a substantial amount of research has been carried out in recent years to remedy this problem. This includes establishment of long-term and spatially comprehensive monitoring programs for some marine communities (e.g. subtidal reefs) as well as habitat mapping programs along the Victorian coast. While research has been conducted within Port Phillip Bay and Western Port in the last 30 years, it has only been in the past decade that larger scale, (and in some cases) longer-term monitoring programs have been established along the Victorian coast. Data from these programs are providing essential information about marine biodiversity in Victoria, and will become more valuable over time. However, in many cases, studies of marine systems in Victoria are limited in spatial and temporal coverage, have collected different types of data for different requirements, and provide little information about the dynamics of marine communities and how these communities change in response to environmental pressures. Furthermore, even where data are available, very large natural spatial and temporal variability limits the ability to detect changes in response to known environmental threats (e.g. for seagrass and intertidal reef communities), particularly over large spatial scales, and therefore often precludes the setting of practical, quantitative and spatially comprehensive indicators of condition.

In lieu of adequate data and understanding, our approach to assessing condition in this part of the report has been to describe some general features of the major marine communities in Victoria and to provide a qualitative assessment of condition using the available information. Conceptually useful indicators are suggested for some habitats where these indicators are presumed to respond to known environmental pressures operating in Victoria. However, because of the caveats outlined above, there is considerable uncertainty in this assessment. Because of the fundamental lack of knowledge of the dynamics of marine species and communities it is difficult to quantify the vulnerability or likely consequences to marine systems of contemporary environmental pressures. Targeted science focussing on ecosystem dynamics in response to known threats is necessary to overcome these hurdles. In the meantime, informed, threat-based management using existing information is required to protect Victoria's marine biodiversity.

Objectives

- Prevent future declines in the populations of fished species
- Reverse declines in the populations of over-fished species
- Prevent further introduction of exotic marine species, particularly those likely to be destructive to native communities, such as *Caulerpa taxifolia*
- Prevent the spread of existing marine pests, particularly noxious species such as Japanese Kelp (*Undaria pinnatifida*) and the Northern Pacific Seastar (*Asterias amurensis*)
- Protect and maintain the integrity and dynamics of ecological communities within Marine National Parks and Marine Sanctuaries

State

Shallow subtidal rocky reef communities

Indicator CES19 Conversion of subtidal reef communities to simplified states

Subtidal reefs in Victoria have been systematically surveyed at 14 locations and approximately 90 sites extending from Cape Howe in the east to Merri Marine Sanctuary in the west[132]. Many of these locations have been surveyed multiple times, particularly in central Victoria where some reefs have been surveyed up to 11 times since 1998[133]. These surveys provide some spatial and temporal coverage with which to assess the condition of many Victorian reefs against this indicator.

Shallow subtidal reefs in Victoria are dominated by complex macroalgal assemblages, which often include species of large canopy-forming brown algae or kelp (Figure CES3.1). In many parts of the world the condition and extent of macroalgal assemblages have been declining in response to overfishing, declining water quality and invasive species[134]. These three pressures can cause the replacement of complex macroalgal communities with greatly simplified reef assemblages. For example, overfishing of top predators can result in increases in population densities of herbivores (mostly sea urchins), creating highly simplified habitats called 'urchin barrens' (Figure CES3.1)[135]. Urchin barrens can be a natural component of subtidal reef communities, but it is generally recognised that regionally widespread, locally homogenous (i.e. not patchy) and persistent (years) urchin barrens are indicative of degraded reef communities[136]. Declining water quality can also create simplified reef assemblages by facilitating the establishment of fast-growing, ephemeral algae, which may prevent recolonisation of reefs by kelps[137]. Furthermore, introduced species of macroalgae can exclude native species and can drastically alter community structure and dynamics[138]. In general, *extensive* and *persistent* urchin barrens, turf-algal assemblages or assemblages dominated by introduced species represent simplified community states and indicate that large changes have occurred to reef habitats over time.

Little is known of the dynamics of subtidal reef communities in Victoria and so it is difficult to assess how susceptible Victorian reefs are to the changes described. However, each of these changes does occur in response to known pressures that are, or could potentially occur, along the Victorian coast. Furthermore, while Victoria's subtidal reef communities vary spatially making it difficult to generalise among locations, the three changes described represent clear departures from the complex macroalgal assemblages that are characteristic of healthy reefs.

Figure CES3.1 Subtidal reef habitats: A common canopy-forming brown algae (Ecklonia radiate) on Victorian shallow subtidal reefs (left) and urchin barren habitat (right)
Photo: Sean D. Connell

Currently, very few surveyed reefs are dominated by simplified states. Subtidal reefs along the open coast west of Point Hicks are generally dominated by native species of large canopy-forming macroalgae including common kelp (*Ecklonia radiata*), crayweed (*Phyllospora comosa*), string kelp (*Macrocystis angustifolia*) or a range of fucalean algae such as Cystophora spp or *Sargassum* spp [139].

Exceptions to this pattern occur in far eastern Victoria and in Port Phillip Bay. In eastern Victoria, there are large areas of urchin barrens at Cape Howe, Gabo Island and Tullaberga Island[140]. Barrens in these locations generally occur within a matrix of kelp-dominated habitat and because these locations have only been surveyed twice in recent years it is premature to draw conclusions about longer term trends[141]. Eastern Victorian reefs are at the western edge of the distribution of the black sea urchin (*Centrostephanus rodgersii*), which has created extensive areas of urchin barrens in New South Wales. The black sea urchin is native to eastern Australia (NSW) and is currently expanding its range southwards.

It is not known if *C. rodgersii* is capable of extending its distribution further along the Victorian coast. In Victoria, urchin barrens have not been recorded west of Point Hicks and the urchin has not been recorded west of Beware Reef in eastern Victoria.

Subtidal reef communities in northern Port Phillip Bay lack large stands of canopy-forming algae. Instead, these reefs are dominated by smaller species of brown, red and green algae. Of particular significance is the high abundance of filamentous brown and red turf algae, which provide up to 40% of the algal cover at some locations[142]. Reefs in northern Port Phillip Bay are naturally exposed to higher levels of sedimentation and nutrients because of their proximity to the entrance of the Yarra River and other freshwater drainages (see CES2 Water Quality). However, sedimentation and nutrient levels are likely to have increased as the surrounding catchment has been altered by human activity. Without older baseline information (systematic monitoring of reefs in northern Port Phillip Bay began in 2003), it is not known if these reef communities have changed in response to changing environmental conditions.

Some reefs in northern Port Phillip Bay have also been invaded by the large brown Japanese kelp *Undaria pinnatifida*. This species has been observed in dense stands on broken basalt reefs on the northeastern side of the bay, and is likely to strongly influence community structure where it occurs. This species has invaded and displaced native macroalgal assemblages in Tasmania and given its invasiveness, there would appear to be strong potential for *U. pinnatifida* to expand its current range to the southern parts of Port Phillip Bay and to reefs in Westernport Bay.

Given that kelp deforestation and undesirable community states are a feature of many temperate rocky reef environments around the world, on the basis of this indicator Victorian subtidal reef communities would be considered in good condition. Established long-term monitoring programs should allow detection of undesirable changes in some reef habitats in the future. However, more study is needed to improve understanding of the dynamics of Victorian subtidal reef communities, particularly in response to fishing pressure and declining water quality. Consequently, our understanding of the vulnerability of Victorian subtidal reefs to drastic changes in community structure is limited, but it is likely that these pressures will have a negative effect.

Recommendation

CES3.1 Establish a long-term monitoring program to routinely monitor key subtidal reef communities along the Victorian coast to determine whether reef communities are changing in response to changing environmental conditions.

Intertidal rocky reef communities

Intertidal reefs create habitat for a diverse assemblage of animals and plants between the high- and low-water tide marks. Because of high levels of natural variability in both physical conditions and biota, development of useful indicators of environmental condition in these habitats has been difficult[143] and, in Victoria, is the subject of ongoing work[144]. Localised case studies and recent, biological surveys provide some indications of the current state of Victorian intertidal reef environments in some locations [145]. A qualitative description of condition has been done on the basis of this work, however there is considerable uncertainty associated with this assessment.

Box CES5 Eastern Treatment outfall at Boags Rock (near Gunnamatta)

Exposure to elevated levels of ammonium and freshwater from the Eastern Treatment Plant outfall at Boags Rocks in central Victoria has substantially changed community structure on the nearby intertidal reef[146]. The brown macroalgae, Neptune's Necklace (*Hormosira banksii*) and Bull Kelp (*Durvillaea potatorum*) no longer occur on the reef at Boags Rocks and have been replaced by ephemeral green algae, high densities of limpets and other gastropods and aggregations of a spionid polychaete worm (*Boccardia proboscidea*). The apparent influence of the ocean outfall at Boags Rocks on intertidal rocky reef communities is highly localised, with the structure of assemblages on nearby reefs indistinguishable from more remote sites (see also CES2 Water Quality).

For the open coast, it is very difficult to detect signatures of degradation on intertidal reefs in response to key contemporary threats, given naturally high variation in community structure[147]. Highly-localised degradation has occurred at Boags Rocks (Box CES5), but there appear to be few clear signatures of degradation (which may include, for example, high covers of ephemeral algae) at most studied locations[148].

Intertidal reefs in Port Phillip Bay may be degraded. While these reefs support relatively diverse intertidal assemblages, they tend to show more consistent signs of environmental degradation, including consistently low coverage of brown macroalgae, effects of shellfish harvesting and invasion by introduced species[149]. Intertidal habitats in Port Phillip Bay are particularly vulnerable to degradation because of the small number and limited size of intertidal reefs in the bay, the distinct embayment assemblages that these reefs support, and their proximity to a very large population centre.

Seagrass communities
Indicator CES20 Changes in the distribution and extent of seagrass habitats

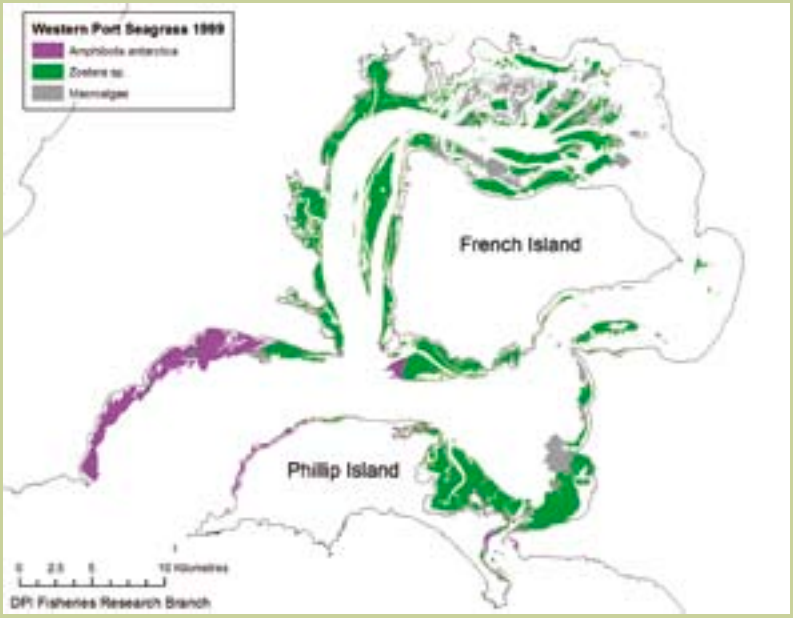
Seagrasses are marine flowering plants that grow on soft-sediment habitats in relatively sheltered environments where they can form extensive meadows. Declines in the distribution and extent of seagrass habitats have been recorded in many locations around the world[150]. These declines have often been attributed to human activities that degrade water quality or directly disturb sediment habitats (e.g. dredging) but also occur in response to natural disturbances such as sand movement and storms[151] (see CES 2 Water Quality). In Victoria, four major habitat-forming seagrass species create extensive seagrass habitats in sheltered locations in Port Phillip Bay, Western Port, Corner Inlet and the Gippsland Lakes, as well as in several smaller bays and inlets along the coast. Habitat-mapping (in Port Phillip Bay and Westernport Bay) and analysis of historical aerial photographs allows some assessment to be made of changes in the distribution and extent of seagrass habitats in Victoria over the last 60 years. Some caution must be used when drawing conclusions based on these long-term patterns, as studies have used different mapping techniques and field verification methods in mapping seagrass distribution[152].

Seagrass habitats in Victoria have shown large, shorter-term (5-10 year) fluctuations in area and also show some signs of stability over longer periods of time (50 year). The major pattern of change in these habitats throughout Victoria appears to be a continual cycle of seagrass losses followed by re-establishment and regrowth. For example, there were well-documented, substantial (up to 70%) declines in seagrass coverage in Western Port between the mid-1970s and mid-1980s[153] followed by substantial recovery of these seagrass beds in recent times [154] (see Box CES6). Less dramatic patterns have been observed in Port Phillip Bay, Corner Inlet and the Gippsland Lakes[155].

Box CES6 Seagrass distribution in Western Port

Seagrass coverage in Western Port was subject to dramatic change between 1973/74 and 1983/84. During this period, seagrass coverage declined almost 75% from approximately 230 km^2 to just 59 km^2 [156]. Over the next 20 years, seagrass habitats showed signs of substantial regeneration, and by 1999 covered an area of 131 km^2. In 1999, seagrass habitats in Western Port were distributed across most of their former range, although there has been limited or no recovery on mudflats in the north-east of the bay (Figure CES3.2)[157].

Figure CES3.2 Seagrass distribution in Western Port in 1999
Source: DPI Fisheries Research Branch



Within these broad, bay-wide patterns, large fluctuations in the abundance of seagrass at individual locations occur on scales of 1-50 years[158]. For example, at a single site near Leopold in the Geelong Arm in Port Phillip Bay there have been dramatic changes in seagrass coverage over the last 40 years (Figure CES3.3)[159]. Between 1970 and 1974 seagrass coverage declined by 80%. Over the next 10 years, seagrass on this site recovered to historically high levels by 1984 before decreasing again the following year by 60%.

A similar pattern of large fluctuations in seagrass distribution at an individual location has been observed at Blairgowrie, on the Mornington Peninsula in Port Phillip Bay. From the 1950s, a gradual increase in seagrass distribution has been observed over 40 years (Figure CES3.3). More recently, intensive monitoring within Port Phillip Bay between 2000 and 2005 showed declines in seagrass cover of 70% at two sites (Blairgowrie and Point Richards) whereas at a third site (Kirk Point) seagrass cover increased by 80%[160]. Similar, if less dramatic patterns are observed at nearly all intensively monitored locations throughout Victoria. In some cases, seagrass beds have disappeared completely, as seen in the north-east of Western Port, where seagrass beds have not re-established since their decline in the 1980s (Box CES6).

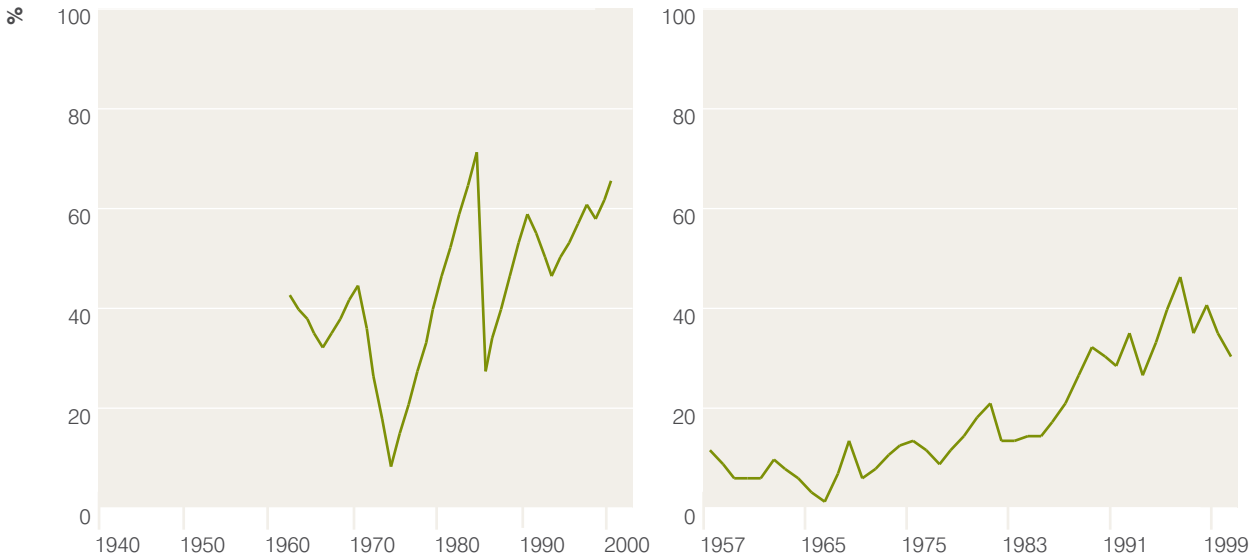
The significance of the large fluctuations in seagrass coverage observed in Victoria on both local and large scales is difficult to interpret. Seagrasses are highly vulnerable to many pressures associated with human activity and some declines within Victoria have been attributed to human-caused environmental changes such as dredging and declining water quality[163]. But fluctuations in seagrass coverage may not always be the result of human activity and may be a response to natural pressures such as natural sand movement smothering habitat. It is unclear if the recovery of seagrass beds in affected locations is due to subsequent improvements in environmental conditions that may have occurred as a result of improved environmental management practices. For these reasons, the validity of using seagrass distribution over short timescales (5-10 years) to describe environmental quality is low. Nevertheless, given the important ecosystem services provided by seagrass habitat (for example, as a fish nursery), and that fact that historical data is available, there is some value in using this as an indicator. This issue highlights the value not only of historical data, but also of the importance of continued monitoring in the future, so that long-term trends can be established and the best management decisions made.

Soft sediment communities

Although vulnerable to a range of pressures including bottom trawling and effluent discharge, very little is known about the general condition of open-coastal sediment habitats in Victoria. However, localised changes in community structure have been documented, particularly near sites of effluent discharge along the Victorian coast. Sediment communities close (< 700m) to the Boags Rocks ocean outfall have shown reductions in species diversity and are dominated by spionid worms, a group of species that is often associated with high nutrient conditions[164]. A similar outfall near Black Rock, near Barwon Heads, had little or no impact on subtidal sediment community structure shortly after it became operational. In general, however, changes to community structure around open coastal outfalls do occur but tend to be localised.

Soft sediment communities can be vulnerable to introduced species. The New Zealand screw shell (*Maoricolpus roseus*) has recently invaded deepwater sediment habitats in far eastern Victoria, including within the boundaries of Point Hicks Marine National Park[165]. This species commonly occurs in very high densities and can form beds covering enormous areas of soft-sediment habitat. The New Zealand screw shell is likely to have caused large changes to benthic community structure where it occurs. The invasion of this species is particularly significant as it has the potential to strongly impact the highly diverse soft-sediment assemblages that are a feature of Bass Strait.

Figure CES3.3 Area of seagrass cover as a percentage of total study area at Leopold (left) and Blairgowrie, 1940-2000 (right)
Source: Jenkins et al (2000)[161] & Ball et al (2008)[162]



Compared to open-coastal sediment habitats, there is better understanding of the condition of soft sediment communities in Port Phillip Bay due to the significant social and economic value of the bay. One example is the data collection that has occurred as part of management responses to pressures such as introduced marine pests and the closure of the scallop fishing industry in the 1990s. Consequently, it is known that sediment communities in Port Phillip Bay have changed considerably over the last century, particularly over the last 40 years. Since the 1970s there has been an increase in the proportion of filter-feeding invertebrates and a decrease in the number of deposit feeders[166]. This is likely due to an increase in the abundance of introduced filter-feeding species (e.g. European fan worm, *Sabella spallanzanii*), a decrease in nutrient levels in Port Phillip Bay and overfishing of some species[167]. Most of the changes observed in soft sediment communities are irreversible and represent degradation of environmental condition.

Deep reef communities

Hard substrata in deep water (greater than 20 m) provides habitat for assemblages of sessile invertebrates such as sponges, ascidians, bryozoans and corals. In turn, these invertebrates create habitat structure and provide food for mobile invertebrates and fish. Deep reef communities can be extraordinarily diverse; phyletically, they probably form one of the most diverse ecosystems on the planet (Figure CES3.4). In Victoria, assemblages of sessile invertebrates on deep reefs occur in the deep canyons at the entrance to Port Phillip Bay[168], on rocky coasts that descend rapidly into deep water such as at Wilsons Promontory, and also on rocky outcrops and cobble fields along the Victorian coast and in Bass Strait[169]. Some species of encrusting coralline algae grow unattached to any substratum to form free-living rhodoliths, which can be nodular or branched[170]. Large numbers of rhodoliths form *rhodolith beds*, which in turn create habitat structure for invertebrates and fish[171]. Deep water marine habitat mapping of Marine National Parks discovered extensive rhodolith beds off Point Addis, Cape Howe and Point Hicks[172].

Recent subtidal mapping programs along the Victorian coast have also located significant deep reef habitats, particularly in Victorian Marine National Parks and Sanctuaries. Knowledge about the ecology of these habitats is limited, so quantitative or qualitative assessments of habitat condition are not yet possible. Many of these habitats are vulnerable to human activities, particularly demersal trawl fishing, which can disturb these habitats and remove sessile invertebrates over large areas[173].

Recommendation

CES3.2 Provide ongoing support and adequate funding to continue marine habitat mapping of Victoria's deep water communities at appropriate spatial scales to provide a better understanding of habitat extent and condition. Information obtained should be used to inform the management of both Commonwealth and Victorian fisheries.

Figure CES3.4 Deep reef community showing diverse assemblage of sessile invertebrates such as sponges and gorgonian corals
Photo: Sean D. Connell

Marine mammals

Indicator CES21 Trends in abundance of marine mammals that were previously hunted in Victoria

Historically, several species of whale and seal that commonly occur in Victoria were hunted either in Victorian waters or elsewhere. Populations of these species, including the Blue Whale and Southern Right Whale, were seriously depleted before hunting ceased. Trends in population status provide an indication of the current status of these species, however there is very little data with which to assess the current population size of many of these species. The task is made more difficult because these species are inherently difficult to study and range over very large areas. Trends in the population status of two previously exploited species are considered below.

The pre-exploitation population size of Southern Right Whales in Australia is estimated to have been around 40,000[174]. After protection in 1935, the estimated global population size was about 1,000. Globally, the species has shown signs of recovery, with current estimates of total population size around 8,000[175]. There has been no clear positive trend in Southern Right Whales numbers visiting western Victoria in the last 10 years[176] and it remains listed as a threatened species under the State's *Flora and Fauna Guarantees Act 1998*.

The Blue Whale is an endangered species that visits the waters off south-west Victoria. Blue Whales gather annually to feed at the Bonney upwelling system, located along the continental shelf from Robe in South Australia to Portland in Victoria[177]. It has been estimated that 350,000 Blue Whales were hunted in the Southern Hemisphere between 1904 and 1967, with an estimated population of 2,300 remaining in the Southern Hemisphere[178].

The population size of Australian Fur Seals prior to exploitation in the 19th century has been estimated at approximately 200,000 animals producing up to 50,000 seal pups annually[179]. Commercial exploitation substantially reduced the population and recovery has only occurred very slowly in the last 150 years. However, more recently there has been an increase in the total population, suggesting stronger recovery has occurred in the last 10-20 years[180]. Considering that seal pup numbers are an indicator of total population size, seal pup numbers were approximately 12,000 in the late 1980s, 17,000 in the mid to late 1990s and approximately 20,000 in 2002. Consequently, the current total population is estimated at 96,000 individuals[181]. Nearly 80% of Australian fur seals are born in Victorian waters.

Threatened marine communities and species

Indicator CES22 Marine communities and species listed as threatened

Assessment of threatened communities and species in marine environments generally lags well behind similar assessments for terrestrial environments, and this is particularly the case for marine flora, invertebrates and fish. There is generally very little known about the population status of marine species or their response to key environmental threats, so official lists of threatened species are not always a true reflection of the number or vulnerability of marine species. Despite this limitation, the advisory list is the best starting point from which to gather further population data. Of particular note in Victoria is the large numbers of species of invertebrates and macroalgae that are apparently rare or have a restricted distribution and so are inherently vulnerable to pressures and environmental changes[182].

There are three major lists of threatened species that include Victorian marine organisms or communities: *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act); Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act); and the Advisory List of threatened vertebrate fauna in Victoria. Species listed under the EPBC Act and the FFG Act have statutory protection. The Advisory List is maintained by the Victorian Department of Sustainability and Environment but has no statutory authority.

Species from all of the main taxonomic groups, except marine flora, are considered threatened in Victoria, although there is a significant bias towards charismatic fauna, particularly birds (Table CES3.1). In addition, there is one marine community, the San Remo marine community, that is listed as threatened under the FFG Act.

Table CES3.1 Threatened marine fauna that occur in Victoria[iii]

Crustaceans	Scientific name	Advisory	EPBC	FFG
ghost shrimp	*Eucalliax tooradin*	NA		L
ghost shrimp	*Michelea microphylla*	NA		L

Echinoderms	Scientific name	Advisory	EPBC	FFG
brittle star	*Amphiura triscacantha*	NA		L
sea-cucumber	*Apsolidium densum*	NA		L
sea-cucumber	*Apsolidium handrecki*	NA		L
brittle star	*Ophiocomina australis*	NA		L
sea-cucumber	*Pentocnus bursatus*	NA		L
sea-cucumber	*Thyone nigra*	NA		L
sea-cucumber	*Trochodota sheperdi*	NA		L

Cnidarians	Scientific name	Advisory	EPBC	FFG
stalked hydroid	*Ralpharia coccinea*	NA		L

Molluscs	Scientific name	Advisory	EPBC	FFG
chiton	*Bassethullia glypta*	NA		L
marine opisthobranch	*Platydoris galbana*	NA		L
marine opisthobranch	*Rhodope genus*	NA		L

Fishes	Scientific name	Advisory	EPBC	FFG
Freshwater Herring	*Potamalosa richmondia*	RE		L
Australian Mudfish	*Neochanna cleaveri*	CE		L
Australian Whitebait	*Lovettia sealii*	CE		L
Australian Grayling	*Prototroctes maraena*	VU	VU	L
Empire Gudgeon	*Hypseleotris compressa*	VU		L
Great White Shark	*Carcharodon carcharias*	VU	VU	L
Pale Mangrove Goby	*Mugiligobius platynotus*	VU		L
Orange Roughy	*Hoplostethus atlanticus*	CD	CD	
Grey Nurse Shark	*Carcharias taurus*	DD	CE	L
Southern Bluefin Tuna	*Thunnus maccoyi*			L

Reptiles	Scientific name	Advisory	EPBC	FFG
Leatherback Turtle	*Dermochelys coriacea*	CE	VU	L

Mammals	Scientific name	Advisory	EPBC	FFG
Blue Whale	*Balaenoptera musculus*	CE	EN	L
Southern Right Whale	*Eubalaena australis*	CE	EN	L
Bottlenose Dolphin (PPB genotype)	*Tursiops sp.*	EN		I
New Zealand Fur Seal	*Arctocephalus forsteri*	VU		
Humpback Whale	*Megaptera novaeangliae*	VU	VU	L
Sei Whale	*Balaenoptera borealis*	DD	VU	
Bryde's Whale	*Balaenoptera edeni*	DD		
Fin Whale	*Balaenoptera physalus*	DD	VU	

iii Codes used in the following tables to describe the conservation status under the Advisory List and EPBC Act are as follows: Critically Endangered (CE), Endangered (EN), Vulnerable (VU), Conservation Dependent (CD), Near Threatened (NT), Data Deficient (DD), Not Applicable (NA). For the FFG Act, (L) indicates that the species is listed, and (I) indicates that the species is ineligible to be listed.

Birds	Scientific name	Advisory	EPBC	FFG
Intermediate Egret	*Ardea intermedia*	CE		L
Grey-tailed Tattler	*Heteroscelus brevipes*	CE		L
Fairy Tern	*Sterna nereis nereis*	EN		L
Great Knot	*Calitris tenuirostris*	EN		L
Gull-billed Tern	*Sterna nilotica macrotarsa*	EN		L
Little Egret	*Egretta garzetta nigripes*	EN		L
Terek Sandpiper	*Xenus cinereus*	EN		L
Wandering Albatross	*Diomedea exulans*	EN	VU	L
Black Bittern	*Ixobrychus flavicollis australis*	VU		L
Black-browed Albatross	*Thalassarche melanophris*	VU	VU	I
Black-tailed Godwit	*Limosa limosa*	VU		
Common Sandpiper	*Actitis hypoleucos*	VU		
Fairy Prion	*Pachyptila turtur*	VU	VU	
Great Egret	*Ardea alba*	VU		L
Greater Sand Plover	*Charadrius leschenaultii*	VU		
Grey-headed Albatross	*Thalassarche chrysostoma*	VU	VU	L
Hooded Plover	*Thinornis rubricollis rubricollis*	VU		L
Lesser Sand Plover	*Charadrius mongolus*	VU		L
Little Tern	*Sterna albifrons sinensis*	VU		L
Royal Albatross	*Diomedea epomophora*	VU	VU	L
Royal Spoonbill	*Platalea regia*	VU		
Shy Albatross	*Thalassarche cauta*	VU	VU	L
Southern Giant-Petrel	*Macronectes giganteus*	VU	EN	L
Whimbrel	*Numenius phaeopus*	VU		
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	VU		L
White-faced Storm-Petrel	*Pelagodroma marina*	VU		
Yellow-nosed Albatross	*Thalassarche chlororhynchus*	VU	VU	L
Black-faced Cormorant	*Phalacrocorax fuscescens*	NT		
Caspian Tern	*Sterna caspia*	NT		L
Common Diving-Petrel	*Pelecanoides urinatrix*	NT		
Eastern Curlew	*Numenius madagascariensis*	NT		
Grey Plover	*Pluvialis squatarolaulva*	NT		
Long-toed Stint	*Calidris subminuta*	NT		
Northern Giant-Petrel	*Macronectes halli*	NT	VU	L
Pacific Golden Plover	*Pluvialis fulva*	NT		
Pacific Gull	*Larus pacificus pacificus*	NT		I
Pectoral Sandpiper	*Calidris melanotos*	NT		
Pied Cormorant	*Phalacrocorax varius*	NT		
Red Knot	*Calitris canutus*	NT		
Sanderling	*Calitris alba*	NT		
Sooty Oystercatcher	*Haematopus fuliginosus*	NT		
White-fronted Tern	*Sterna striata*	NT		
White-winged Black Tern	*Chlidonias leucopterus*	NT		
Little Bittern	*Ixobrychus minutus*			L
Amsterdam Albatross	*Diomedea amsterdamensis*		EN	
Tristan Albatross	*Diomedea dabbenena*		EN	
North. Royal Albatross	*Diomedea sanfordi*		EN	
Buller's Albatross	*Thalassarche bulleri*			L
Indian Yellow-nosed Albatross	*Thalassarche carteri*			L

Pressures

Activities in catchments adjacent to marine environments

Activities in catchments adjacent to marine environments can severely impact marine habitats and organisms, principally by influencing marine water quality. The alteration of streams' flow regimes due to dams, weirs and other barriers can affect marine biodiversity, particularly estuarine species that need both fresh and salt water habitats for their lifecycle (see Part 4.3 Inland Waters). In addition, freshwater enters the marine environment via estuaries, stormwater, urban runoff and effluent discharges, causing elevated levels of nutrients, suspended sediments and various pollutants to enter the marine environment. Elevated nutrient levels can result in algal blooms, loss of sensitive species (e.g. kelp), decreases in dissolved oxygen and subsequent die-off of susceptible fish and invertebrates. High levels of suspended sediments can limit primary productivity in the sea by reducing light levels to marine plants and algae. Pollutants, including organochlorines, acid sulphates, heavy metals and hydrocarbons can result in death or disease in affected organisms. Some pollutants can accumulate within the tissues of individual animals (bioaccumulation) and/or increase in concentration in higher trophic levels (biomagnification), both of which can lead to chronic poisoning even if absolute levels of a toxin in the environment are low. For an assessment of this issue in relation to marine environments see CES2 *Water Quality*.

Catchment management practices that reduce flows into to the sea can also affect species of fish that use both marine and freshwater habitats. These fish regularly move between the two habitats, often to breed. Artificial reductions in river flows or closure of estuary mouths may severely affect these species.

Commercial and recreational fishing

Commercial and recreational fishing can have widespread effects on marine ecosystems[183]. Fishing can directly remove large numbers of individuals of targeted species from marine environments and impact large numbers of unwanted species (bycatch). Removing biomass from marine habitats can also substantially alter numbers of remaining species.

There are several important commercial and recreational fisheries in Victoria. Fishing at appropriate (sustainable) levels allows species to be harvested without impacting the ability of the species to maintain or increase population size through reproduction. Overfishing occurs when high levels of fishing pressure reduces the ability of a targeted population to replenish itself and so its population declines. In general, all major Victorian fisheries are considered to be either close to full exploitation or are already fully exploited[184] (e.g. Southern Rock Lobster), which means that the current level of fishing pressure is at the maximum sustainable level, given current awareness of threats and stock status (see Box CES7). Illegal harvesting of some species is a problem, particularly for high value species such as abalone and rock lobster.

In addition to catching targeted species, a large number of bycatch species (i.e. non-taget fish species, marine invertebrates and other species such as birds and marine mammals) are caught in fishing operations. Furthermore, discarded fishing gear drifts on ocean currents and can continue to catch marine species (*ghost-fishing*). The amount of bycatch depends strongly on the type of fishing gear used. Bycatch is minor or non-existent for rock lobster and abalone fisheries in Victoria[188]. However, bycatch is a larger problem for trawl, gillnet and long-line fisheries in Victorian waters and can sometimes represent up to 40% of the total catch[189]. There is limited information on the ecological impacts of bycatch on marine ecosystems in Victorian marine systems, with preliminary research indicating that reported bycatch levels for Victorian-based marine fisheries are likely to be minimum levels[190]. Further on-ship observations are required to clearly determine the ecological impacts of bycatch on Victorian marine ecosystems.

Some fishing methods such as trawling and scallop dredging can directly disturb benthic habitats because the fishing gear is in direct contact with the seafloor. Deep reef and soft sediment habitats are most vulnerable to this impact, which is more likely to be an issue in areas of higher fishing intensity such as in far eastern and western Victoria.

Box CES7 Southern Rock Lobster in Victoria

Many severe environmental pressures pre-date serious attempts to describe the condition of marine biodiversity and so, in many cases, contemporary definitions of environmental baselines lack an appropriate historical context. For example, there are strong indications that Southern Rock Lobster (*Jasus edwardsii*), which is worth $20 million annually[185], declined in abundance in Victoria from the 1950s to the 1990s in response to high fishing pressure[186], although baseline population levels (those prior to the 1950s) are unknown. Victorian fisheries management arrangements are explicitly targeted at ceasing overfishing and putting in place plans to recover depleted stocks. The total allowable commercial catch of rock lobster in Victoria has been set at levels that should allow populations to recover from historical overfishing. Promisingly, there has been some indication of recovery towards 1950 population levels in eastern Victoria, but not in western Victoria (see also Part 3.3 Materials).

One of the risks associated with the lack of baseline population data is that, in the absence of holistic ecological management principles, it may be assumed that 1950s population levels are ecologically functional when in fact they may not be. Such a situation can lead to a condition known as the *shifting baseline syndrome*[187],, which can result in the gradual, and often unnoticed, erosion of the health and integrity of marine ecosystems and biodiversity (see also Part 5 Living Well).

Introduced species

Most introduced species are transported into Victorian waters via ships' ballast water or from hull fouling (attached to the external underside of ships). Introduced species are a major threat to the integrity of marine ecosystems in Victoria. While the effects of many introduced species are relatively benign, particularly invasive species have the potential to drastically alter the structure and dynamics of marine ecological communities. Impacts of introduced species include displacement of native species, altered nutrient cycling, changes to marine trophodynamics and changes to biogenic habitat structure.

Highly destructive invasive species such as the marine alga *Caulerpa taxifolia* have been recorded in South Australia and New South Wales. There is a high potential for this species to invade marine habitats in Victoria in the future. There is also a high potential for existing introduced species to extend their distribution within Victoria. This is particularly the case for Japanese kelp (*Undaria pinnatifida*). This species has been observed in dense stands on broken basalt reefs on the north-eastern side of Port Phillip Bay and could have significant impacts on subtidal reef communities if it establishes itself in southern Port Phillip Bay[191]. Another example is the Northern Pacific Seastar (*Asterias amurensis*), which poses a significant threat to bivalve communities, in particular the Australian scallop[192].

Initial studies suggest that introduced species are likely to have widespread and in some cases compounding effects on marine environments[193] yet the extent of ecological impacts of introduced species in Port Phillip Bay is largely unknown. Given the numbers and wide distribution of introduced species in the marine environment, their impacts are likely to be substantial. It is also important to consider that many introduced species are now influential components of the ecology of Port Phillip Bay. For example, the introduced East Asian bivalve (*Theora lubrica*) and the introduced crab (*Pyromaia tuberculata*) are dominant components in the diet of many bottom dwelling fish species in the bay[194].

Indicator CES23 Number of introduced species in Victorian marine environments

Some surveys for introduced marine pests have been done in Victoria's commercial ports and harbours. Few, if any, formal surveys have been done outside these locations and there have been no published surveys in the last five years. On the basis of the surveys that have been done, some of Victoria's bays and inlets, and particularly Port Phillip Bay, have been heavily invaded by introduced species (Table CES3.2). Port Phillip Bay is considered to be one the most invaded marine ecosystems in the Southern Hemisphere, with 161 introduced species representing up to 13% of all benthic sediment and encrusting species recorded in the bay[195]. The most abundant soft-sediment invertebrates in Port Phillip Bay are now introduced species[196]and the number of invasions to Port Phillip Bay appears to be increasing[197].

Indicator CES24 Number of introduced species that have the potential to cause large impacts

The impact of most marine introduced species is unknown. However, the Australian Department of Agriculture, Fisheries and Forestry, under the auspices of the National Introduced Marine Pest Coordinating Group (NIMPCG) has adopted a "Trigger List" of introduced species that are considered to have the potential to have a high impact in their introduced range. This list is used for responding to new pest incursions, however, it does illustrate that a number of species that are considered to have the potential to cause large impacts already occur in Victoria, mostly in Port Phillip Bay (Table CES3.3). A recent CSIRO report ranks the ecological impact of existing marine pests in Australia using qualitative criteria[204]. Several of the species considered to have high impact in this study also occur in Victoria (Table CES3.3). In addition, three existing marine pests are listed as noxious under the *Victorian Fisheries Act 1995*.

Table CES3.2: The number of introduced marine species in Victoria's major ports and harbours.

NOTE: Except for the survey by Hewitt et al. 2004, all surveys concentrated on commercial shipping wharves and some shipping channels and dredge spoil disposal grounds.

Location	Survey dates	No. of introduced species
Port Phillip Bay Hewitt *et al.* 2004[198]	1995-1996 and museum collections	161
Port of Melbourne Cohen *et al.* 2001[199]	1999-2000	29
Port of Geelong Currie *et al.* 1998[200]	Aug-Oct 1997	20
Western Port Parry and Cohen 2001[201]	July 2000	18 (12 self-sustaining)
Port of Hastings Currie and Crookes 1997[202]	March 1997	7
Portland Harbour Parry *et al.* 1997[203]	Apr-May 1996	9

Table CES3.3: Introduced marine species in Victoria that have the potential to cause large impacts

Species name	Common name	Noxious (Fisheries Act 1995)	NIMPCG Trigger list (2006)	Potentially high impact (Hayes et al 2005)
Asterias amurensis	North Pacific seastar	Y	Y	Y
Sabella spallanzanii	European fan worm	Y	Y	Y
Undaria pinnatifida	Wakame (Japanese)	Y	Y	Y
Carcinus maenas	Eur. shore crab		Y	Y
Crassostrea gigas	Pacific oyster			Y
Corbula gibba	European clam		Y	
Maoricolpus roseus	New Zealand screw shell		Y	
Codium fragile spp. *tomentosoides*	Green macroalga		Y	Y
Ciona intestinalis	Solitary ascidian			Y
Bugula neritina	Bryozoan			Y

Once established, the full control of pests is almost invariably unsuccessful and thus greater emphasis needs to be placed on prevention, early detection and rapid response. One of the greatest impediments to detection is the lack of taxonomic expertise required to make positive identifications of introduced species.

Litter

Disposal of litter and other forms of material waste is an ongoing problem in marine environments. Sources of litter are varied and include terrestrial and ship-based sources. Litter will often take long periods of time to break down and fish, seabirds and marine mammals can ingest or become tangled in litter, often resulting in death. The increase in litter in the ocean can also act as a 'raft' for marine species, increasing the potential of exotic species to enter the local environment[205]. As discussed above in the *Commercial and recreational fishing* section, discarded fishing gear (i.e. trawl nets) can drift on ocean currents and can continue to harm species such as whales, dolphins and sea birds.

Visitation

People visit marine environments for a range of reasons including fishing, boating, swimming, snorkelling, diving and sightseeing. Some activities associated with visiting marine environments can cause environmental damage. Disturbance to seagrass habitats from boat anchors may occur. People may harvest intertidal animals and plants for food, bait or other uses, despite warning signs informing that this is prohibited. Harvesting of intertidal molluscs has reduced the abundance and average size of larger species on reefs in Port Phillip Bay[206]. Trampling can reduce cover of the common macroalga, Neptune's necklace (*Hormosira banksii*), with consequent changes to other macroalgae and invertebrates. The extent of damage caused by many of these activities is largely unknown but could be substantial, particularly in small areas receiving large numbers of visitors. Visitation is also likely to increase in proportion to any increases in the number of people living near the coast. It should be noted that although a high visitation rate constitutes a genuine environmental pressure, human experiences can have positive environmental outcomes, including increasing familiarity and appreciation of marine biodiversity.

Aquaculture

Marine aquaculture in Victoria occurs within Aquaculture Fisheries Reserves (AFR), declared under the Fisheries Act 1995. With the exception of Portland, all are located within Port Phillip Bay and Western Port (Figure CES3.5).

Figure CES3.5 Aquaculture fisheries reserves in Port Phillip Bay and Western Port
Source: DPI

The potential impact of aquaculture on biodiversity will depend on the species, management practices and legislative framework under which each facility must operate. Physical disturbance of the site can occur with the construction and maintenance of infrastructure. Other potential impacts include risk of disease from the farmed species and food supply, introduction of non-endemic species or genetically different individuals to wild populations, and increased nutrient load to water and sediment. Generally aquaculture is well managed, however, pressures can impact on both native species in adjacent waters, and onto the aquaculture industries themselves. There have been cases where these pressures have led to the abandonment of large areas of aquaculture infrastructure that were no longer viable[207], indicating the importance of monitoring the effect of interconnectedness with surrounding marine systems.

In addition to the sea-based facilities, there are six land-based abalone aquaculture facilities. All are open systems; that is, water is pumped from the sea to be used in the facility and, following some treatment, is discharged back into the marine environment. Although physical disturbance to the seafloor and marine waters is reduced with land-based facilities, potential impacts such as increased delivery of nutrients and pathogens, and the opportunity for escapees to mix with wild populations still exist.

Dredging

Dredging of channels has occurred for many years in Victoria, and is required to allow access by private and commercial vessels to bays and inlets along the Victorian coast. Dredging operations directly disturb benthic habitats and often temporarily reduce water quality by increasing concentrations of suspended sediments in the water column. Benthic organisms are vulnerable to direct disturbance from dredging operations. Marine macroalgae and seagrass are also vulnerable because their photosynthetic capacity is reduced due to low light levels caused by high turbidity (see CES2 Water Quality).

Coastal and urban development

Most of Victoria's population lives close to the coast, which puts direct pressure on marine environments through increased coastal development. Besides contributing to marine water quality issues (see CES2 Water Quality), coastal development such as building marinas or reclamation of sensitive intertidal habitats, such as mangroves and salt marshes, can directly disturb marine habitats and organisms (see CES1 Coastal Modification).

Mineral exploration and extraction

There are substantial oil and gas reserves off the coast of Victoria. Oil and gas are currently being extracted from some of these reserves and exploration for new reserves is continuing. Activities associated with extraction and exploration of minerals in marine environments can disturb marine habitats and organisms. Oil and gas platforms and drilling operations directly disturb benthic habitats in areas immediately adjacent to drilling operations. The use of seismic equipment for mineral exploration may interfere with cetaceans. Exploration and extraction of mineral resources in marine environments also increases the risk of spills of drilling fluids and hydrocarbons.

Climate change

The impacts of climate change on marine biodiversity are discussed in detail in CES4 Climate Change. Likely impacts include sea level rise, increased sea surface temperature, altered ocean currents, storm surges and flooding, as well as changes in ocean salinity and pH. Sea level rise and flooding directly threaten coastal vegetation, especially given the extent of coastal development, which constrains retreat of coastal ecosystems. Acidification of oceans threatens coral and shelled organisms by reducing the availability of carbonate, from which shells and coral structures are composed. Other likely effects of climate change on marine and coastal biodiversity include changes in habitat distribution, changes in population and ecosystem dynamics and increases in the range and incidence of diseases (see CES4 Climate Change).

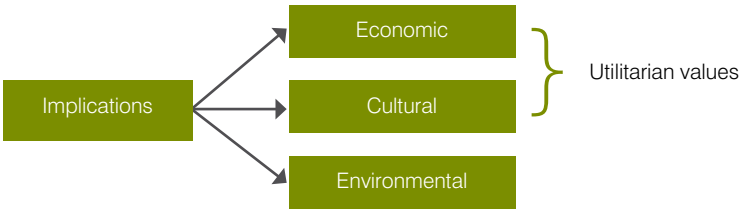
Implications

The marine biodiversity of Victoria is a unique and valuable asset. The implications of biodiversity loss can be classified under three broad types (see Figure CES3.6).

Environmental implications include ecosystems services such as nutrient cycling, and cumulative effects such as a reduction in diversity that affects the ability of species to adapt to a changing environment. Marine biodiversity provides critical ecosystem services for life on Earth. Phytoplankton, for example, are free-floating microscopic ocean plants responsible for creating about half of the oxygen on earth as well as playing a critical role in nitrogen cycling (see Figure CES2.4) and providing a food source for larger animals. Phytoplankton also act as a global carbon sink, without which the scale of the effect on the atmosphere of the current rate of carbon dioxide emissions would be far more severe (see Part 4.1: Atmosphere, Climate Change).

In comparison to terrestrial species, there is generally a lower level of understanding and a different approach to the decline in marine biodiversity. For many marine issues, it is a case of *out of sight, out of mind*. The degree of interdependence that exists between the marine environment and other ecological and climatic systems is extensive, making modelling of future scenarios difficult. Nevertheless, there is strong evidence that a reduction in marine biodiversity, particularly in populations of certain ecological *keystone species* would have implications on a global scale[208]. Furthermore, it is likely that some of the changes that are occurring will constitute permanent and irrevocable modification of marine ecosystems, including further species extinctions[209]. For example, many top level predators play an important role in managing the abundance of other species in the ocean. Recent information shows that the unsustainable fishing of sharks will have worldwide 'cascading' effects on marine ecosystems[210].

Figure CES3.6 The implications of a decline in marine biodiversity



In addition, the interactions between a reduction in keystone species and other stressors such as climate change could give rise to cumulative effects; that is, effects greater than either stressor alone would create[211]. Because of the lack of understanding concerning such issues, it has been argued that marine biodiversity should be managed according to the precautionary principle[212].

Cultural and *economic* implications refers to the effects that humans will experience as a result of environmental changes and directly as a result of depauperate marine environments. Currently Victoria's economy gains great benefit from healthy marine biodiversity. For example, the Victorian abalone industry, worth $60 million per year, is threatened by the naturally occurring *Ganglioneuritis* virus, thought to be exacerbated by common aquaculture procedures[213].

In Victoria, approximately 8000 people are dependent on seafood landed or produced here for the bulk of their employment. About $180 million of seafood product is landed at Victorian ports. Approximately $130 million is from Victorian managed fisheries, while the rest is from a combination of Commonwealth and Tasmanian fisheries. With Victoria's clean unpolluted waters, our commercial fish catch is keenly sought by both the domestic and overseas markets[214].

While fish stocks have declined, Port Phillip Bay still supports socially and economically valuable finfish fisheries. These include stocks of snapper, which have recently increased because of reduced commercial fishing activity in the bay[215]. Examples of economic implications of degraded marine biodiversity include a reduction in fish stocks, negatively affecting industries and towns that rely on fishing to make a living. The historic decline in economically valuable species such as abalone and rock lobster are examples of this.

Similarly, 'ecotourism' businesses can be affected by a reduction in marine biodiversity. A reduction in Fairy Penguin numbers, for example, could have severe implications for tourist operators at Phillip Island. This is of particular concern for Victoria, as the livelihood of towns such as Lake Entrance, Warrnambool and others depends upon fishing and therefore on the health of local marine biodiversity.

Cultural and economic implications are representative of what are typically known as *utilitarian values* (see Figure CES3.7), in that they describe the practical uses that humans derive from marine biodiversity. Utilitarian values also include the *intrinsic values* that humans ascribe to marine biodiversity and their sense of wonder for the sea. Concern has been raised by divers and other users of Port Phillip Bay over the impact that the incursion of marine pests has had on such species as the Weedy Sea Dragon (Victorian Marine Emblem). The intrinsic value of other species is also noted by people who report spiritual experiences when swimming with the Bottlenose Dolphins in Port Phillip Bay or sighting migrating Humpback Whales off the coast at Warrnambool.

Due to the connectivity of all oceans, and the interdependence between marine, terrestrial and atmospheric systems, the implications of a decline in marine biodiversity may be far-reaching, especially under the additional pressure of a changing climate. Because of this interdependence, while protecting marine biodiversity in Victoria is essential, Victoria also has an important role to play in advocating the protection of marine biodiversity and ecological process in Australian and in international waters. Quite apart from protecting the important role that local marine biodiversity plays in the Victorian economy and culture, protecting marine biodiversity on a global scale will enable ecosystems, including those that Victorians directly depend upon, to better adapt to climate change.

Management responses

Response Name
Land & Biodiversity in a Time of Climate Change White Paper

Responsible Authority
Department of Sustainability & Environment

Response Type
Policy/Strategy

The Land and Biodiversity in a Time of Climate Change White Paper, due for release in 2009, will set the environmental policy and investment direction for natural resource management, land health and biodiversity, including marine biodiversity, for the next two decades. The process for developing the White Paper has commenced, with the key themes outlined in the preceding Green Paper, released in early 2008. The Green Paper discusses various management options relating to marine biodiversity, including options for improving catchment management, better managing aquatic ecosystems, improving our management of pests and expanding our knowledge base. A renewal of the Victorian Biodiversity Strategy was also announced as part of *Our Environment, Our Future* and will be considered in the context of the outcomes of the White Paper (see Part 4.2 Land & Biodiversity for further details).

Response Name
Fisheries Act 1995

Responsible Authority
Department of Primary Industries

Response Type
Legislation

The *Fisheries Act 1995* provides the legislative framework for the regulation, management and conservation of Victoria's fisheries. The objectives of the Act set a basis for the ecologically sustainable management of Victoria's fisheries and aquaculture industries.

Fisheries Management Plans have been developed under the Act to manage a region (e.g. Mallacoota Inlet Fisheries Reserve Management Plan) or species (e.g. Victorian Rock Lobster Management Plan) and set indicators, targets and monitoring methods. Current reviews and development of Fisheries Management Plans use ecosystem-based fisheries management principles to ensure environmental factors are considered in management decision making. Fisheries Management Plans are only as successful as the information available, so further consideration should be given to ensure critical knowledge gaps are bridged.

Aquaculture Management Plans developed under the *Fisheries Act* provide operational rules for the management of specific aquaculture reserves. Plans include environmental performance indicators and management triggers use to manage the impact on the marine environment. Guidelines for Environment Baseline Surveys & Ongoing Monitoring of Aquaculture Fisheries Reserves in Port Phillip Bay were established by the DPI in 2006 to provide detailed guidance on the environmental monitoring required for aquaculture licence holders. The strategic planning and regulation established under the Act provide a basis for the aquaculture industries to operate in an ecologically sustainable manner.

Despite the Fisheries Management Plans, several fisheries in Victoria are believed to be *fully exploited* and sustainable at current levels and within current ecological conditions, which may be changing[216] (see CES4 Climate Change). As such it is likely that their resilience to compounding exogenous pressures has been reduced.

All Victorian export fisheries must be accredited by the Commonwealth Government under the *Environment Protection and Biodiversity Conservation Act 1999* and meet Commonwealth guidelines to demonstrate ecologically sustainable practices.

Recommendation

CES3.3 Ensure Fisheries Victoria is provided with sufficient resources and financial support to properly research and monitor fisheries stocks. Where fisheries are depleted, ensure that Fisheries Management Plans allow for the recovery of populations such that their resilience to known environmental pressures, such as the effects of climate change, as well as to unknown pressures, is rebuilt.

Response Name
Interim Victorian Protocol for Managing Exotic Marine Organism Incursions (1999)

Responsible Authority
Department of Sustainability & Environment

Response Type
Process

The *Interim Victorian Protocol for Managing Exotic Marine Organism Incursions* (the Protocol) was established in 1999 to minimise the adverse effects of future incursions of exotic marine organisms into Victorian waters. The protocol outlines the response processes and responsibilities of other agencies, primarily the Department of Sustainability & Environment, Environment Protection Authority, Australian Quarantine and Inspection Services, CSIRO and the relevant port authority.

In late 2003, a Northern Pacific Seastar (*Asterias amurensis*) was found at Andersons Inlet at Inverloch, Victoria. The seastar was already common in Port Phillip Bay and was identified as an introduced species that was potentially damaging to native marine communities and species. The Protocol provided the management structure to successfully eradicate the seastar from the area. In the debrief report to the emergency response at Andersons Inlet[217], it was highlighted that the Protocol should be updated in 2005 to ensure consistency with the national arrangements being developed at the time. The *Intergovernmental Agreement on a National System for the Prevention and Management of Marine Pests Incursions* was signed in April 2005. The agreement outlines a national framework for a coordinated approach to the protection of Australia's marine environment from invasive marine pests. To date, the protocol for Victoria remains an interim arrangement and should be finalised in accordance with the national framework. Furthermore, eradication of marine pests may not be possible if the incursion is not detected early and the pest has had an opportunity to establish. Therefore, there should be a strong emphasis on identification, prevention and rapid response to incursions in the final Protocol.

Recommendation

CES3.4 Update and finalise the Interim *Victorian Protocol for Managing Exotic Marine Organism Incursions* for marine pest management in Victorian waters, with greater emphasis on identification, prevention and rapid response to incursions.

Response Name
Waste Management Policy (Ships' Ballast Water)

Responsible Authority
Environment Protection Authority

Response Type
Policy/Strategy

The *Port Phillip Bay Environmental Management Plan* identifies the risks of nutrients and marine pests as priorities to be addressed in the management of the bay. In response, the EPA established the *Waste Management Policy (Ships' Ballast Water)* in July 2004 to protect Victoria's environment from marine pests from domestic ballast. The policy establishes a control for vessels entering Victorian waters with ballast water that originates from an Australian port or within the territorial seas of Australia. The *Environment Protection (Ships' Ballast Water) Regulations* 2006 support the policy and provide a mechanism for the EPA to establish reporting and fee requirements for vessels, including penalties for non-compliance. Any fees charged are returned into the management system to ensure the ongoing implementation of the program.

The Australian Quarantine and Inspection Service (AQIS) manage the risks of international ballast water under the *Australian Ballast Water Management Requirements* (2007). These requirements are established with the legislative backing of the *Quarantine Act 1908.* The EPA policy for domestic ballast water was developed to complement the regulations administered by AQIS.

If a marine pest incursion from ballast water does occur in Victorian waters, the *Interim Victorian Protocol for Managing Exotic Marine Organism Incursions* provides the response protocol to eradicate the pest from the incursion area. However, eradication may not be possible if the incursion is not detected early and the pest has had an opportunity to establish. To avoid this, a monitoring program should be established to determine the existing distribution of marine pests and routinely monitor for new incursions.

Recommendation

CES3.5 Establish monitoring program for marine pest distribution and routinely monitor for new marine pest incursions in Victorian marine waters, particularly focusing on marine pest distribution in Port Phillip Bay.

Response Name
National Parks Act 1975

Responsible Authority
Parks Victoria/Department of Sustainability and Environment

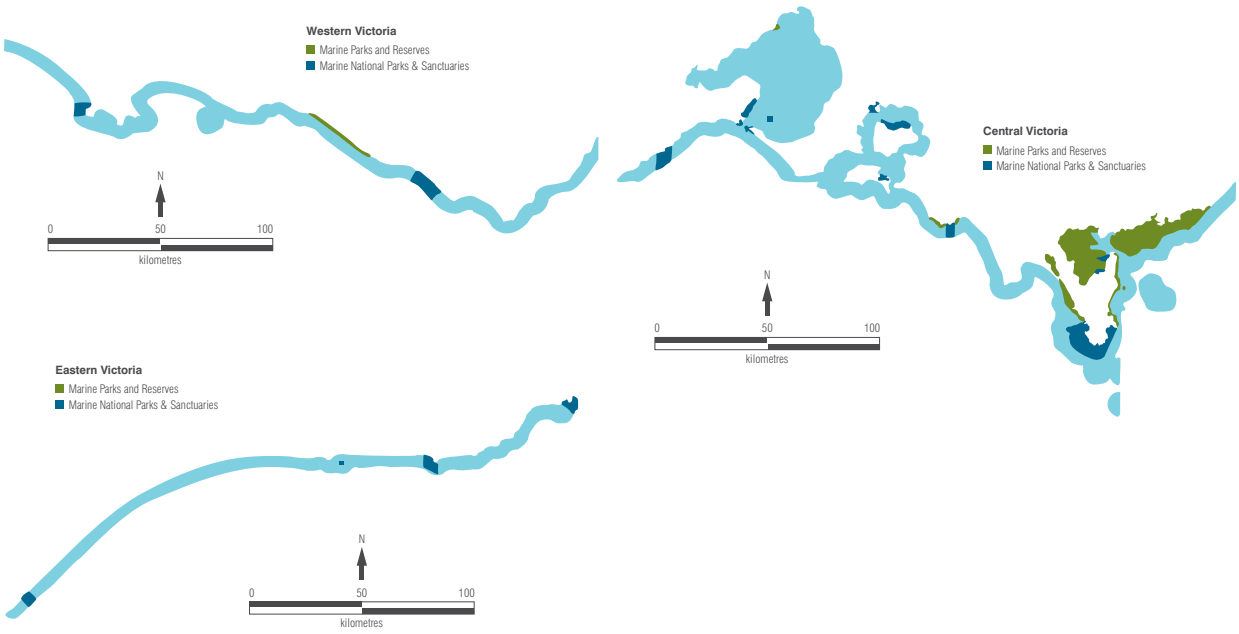
Response Type
Legislation

In 2002, a system of marine protected areas was set aside in Victorian waters. Thirteen Marine National Parks and 11 Marine Sanctuaries[218] now protect over 5% of Victoria's coastal waters to the State limits, 5.5 km offshore. In addition, several marine and coastal parks provide a level of protection and public access to a further 6.6% of the Victorian marine environment. The area of the Victorian marine environment that falls under these protected areas is shown in Table CES3.4 and their locations are shown in Figure CES3.7.

Table CES3.4 Area and percentage of total Victorian waters protected along Victoria's coast by type, 1997 and 2008
Source: DSE[219]

Public Land Type	Area (ha)	Area Totals (ha)		% of Vic. Waters	
		1997	2008	1997	2008
Marine Reserve	6,626.1				
Marine & Coastal Park	65,898.0	0	68,956	0	6.6%
Marine National Park	52,014.8				
Marine Sanctuary	558.1	0	52,573	0	5.1%
Total Marine Parks			121,529		11.7%

Figure CES3.7 The location of Victorian marine reserves by type 2008
Source: DSE[220]



In addition to the marine parks described above, six of the 11 Victorian wetlands listed under the international convention on wetlands, the Ramsar Convention, are located on or near the coast (See Part 4.3, Inland Waters).

The *Strategy for Marine National Parks & Marine Sanctuaries 2003-10* provides the scope and direction of management plans for these areas. A management plan has been established for each of the marine national parks and marine sanctuaries that provides a consistent and Statewide approach to managing these reserves. As the parks and sanctuaries are established under the *National Parks Act 1975*, a number of activities are prohibited to ensure the protection of the marine environment within the reserve. Compliance arrangements require ongoing cooperation between Parks Victoria and Fisheries Victoria to ensure compliance with the legislation and protection of marine biodiversity within the reserve.

Evaluation of marine biodiversity responses

It is acknowledged that in many cases understanding of Victoria's marine communities is relatively limited[221]. While continuing to study and increase understanding of the marine environment, a gap in knowledge of Victoria's marine environment should not be seen as a reason to limit the management of the State's marine biodiversity. As outlined as a suggested approach in the *Land and Biodiversity at a time of Climate Change* Green Paper, examining an asset-based approach to the management of the marine environment may provide a useful framework for marine biodiversity management (Box CES8). Using this approach provides a mechanism to set management priorities and provide direction for research and monitoring in the absence of data for all systems.

Box CES8 Asset-based approach for land and biodiversity management[222]

An asset-based approach to land and biodiversity management prioritises funding and research towards increased understanding of risks to assets, rather than collecting information on a species or system for academic value, or delaying decision making until a depth of knowledge is held on all elements of a system. This approach has value in land and biodiversity management as it can be used as a basis to protect, rehabilitate and manage natural resources without requiring that all elements of a system are understood before taking action.

There are several key elements to asset-based management. These include:

- *Asset Identification* - Identification of entities within a region that are considered assets and examining the ecosystem services they provide.
- *Asset Valuation* – Assessing the range of values associated with the asset, including the importance of the asset on the national, state and local community level. Asset valuation can be used to compare the importance of the asset against other assets.
- *Assessing Threats and Risks* – Consider the rate of change in asset condition, as well as the nature, magnitude, trend and probability of threats to an asset.
- *Planning and Investment* – Use information to prioritise future actions and investment.

Asset-based management holds particular value for marine ecosystems. While little is known about the requirements and life histories of a broad range of species and systems, management decisions are still required to ensure the ongoing protection of marine ecosystems. By identifying the key marine and coastal assets and their values, and identifying the risks posed to them by a range of natural and human-induced processes, planning and investment can be directed in a sustainable way in the absence of deep scientific knowledge on all elements of the asset in question.

Recommendation

CES3.6 Examine opportunities for applying an asset-based approach to managing the marine environment.

Knowledge of Victoria's marine environment is sufficient to conclude that Victoria's marine biodiversity is unique and diverse. A significant pressure on maintaining this biodiversity is the impact of introduced species on the marine environment. A number of management responses have been established to manage the risk of marine pests; however, species introductions still occur, and, once established, are extremely difficult to eradicate. The most effective way of controlling marine pests is to stop them entering the marine environment in the first place. This is why effective ballast water legislation and programs are important.

The EPA's domestic ballast water program provides a framework for managing the risk of marine pests that may be introduced into Victorian waters via ships' ballast water. The development of a national program for managing domestic ballast water within Australian waters is currently being discussed at a national level and this initiative should be encouraged. It is also important that the Australian Quarantine and Inspection Service continue to develop appropriate legislation and guidelines to manage the risk of marine pest incursions from ballast water.

Recommendation

CES3.7 Continue to support and implement state, national and international ballast water programs to minimise the risk of marine pest incursions in Victorian waters.

If a marine pest does become established in an area, it is important that its movement is restricted to avoid colonisation of new areas. Although marine pests may naturally migrate, recreational activities such as boating can accelerate the rates of spread. Awareness and education campaigns targeting recreational boaters (e.g. *Aquatic Pests – Treat 'em mean, keep your boat clean* campaign) should continue. Increasing the understanding of marine pest distribution (in particular within Port Phillip Bay) and the development of a monitoring program will improve the effectiveness of Victoria's current management responses to the issue.

Recommendation

CES3.8 Continue awareness campaigns on the risk of spreading marine pests by recreational boaters.

Areas of the marine environment are protected through Victoria's Marine National Park and Marine Sanctuary network. Marine National Parks and Marine Sanctuaries not only provide protection for areas of the marine environment, they are also used to raise community awareness and educate the community about marine biodiversity issues.

Regulation and protection of Marine National Parks and Sanctuaries to ensure compliance with the *National Parks Act 1975* requires ongoing cooperation between Parks Victoria and Fisheries Victoria. Whilst the Act provides 'legislative protection' for highly valued areas along the Victorian coast, the protection of marine biodiversity in these areas through policing and enforcement is critical. Research has highlighted illegal activities decreasing and marine species recovering with the level of enforcement increasing in marine reserves[223]. With the current level of policing of marine reserves restricted by resource availability, further support is required to allow Parks Victoria and Fisheries Victoria to adequately police Marine National Parks and Sanctuaries. Enforcement of recreational activities should focus on marine reserve areas close to major urban centres[224].

Recommendation

CES3.9 Determine gaps in current capacity to ensure effective compliance of Marine National Parks and Sanctuaries. At the conclusion of the review, State Government should fund and resource any critical recommendations.

Continuing research and investigation, in particular continuing marine habitat mapping, is important in order to provide a basis for assessing the adequacy of the current protected marine areas. The fifth IUCN World Parks Congress held in South Africa in 2003 called upon the international community to establish a system of marine and coastal protected areas, aiming for at least 20-30% of each habitat by 2012. A better understanding of the marine habitats along the Victorian coast will provide valuable information for a review of the current representation of marine protected areas.

Recommendation

CES3.10 Continue marine habitat mapping program and use information to determine adequacy of Victoria's protected marine areas and examine opportunities to expand marine areas under protection.

For further information

Museum Victoria
http://museumvictoria.com.au/

Parks Victoria
http://www.parkweb.vic.gov.au/1bays.cfm

CES4 Impacts of Climate Change on Coasts, Estuaries and the Sea

Key findings

- The climate change factors of altered ocean currents and increasing sea surface temperature will affect coastal and marine systems via increased storminess and rising sea levels respectively.
- Increasing oceanic acidification, resulting directly from increased atmospheric carbon dioxide, and oceanic stratification will both impact marine biodiversity and, in turn, the industries and communities that depend upon it.
- The effects of increasing atmospheric CO_2 concentrations on the carbonate system in seawater are not reversible in human time scales.
- Coastal settlements and biodiversity are already affected and will continue to be affected by storm surges, which will intensify with rising sea level and localised land subsidence. Models show that storm surges of up to 2.3 metres above sea level could be expected by 2070.
- Coastal settlements are likely to be subject to flooding and inundation, which could damage infrastructure and put residents' health and safety at risk.
- Biodiversity in coastal environments is already under threat from a number of environmental pressures. The effects of climate change represent an additional pressure under which certain coastal ecosystems are unlikely to persist.
- In regard to existing marine systems, there are likely to be numerous, interdependent climate change-related factors causing pressure on populations and altering breeding patterns and distribution.

Objectives

- To reduce the vulnerability of Victoria's coastal and marine systems to the effects of projected climate change through mitigation and adaptation
- To foster further government and community resilience to the effects of climate change on Victoria's coastal and marine systems

Description

The effects of climate change are starting to become apparent. As well as the phenomena described in Part 4.1 Atmosphere: Climate Change, global climate change is characterised by increasing sea surface temperature and altered ocean currents. These in turn affect weather patterns, sea levels and other marine and coastal conditions. Certain effects, such as storm surges and flooding, are considered very likely in the short term (≈50 years). Due to the complex inter-relationships that exist between oceanic and atmospheric systems, and incomplete understanding of marine systems, the full, long-term effects of climate change on coasts, estuaries and marine systems are not known, making the use of traditional environmental indicators less useful in describing the issues. Nevertheless, given that characteristics of climate change (specifically sea level rise) are tracking on the upper limit of recent projections[225], it is widely thought that the coastal and marine ecological systems upon which Victoria was founded will be subject to *significant change*. Without immediate mitigation and adaptive measures, these changes are likely to be increasingly difficult for human and other biological systems to adapt to.

A large proportion of Victorians live in coastal settlements, including Melbourne, and there is a persistent trend of 'sea change', the phenomenon that sees increased migration towards coastal regions (see Part 2 Driving Forces). Climate change will affect these communities through sea level rise and an increase in storm surges. In the short term, an increase in erosion rates, periodic flooding and, in the longer term, permanent inundation and altered coastlines, are likely to be the result. It is expected that all Victorian coastal communities will be affected to some extent, with low lying areas clearly the most vulnerable.

The effects of atmospheric and oceanic changes due to climate change are expected to be detrimental to biodiversity. Coastal ecological communities, many of which are already threatened by habitat loss due to urban growth and farming, are particularly at risk. Similarly, as a consequence of complex interactions between temperature, currents, salinity and acidity levels, the full effects of climate change on marine systems are not well understood. However, there is already evidence that increased sea temperatures are affecting the breeding patterns, abundance and distribution of a range of species, from plankton to marine mammals such as dolphins.

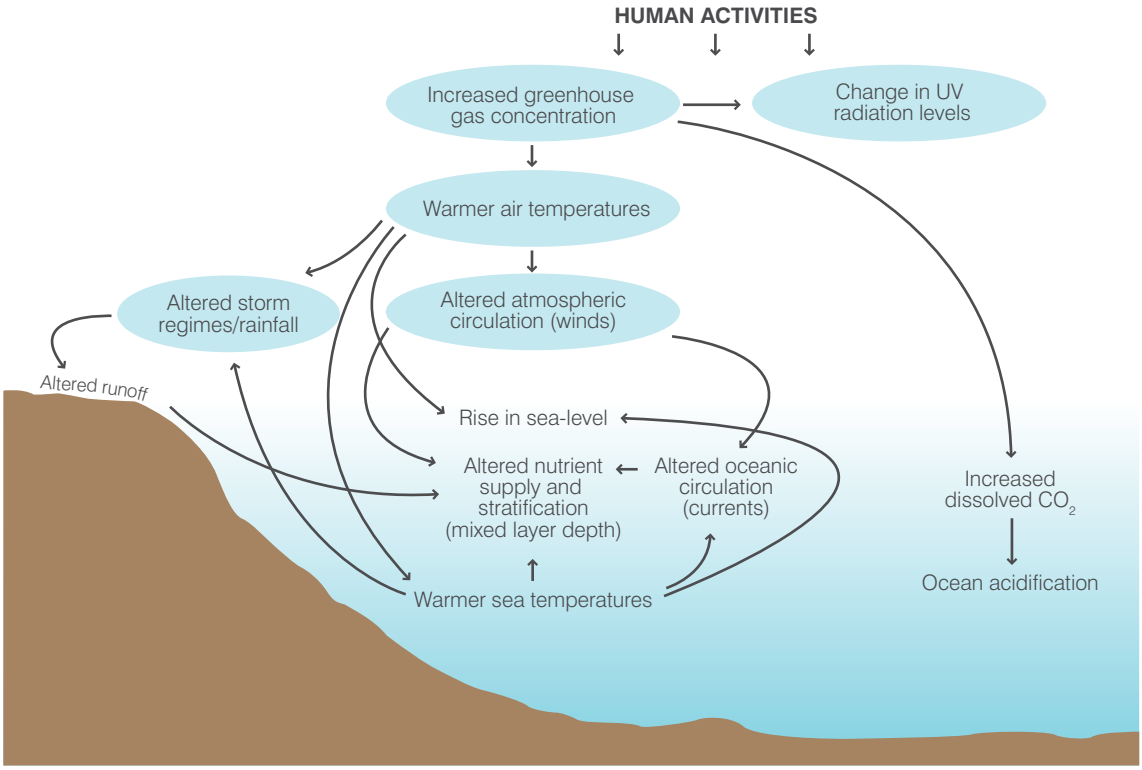
As well as the effect on residential areas, climate change will affect the economy through businesses that rely on marine and coastal environments. Fishing industries that rely on marine species vulnerable to changing currents and sea temperatures are likely to be affected. Similarly, coastal communities that are dependent upon tourism are also vulnerable. Climate change is also likely to inflict significant economic cost on coastal communities through the need to repair or replace infrastructure after storm damage and to adapt existing infrastructure to the changing conditions.

State

For a complete description of the broad mechanisms and effects of anthropogenic climate change refer to Part 4.1 Atmosphere, Climate Change.

The causal relationships between aspects of climate change most important to marine and coastal systems are complex. They are represented in a simplified manner in Figure CES4.1.

Figure CES 4.1 Simplified representation of climate change–associated phenomena on coastal and marine systems
Source: Poloczanska et al[226].



In many cases the relationships illustrated above are not well understood, with modelling becoming increasingly uncertain the further into the future projections are made. In addition to this level of uncertainty, it is also expected that as climate change progresses, compound effects will occur, in some cases further exacerbating pressures on coastal and marine systems.

Two phenomena, altered currents and increasing ocean temperatures, are the most significant factors that account for the effects of climate change on coastal and marine systems[227]. Also of importance are changes in ocean chemistry, in particular acidification, an issue that is directly caused by increasing atmospheric carbon dioxide.

Altered currents

A fundamental feature of climate change is altered ocean currents. This occurs via a number of mechanisms, one of which is the addition of fresh water to the sea from melting glacial and polar ice. It is thought that the subsequent decrease in density of surface water could slow or stop global oceanic (thermohaline) circulation, currents important for predictable weather patterns. There is a large amount of uncertainty as to the likelihood, severity and timeframe over which this may occur but it is generally thought that such an effect would be extremely difficult to reverse. This uncertainty is illustrative of the complexity of most climate systems and the limitations of predictive modelling.

The East Australian (ocean) Current (EAC) is of particular significance as it brings warm water south along the east coast of Australia from the tropics. The EAC is important for migratory fish species and is therefore also important for fisheries and the industries that depend on them[228]. As a feature of worldwide average ocean temperature increases, the EAC is currently exhibiting signs of intensification (see Box CES9). This intensification of the EAC (also partly caused by ozone depletion)[229] means that warmer water is being brought further south[230]. Projections indicate that the greatest temperature changes in the southern hemisphere will occur in South East Australia and are due to this effect. This change could have a number of effects on marine biodiversity (see *Implications*).

Box CES9 The affect of stratospheric ozone depletion on the East Australian (ocean) Current

Ozone absorbs UV and sunlight. As ozone is depleted, less UV is absorbed, leading to a stratospheric cooling trend which is stronger closer to the south pole. The temperature gradient between this cool air and warmer air generates stronger westerlies near the pole, intensifying the *polar vortex.* This leads to the entire westerly system shifting polewards, intensifying in the high and polar latitudes. As the energy is confined more and more to high latitudes, mid-latitude winds decrease slightly. These wind changes start in the stratosphere, and the maximum changes reach the surface some three months later, in summer, when the EAC happens to be strongest and penetrates furthest to the south.

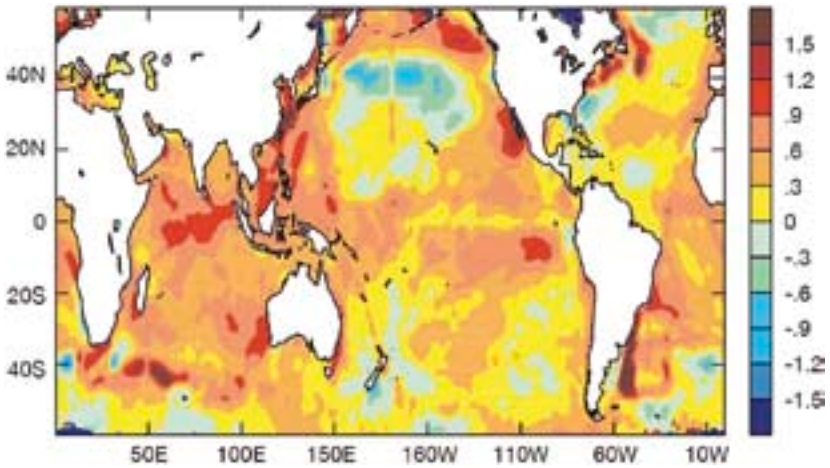
Under historic conditions, the EAC is mostly driven by wind. When winds shift and strengthen polewards due to the changes described above, the EAC also intensifies and shifts polewards[231] (see also Part 4.1 Atmosphere, Stratospheric Ozone).

Altered ocean currents lead to changes in weather patterns. The combination of altered currents, particularly the changing EAC, and sea level rise is likely to have implications for Victorian marine and coastal systems, both human settlements and biodiversity. These are covered in Pressures.

Increasing sea surface temperature

Sea surface temperature increase is also one of the fundamental features of climate change. Worldwide observed sea surface temperature changes range from -0.9°C to +1.5°C over the last 56 years and, on average, show a gradual increase (Figure CES 4.2). However, it is not known whether this observed change is due to greenhouse gas-induced global warming or natural variability resulting from El Niño and the Southern Oscillation Index (see Part 4.1 Atmosphere, Climate Change).

Figure CES4.2 Pattern of observed linear sea surface warming 1950-2006 (°C)
Data source: CSIRO[232]



There has been significant warming in the seas off south-western and south-eastern Australia, the latter associated with changes to the East Australian Current (EAC) (see Altered currents). Under conditions of projected accelerated climate change, sea surface temperatures will further increase, particularly in south east Australia, where projections suggest the greatest change in the southern hemisphere[233].

Globally, one effect of sea surface temperature increase is thermal expansion, a contributing factor in sea level rise (see Sea level rise, and Part 4.1 Atmosphere: Climate Change). More locally, increasing sea surface temperatures have impacts for local weather systems and can affect biodiversity (See Implications).

Pressures

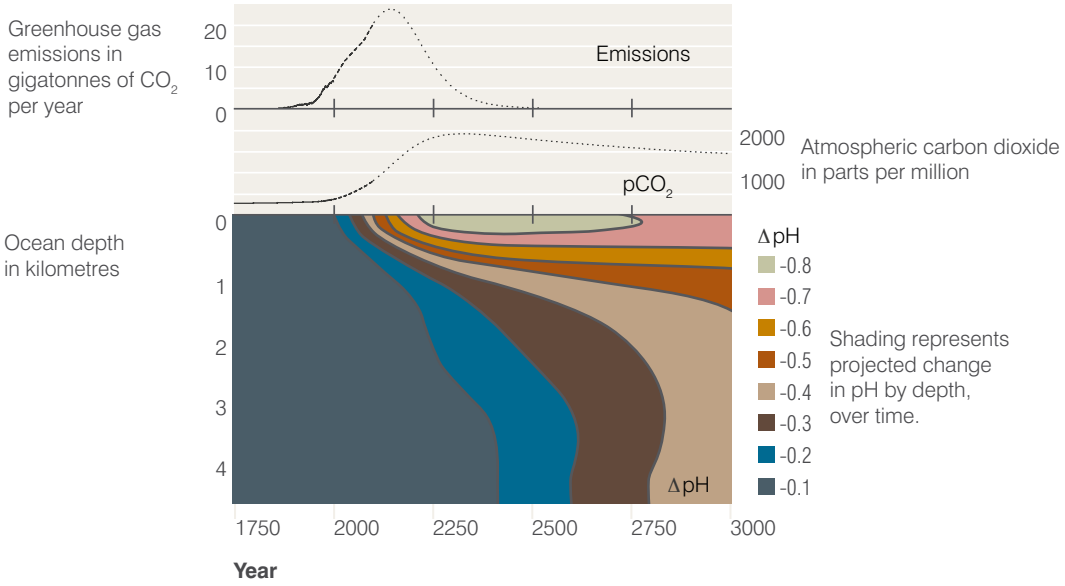
The two characteristics of climate change that are described above, as well as others described in Part 4.1 Atmosphere: Climate Change (for example, increased carbon dioxide concentrations and increasing air temperature), interact to alter natural systems. Ocean acidification, sea level rise and altered weather patterns are three phenomena attributable to climate change that are of significance to Victorian marine and coastal systems.

Ocean acidification

Carbon dioxide is constantly being absorbed by the oceans. This absorption rate increases under conditions of increased atmospheric concentrations of carbon dioxide, up to a point of saturation[234]. It is estimated that the world's oceans have absorbed half of all human-emitted carbon dioxide, providing some buffer from the effect of carbon dioxide on atmospheric temperatures.

Carbon dioxide in the ocean combines with water to create weak carbonic acid. However, as more carbon dioxide is absorbed, the ocean becomes more acidic. For many thousands of years the ocean has had a slightly alkaline pH level of between 8 and 8.3[235]. It is estimated that the average pH of the oceans has dropped 0.1 units in the period 1700-1994 and will drop a further 0.3-0.5 units by 2100, reaching a pH as low as 7.78 at the surface with variation depending upon depth, rates of emission and atmospheric concentrations of carbon dioxide (Figure CES4.3)[236].

Figure CES4.3 Projected greenhouse gas emissions, atmospheric CO2 concentrations and resultant ocean acidification by depth to the year 3000.
Data source: Adapted from Caldeira & Wickett[237]



Although apparently slight, this increase in ocean acidification is sufficient to reduce the availability of aragonite, a form of carbonate from which corals and other marine organisms (such as molluscs) make their shells. The result of ocean acidification could be a decline in populations of such species as well as those that feed on them, leading to a resultant modification of marine ecosystems. This would have flow-on effects, putting pressure on communities that rely on marine environments for tourism, recreation and fishing[238].

It has been suggested that oceanic absorption of anthropogenic carbon dioxide over the next several centuries may lead to a pH decrease greater than that which has occurred during the last 300 million years[239]. It has also been posed that the *effects of increasing atmospheric CO_2 concentrations on the carbonate system in seawater are not reversible on human time scales*[240].

While ocean acidification is a significant issue attributable to anthropogenic carbon dioxide emissions, the capacity of the oceans to continue absorbing carbon dioxide and to provide a buffer against climate change is starting to decrease[241]. This is because other anthropogenic climate change factors (specifically sea surface temperature and stratification, covered below) may reduce the carbon dioxide saturation level of oceans. The full effect of this feedback mechanism is unknown, yet it may have serious implications for climate modelling[242]. This level of uncertainty exemplifies the complex interactions between climate change factors. As the unknown effects of climate change (such as acidification) become apparent and climate models are updated, these factors can significantly alter future climate scenarios. However, it is believed that for many climate change-related issues, to wait for the effects to become apparent would be to allow irreversible damage to occur.

Sea level rise

Increased temperature, itself one of the fundamental characteristics of climate change, leads to sea level rise via thermal expansion of the upper layer of the sea in the short term. In the longer term, increased temperature is also likely to add to sea level rise via the addition of water from melting glacial and polar ice. Due to the complexity of interactions between aspects of climate change, there is significant uncertainty about the extent of glacial and polar melting[243].

Since 1961 there has been a global average sea level rise of approximately 10 cm. However, since 1961 the average rate of increase changed from 1.8 mm per year between 1961 and 1992, to 3.1 mm per year since 1993[244]. The IPCC projects that global sea levels will rise between 18 and 79 cm above the 1990 baseline levels by 2100, and increases on the east coast of Australia may be greater than the global mean sea level rise[245]. Global sea level rise may be higher still if there is significant increase in the melting rate of the ice caps[246]. Sea level rise is now tracking on the upper limit of recent projections, indicating that both existing and new policy must be more responsive to the most recent data[247]. This issue is covered in more detail in Part 4.1 Atmosphere, Climate Change.

Recommendation

* For recommendations regarding mitigation of climate change, see Part 3.1 Energy and Part 4.1 Atmosphere

CES4.1 Ensure that all Victorian coastal and marine climate change policy is continually updated using the best and most recent climate change data, including sea level prediction data and that it accounts for uncertainty.

Oceanic stratification

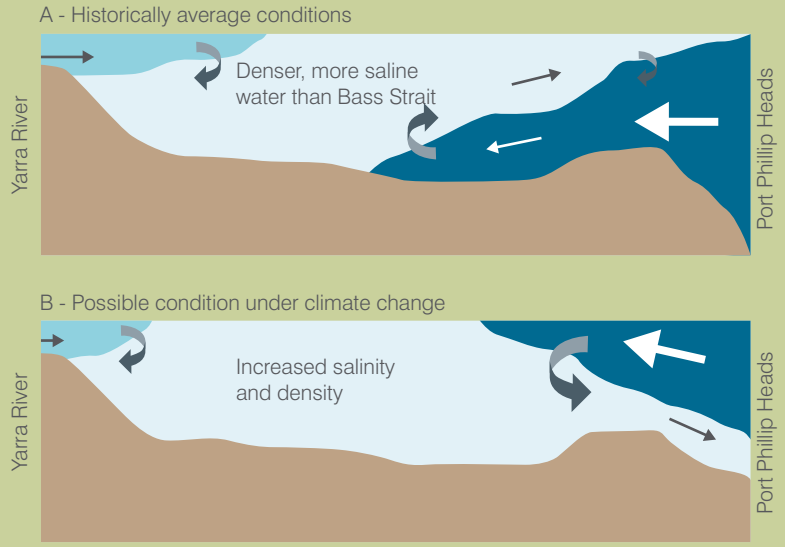
Under historic conditions, as warm surface waters of the EAC that are low in nutrients move south along the east coast of Australia, they cool, sink to depth and are exchanged with deeper water richer in nutrients. This exchange allows water that is depleted of nutrients to be recharged[248].

Under expected conditions of climate change, the warm surface waters of the EAC remain warm for longer, with a reduced density that will slow 'down-welling' and exchange with deep water, creating an intensification of the existing layering effect. This is known as stratification[249]. The main factor in the degree of stratification is water density, which, apart from temperature, is also affected by salinity. In the short to medium term, increasing sea surface temperature will be the primary factor in stratification. However, under conditions of expected climate change, the addition of fresh water (which is less dense than sea water), due to glacial and polar melt, is expected to further contribute to ocean stratification in some regions.

Box CES10 Stratification in Port Phillip Bay

Under historically average conditions, Port Phillip Bay has a slow rate of water flow-through (approximately one year from Yarra mouth to The Heads) driven by a balance of river flow, evaporation and tidal exchange. As a result of enhanced evaporation and reduced river input from the prolonged 1997-2008 drought, the bay is already slightly more saline than Bass Strait. Under the sustained conditions of expected climate change where there are further projected reductions in rainfall and in-flow of fresh water, the bay may become even more saline. Saline water is denser than fresh water, so further increases in the bay's salinity could reduce mixing with the waters of Bass Strait, essentially shutting down flow-through and further increasing salinity in the bay[250].

Figure CES4.4 Historical average conditions of mixing in the bay (A) and mechanism by which possible future effects of climate change on salinity may be affected (B). Note: vertical scale exaggerated
Data source: Adapted from EPA[251]



Altered weather patterns

Climate theory and climate modelling show that increased sea surface temperature and altered currents have an effect on weather. The degree to which Victoria's weather will change is not known, but models predict an increased incidence of severe thunderstorms and local low pressure systems. Features of severe weather include strong winds, with best estimates predicting an increase in wind speed of between 2% and 5% by 2030, and up to 14% in Bass Strait by 2070[252]. While average annual rainfall is predicted to decrease (see Part 4.1 Atmosphere: Climate Change), intense rain events are a feature of altered weather patterns due to climate change, as are increased ocean turbidity and changes to cloud cover. It is likely that the effects of severe weather will be felt mostly on the coast, especially under a scenario of higher sea levels[253]. Severe weather is likely to affect coastal areas via increased turbidity, storm surges and flooding.

Increased turbidity

Turbidity, the level of cloudiness of water due to dissolved organic matter and suspended particulate matter, is a natural state for many marine and estuarine systems. However, as the climate changes, levels of turbidity are likely to increase. High energy events such as tidal currents, storms and large river outflow events (see Part 4.3 Inland Waters) all have the capacity to mobilise fine sediments, leading to increased turbidity[254]. High turbidity results in decreased sunlight reaching phytoplankton, microscopic marine plants, and coastal habitats such as kelp forests and seagrass beds that require it for photosynthesis[255]. As a result, species that feed on these organisms may be impacted. Turbidity can alter fish habitat, thereby affecting breeding and modifying fish assemblages in marine ecosystems. In extreme cases, fisheries and coastal communities that rely on marine species may be affected.

Increased storm surges & flooding

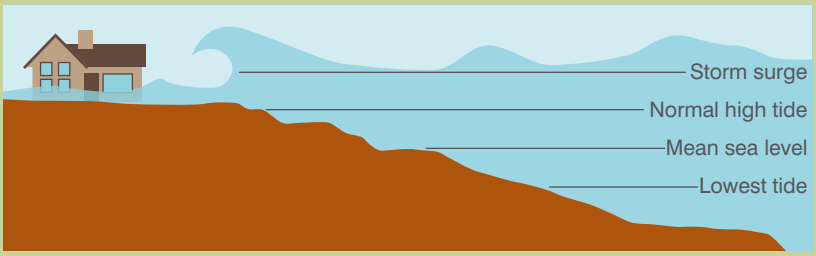
Storm surges and flooding are perhaps the most significant and direct impacts of climate change for coastal ecosystems and settlements and are expected to become more severe under conditions of future climate change[256]. Sea level rise and increased wind speeds are both important contributing factors to the expected increase in storm surge activity attributable to climate change, with sea level rise playing the greater role[257]. The patterns that are most commonly responsible for severe coastal weather in Victoria are cold fronts that move east across Bass Strait. In the east of the state, east coast and southern Tasman Sea low pressure systems can also contribute to severe coastal weather[258].

Storm tides are the combination of storm surge with lunar tides. In Victoria, the highest storm tides occur in Western Port, owing to the greater amplification of storm surges and the high tidal range. The predicted severity of future storm surges varies according to the climate model that is used. In Victoria, the open coast east of Port Philip Bay and Western Port is most at risk due to the higher storm surges that occur along this coastline. By 2070, under conditions of projected worst-case mean sea level rise and projected worst-case increases in average winds, the greatest projected 1 in 100-year storm surge is 2.72 metres above late 20th century mean sea level at Stony Point in Western Port[259]. Smaller storm surges are forecast to occur throughout eastern Victoria, with severity varying according to the type of weather pattern, coastal form and climate change characteristics, particularly sea level rise and wind speed[260]. Several low-lying towns and settlements are at risk, particularly in Eastern Bass Strait, the Gippsland Lakes and Corner Inlet.

Box CES11 Storm Surges

A storm surge is a region of elevated sea level at the coast caused by the combined effect of falling atmospheric pressure and the intense winds of severe weather events, such as local low pressure systems. Storm surges push waves inland, leading to erosion and inundation.

Figure CES4.5 Comparison of storm surge with typical tides
Adapted from CSIRO & Bureau of Meteorology[261] and CSIRO[262].



Falling atmospheric pressure at the centre of a low pressure system increases sea levels by acting like a suction on the ocean surface. The resulting rise in sea level is about 1 cm per hectopascal fall in pressure (the so-called *inverse barometer* effect). Under current climatic conditions, the larger contribution to storm surge is due to wind pushing water against the coast, but in the future sea level rise will play a greater role. Factors influencing the impact of winds on the storm surge include its strength, direction relative to the coast and the way in which the storm moves in relation to the coast. The shape of the sea floor and the proximity to bays, headlands and islands also affect the storm surge height. Wide and gently sloping continental shelves amplify the storm surge, and bays and channels can funnel and increase the storm surge height. Storm surges can interact with other ocean processes such as tides and waves to further increase coastal sea levels and flooding. A storm surge will have maximum impact if it coincides with high tide. The total water levels due to the combination of storm surge with tides are often referred to as storm tides. Breaking waves at the coast can also produce an increase in coastal sea levels, known as *wave setup*.

Implications

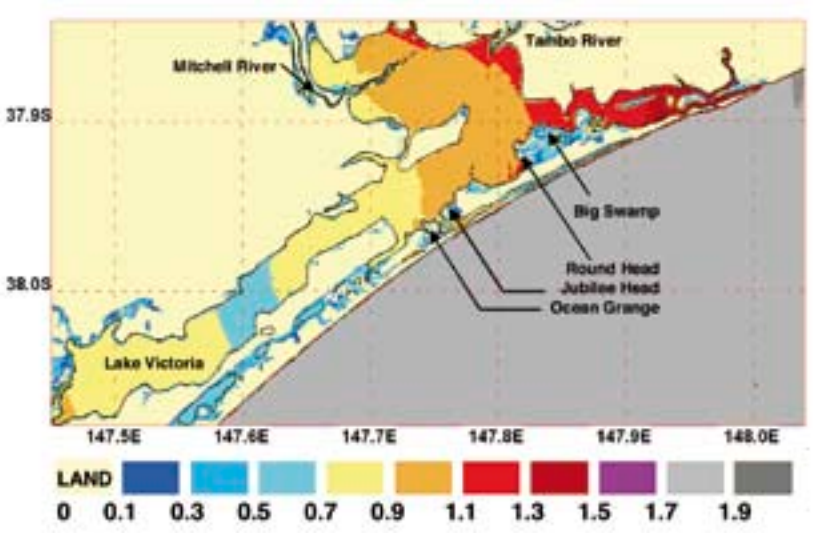
In isolation, each of the above aspects of climate change can have significant implications for coastal, estuarine and marine systems. However, in real scenarios, the interaction between the different aspects of climate change is likely to have compounding effects. For example, the interaction between sea level rise and extreme weather events is likely to increase the incidence and severity of storm surges. For other interactions, however, the effects are largely unknown. The following section looks at some of the conditions under which coastal, estuarine and marine systems are likely to exist in the future as a result of climate change.

Coastal systems

By 2070, under climate change scenarios of high wind speeds and sea level rise, large areas in coastal towns in eastern Victoria as well as the surrounding land are expected to experience inundation during extreme weather events[263]. For example, under the worst case climate scenario for 2070, models show that large magnitude events, which under current climate conditions are anticipated to occur approximately once every 100 years (a '1 in 100-year event'), may occur as often as every five years[264]. Under such conditions, models show that 66 km^2 of land surrounding the Gippsland Lakes will be inundated. Additionally, as a result of storm surges, breaching of the dune barrier that separates the Lakes from the sea could occur. This would result in permanent alteration to the biophysical features of the Lakes, features that currently make it a popular and economically valuable region of Victoria[265]. The extent of inundation around the Gippsland Lakes as a result of a 2070 storm surge is shown in Figure CES4.6.

Inundation risk along the Gippsland coast may be further increased under conditions of land subsidence due to depletion of supporting aquifers, caused by oil and gas extraction. Subsidence of up to 2.3 m has already occurred around the coal mines in the Latrobe Valley (see Part 3.1 Energy), with the potential for further subsidence identified as a risk by the CSIRO[267]. Borehole measurements show that groundwater levels in the Latrobe Group aquifer have been in decline since 1975 and there is some concern that the coastal land surface will subside as a result. Some estimates suggest that parts of the coast could subside by up to 1.2 metres by 2056, but these results are uncertain[268].

Figure CES4.6 Level of likely inundation in metres around the Gippsland Lakes during a 2070, 1 in 100-year stormtide event, under modelled conditions of high wind speed and high mean sea level rise
Data source: CSIRO [266]



In addition, sea water intrusion into freshwater aquifers on the coast has been considered a likely implication of the depletion of inland aquifers such as is occurring to the Latrobe Group[269]. Recent research also suggests that the added climatic effects of storm surges that break natural barriers between marine and freshwater systems and sea level rise are likely to exacerbate this problem[270]. The intrusion of saline sea water into aquifers on the coast will affect coastal communities which currently rely on bore water[271].

Settlements

It is estimated that about 6.0% of Australian addresses are situated within 3 km of shorelines in areas with elevations below 5 m[272]. It is estimated that up to 90% of Victorians live on or within 120 km of the coast[273] and there is a continuing trend toward development in coastal regions (see CES 1 Coastal Modification). An increasing coastal population means that more Victorians and their assets are exposed to the ways in which climate change is affecting the coast.

Damage to buildings and other infrastructure will occur in cases where coastal settlements are not protected from likely storm surges. Both the depth and the pressure of flood waters can damage infrastructure and property, with the extent of damage dependent upon the degree of erosion and the severity of inundation, winds and water retention[274]. The impact of coincident extreme rainfall and storm surges could further exacerbate flooding and have serious implications for settlements. As described above, climate change may also affect the availability of water in coastal settlements if aquifers and rivers become subject to seawater intrusion.

The costs of repairing erosion and damage, of insuring property in vulnerable areas, and of ensuring that services such as fresh water and electricity are maintained is likely to be a significant economic burden on coastal communities[275]. For some existing towns and settlements, particularly those established prior to awareness of the most recent climate projection data, relocation may be the best long-term option (see *Responses*). For coastal towns currently experiencing growth and therefore subject to statutory planning decisions, the absence of clear policy has created uncertainty (See Box CES12). Current and all future coastal urban planning, including provision of emergency services, in areas vulnerable to storm surges and flooding must take into account the likely effects of climate change and associated damaging weather.

Box CES12 Sea level rise and coastal planning - the Toora VCAT case[276]

The township of Toora is located approximately 2.5 kilometres from the coast on the northern side of Corner Inlet in Victoria. In January 2008, the Gippsland Coastal Board successfully sought leave for VCAT to review the South Gippsland Shire Council's decision to grant permits to construct dwellings on each of six small (2-4 hectare) allotments in the Grip Road area, south of Toora. The area is open farmland, in a Farming Zone (FZ). It is low-lying, prone to the effects of a high water table and water-logging and falls under both the Land Subject to Inundation overlay (LSIO) and the Environmental Significance Overlay (ESO3).

Figure CES4.7 Location of Toora in South Gippsland and proximity of the properties under consideration to the township of Toora and the LSIO
Adapted from Department of Planning and Community Development

While a local structure plan has not been developed for Toora, VCAT ruled that approval of such developments in such a location, i.e. outside the existing urban zoned land, would be contrary to the purpose of the Farming Zone. It would reduce the agricultural utility and therefore productivity of farming land in the area and set a precedent for further development, also contrary to the purpose of the Farming Zone.

In addition to these reasons, the process highlighted a gap in definitive policy relating to climate change, specifically sea level rise and the risk of inundation. Due to this gap, VCAT made reference to general precautionary principles, as stipulated under Section 60 of *The Planning and Environment Act (1987):*

60(1) Before deciding on an application, the responsible authority must consider -

(e) any significant effects which the responsible authority considers the use or development may have on the environment or *which the responsible authority considers the environment may have on the use or development* (VCAT's emphasis) [277].

In doing so, VCAT also referred to a 2006 CSIRO report[278] on climate change and sea level rise. While explicitly not adopting the findings of this report, VCAT determined that the additional risk of inundation from sea level rise and coastal subsidence was also grounds to refuse the applications.

The case sets an important precedent for decisions on coastal development and climate change, but also highlights the need for the policy gap to be filled. In the absence of clear guidance from the State, local councils are applying planning assessment criteria on a case-by-case basis, devising their own climate change considerations. So far there has been inconsistency of application across Victoria, and questions have been raised over the level of responsibility being taken on by local governments.

Recommendations

CES4.2 Ensure that all new and upgraded coastal infrastructure is resilient to a modelled 2070 1-in-100-year (or similar appropriate engineering standard) storm event, using the most recent sea level and storm surge projections.

CES4.3 Ensure that coastal land use and community planning is performed with consideration to the long term impacts of climate change and in consultation with all relevant service providers, including local councils and emergency services.

CES4.4 Government should provide guidelines and regional projections using the most recent sea level and storm surge projections, with due consideration for the precautionary principle, and incorporate these into the Victorian Planning Provisions, to assist local governments to make more informed planning decisions on coastal land subject to the impacts of climate change, and to provide the community with greater certainty in regard to these matters.

Coastal biodiversity

Because of the trend towards coastal development (See Part 2 Driving Forces), as well as other factors such as altered fire regimes and pests, many natural coastal systems are already under threat. Climate change represents an additional threat to coastal ecosystems. Coastal and estuarine ecosystems could adapt to changing conditions, particularly sea level rise, by moving inland or laterally. However, in conjunction with the added pressure of urban development and other land uses adjacent to the coast, many coastal ecosystems may be 'squeezed out' and eliminated altogether[279] (see also Part 4.2 Land and Biodiversity). This of particular concern for Victoria, as its east-west coastline prevents polewards migration.

The nature of coastal regions means that there is often a high level of biological diversity within a small area. In some cases, ecological vegetation classes (EVCs) that provide habitat for rare and endangered animals occupy small areas in close proximity to other EVCs and to areas of human settlement. Of over 300 EVCs in Victoria, many are found in coastal bioregions, and of these, a large proportion is endangered or vulnerable[280].

Table CES4.1 Conservation status of coastal* EVCs by bioregion in Victoria
Data source: DSE

Condition	Number
Endangered	35
Vulnerable	39
Depleted	16
Rare	17
Least concern	10
Total	117

For example, of 103 EVCs in the greater East Gippsland region, 59 are vulnerable, rare or endangered and 13 of these are affiliated with coastal or estuarine environments[281]. Without comprehensive intervention, coastal recession attributable to a long-term sea level rise of one metre or higher will eliminate many of these ecosystems entirely.

In the short term, these coastal ecosystems are also vulnerable to storm surges and other coastal expressions of intensifying weather, just as are coastal human settlements. Erosion during storm surges can remove stretches of beach and alter the conditions upon which coastal EVCs depend. For example, in the Gippsland Lakes region there is the potential for rising sea levels to increase rates of erosion along the Ninety Mile Beach, which could eventually lead to breaches in the barrier separating the Lakes from the sea[282].

As with settlements, the impact of coincident extreme rainfall with storm surges could further exacerbate flooding and have serious implications for coastal biodiversity, particularly in estuarine systems. Sediment transport and deposition following heavy rainfall can smother extensive areas of estuarine habitat, killing plants and resulting in loss of breeding habitat essential to many coastal fish and bird species[283]. Within the context of existing pressures on marine fauna populations (see CES 3 Marine Biodiversity), there are likely to be impacts on commercially important coastal fisheries, although the economic impacts are unclear.

Recommendation

CES4.5 That government continue to fund research on the likely implications of climate change for coastal and estuarine biodiversity, and that coastal policy decisions take into account the expected impacts and their relative regions of influence.

Marine systems

Marine biodiversity

Due to its tourism and other economic implications, coral bleaching, predominantly an issue for tropical coastal regions, is the best known effect of climate change on marine biodiversity. However, ocean and atmospheric temperature increases are also expected to have as significant an impact on the distribution and abundance of temperate and polar marine species. In particular, the implications for marine biodiversity in Victorian temperate waters are significant[284] and are likely to have a flow-on effect for coastal industries and fisheries. These include:

Altered distribution: For some species, particularly those that are highly mobile, adaptation to a changing climate is an option. As habitats shift southwards with warming temperatures, southerly migration has been observed in certain species of seabirds and marine mammals.

Shifting ocean ecology: Plankton, the microscopic marine organisms upon which much of the life of the oceans depends, is highly sensitive to temperature and nutrient changes. Shifting oceanic temperatures and other effects such as stratification can modify oceanic conditions under which these organisms have evolved. Species that are adaptable to different combinations of conditions exist, and population shifts in response to changing climate may occur. However, such shifts could bring about other effects, such as changes in populations of larger marine mammals that feed on plankton.

Impacts on population dynamics: The range of the Long-spined Sea Urchin (*Centrostephanus rodgersii*), for example, has extended further south into Tasmanian waters as a result of the increased intensity of the EAC. The urchin feeds on kelp and other seaweeds that are also home to the valuable abalone and rock lobster fisheries. In its new extended range, the urchin feeds unchecked and has formed extensive seaweed-free areas or 'barrens'. This may have an impact on local fisheries and their associated industries[285] (see also CES3 Marine Biodiversity).

A tightening of habitats suitable for certain species: Species that rely on particular combinations of conditions, such as corals, mangroves, kelp and fishes, may be at risk. Corals, many of which rely on a limited temperature range and a rocky substrate upon which to fasten, may be unable to extend their range southwards as their northern extent recedes. In effect, their range may be squeezed between increasing temperature to the north and habitat which is unsuitable for other reasons in the south.

An increase in the incidence and range of diseases: As the temperature of marine animals' habitats increases, temperature-related physiological stress can reduce the effectiveness of the immune response. There is also a strong likelihood that with shifts in warmer ocean temperatures polewards, specifically the EAC, the geographic range of tropical disease and tropical toxic algal bloom species may also shift.

These examples make up a small proportion of all the changes to coastal and marine biodiversity that it has been postulated may occur under climate change scenarios. Other effects are also likely to occur, but the full extent of effects is unknown. Again, this illustrates the considerable uncertainty due to the complexity of biophysical interactions associated with climate change.

Recommendation

CES4.6 That government continue to fund research on the likely implications of climate change for marine biodiversity, assess adaptation capacity and make marine policy decisions that take into account the expected impacts.

Management responses

Response Name:
Climate Change Implications for the Gippsland coast

Responsible Authority:
Gippsland Coastal Board (GCB)

Response Type:
Process

In 2003, the Gippsland Coastal Board (GCB) initiated a two-phase study of the effect of sea level rise on the Gippsland coast in partnership with the CSIRO and with funding from the National Heritage Trust. Phases 1 of the project was completed in 2006 and involved identifying some of the key factors influencing climate and weather events along the Gippsland coast[286].

The study predicted more frequent and more extreme storm events for the Gippsland coast and identified a range of sea level rise implications (see Figure CES4.6). The Gippsland Coastal Board has now completed Phase 2 which examines the vulnerabilities of human and natural assets along the Gippsland coast[287].

This study has provided Government agencies and the Gippsland community with a better understanding of the vulnerability of the Victorian coastal and marine environment to the effects of climate change at a local level. The methods initiated by the GCB and used by CSIRO to develop sea level rise and storm surge predictions set an important precedent and are now being applied in the *Future Coasts* project (below) across the entire Victorian coast.

Response Name:
Future Coasts

Responsible Authority:
Department of Sustainability and Environment

Response Type:
Process

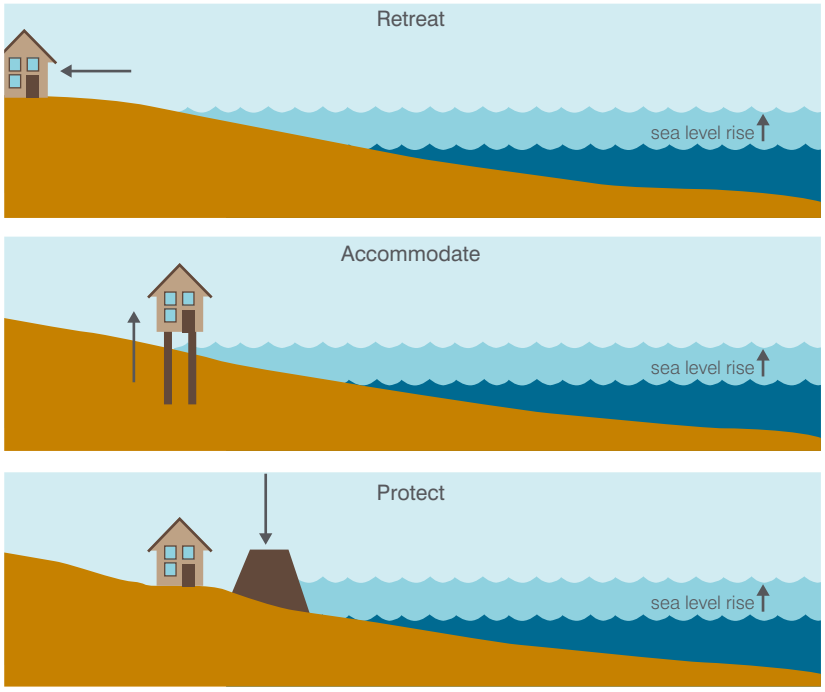
The *Future Coasts* project was initiated under the climate change actions outlined in *Our Environment, Our Future* (see Part 4.2 Land & Biodiversity). *Future Coasts* will assess the vulnerability of Victoria's coastline to climate change and develop strategies and planning tools for local government and coastal managers.

Stage 1 of the project involves collecting the quantitative information required to assess risks to the coastal environment, communities and infrastructure from climate change. This involves using an airborne laser system to capture a high resolution Digital Elevation Model (DEM) of Victoria's entire coastline[288]. Two thirds of the terrestrial coast has been captured, with the seafloor mapping (bathymetric DEM) to follow once the terrestrial mapping is complete[289]. The DEM will map the coastal terrain 10 metres above and the seafloor 10 metres below sea level to very high resolution, a level and scale never previously achieved along the Australian coast.

In the 2008-09 State Budget, $8 million was allocated to *Future Coasts* to complete Stage 1 of the project. An additional $1.8 million was allocated to develop a coastal asset management database for all public assets along the Victorian coast (i.e. local port infrastructure, seawalls, groynes)[290]. This initiative will provide valuable information to incorporate in the *Future Coasts* project and provide greater clarity concerning the vulnerability of coastal infrastructure to the impacts of climate change.

Stage 2 of the *Future Coasts* project involves using projected sea levels and weather patterns to develop wave and coastal processes modelling and assessing the erodibility of the coastline. These outputs will be combined with the coastal terrain and seafloor mapping to determine the vulnerability of the coastline. Stage 2 will also start to look at adaptation options, such as *retreat, accommodation and protection* (see Figure CES 4.8). Stage 2 is not expected to be complete before the end of 2009. It is likely that *Future Coasts* will require a higher level of government funding, depending upon these findings and on the most recent sea level projection data.

Figure CES 4.8 Responses to rising sea levels: retreating, accommodating or protecting.



Evaluation of climate change responses

Dealing with the impacts of climate change presents one of the biggest challenges for the future management of Victoria's coastal and marine environment. As a first world country, Australia has a leading role to play internationally in mitigating climate change by reducing emissions (see Part 3.1 Energy & Part 4.1 Atmosphere, Climate Change). However, atmospheric temperature and sea level rises are now tracking to the higher limit of recent IPCC projections and so the implementation of local adaptive strategies is also urgent. Reducing the vulnerability of Victoria's coast to the sea level rise and increasing numbers of storm surges is a high priority. In order to do this, it is vital that local and regional information is gathered and used to aid robust adaptation. The *Future Coasts* project has the potential to be an important initiative for enabling localised responses to climate change, provided that it is well funded and uses the best and most recent data.

Modelling the effects of climate change on a local and regional scale is an important priority for the State Government. However, it is now vital to begin development of new policies and programs that focus on coastal resilience to climate change at a more regional and integrated level. The *Victorian Coastal Strategy* 2007 provides a number of new actions to better understand and adapt to climate change in the coastal and marine environment and these should be adopted and implemented by government. *Future Coasts* will also develop some strategies and decision support tools which will underpin the process of adaptation, but this work is unlikely to be completed before the *Victorian Coastal Strategy* is revised in late 2008. Therefore, given the fact that new information on the rate of climate change continues to become available, it is important that the planning tools now available are used to plan for the likely upper limit of climate change scenarios. Where there is immediate need for planning certainty, the use of interim tools should also be considered.

Recommendations

CES4.7 Ensure that the Victorian Coastal Strategy provides clear policy to address the coastal impacts of climate change.

CES4.8 Continue the implementation of the Future Coasts project with appropriate resource and funding support to ensure adaptation measures can be implemented along the Victorian coast. Update the Victorian Coastal Strategy as outcomes of the Future Coasts project become known.

At a local level, further work and financial support is required to develop specific adaptation responses and strategies by a range of agencies and decision makers (i.e. local government, Coastal Committees of Management). The Future Coasts project is anticipated to provide valuable information to identify specific areas of risk along the Victorian coast, but the urgency of this threat to the Victorian coast means that in some instances regional and local action will need to occur now. Appropriate targets and monitoring requirements should be considered to ensure the adaptation strategies are appropriate.

Recommendation

CES4.9 Ensure mechanisms are established to provide information to local governments to assist in planning decisions that may be impacted by climate change on the coast.

For further information

Gippsland Coastal Board
http://www.gcb.vic.gov.au/

Land use Planning
http://www.dse.vic.gov.au/dse/nrenpl.nsf/Home+Page/DSE+Planning~Home+Page?open

Sea level rise models for Lakes Entrance
http://sahultime.monash.edu.au/LakesEntrance/