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Conceptual Models for Victorian Ecosystems: Marine and Estuarine Ecosystems

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Conceptual Models for Victorian Ecosystems:

Marine and Estuarine Ecosystems

J.B. Pocklington, J.M. Carey, M.D.T. Murshed & S.A. Howe

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EXECUTIVE SUMMARY

This Marine Conceptual Framework is an appendix to the Pilot program that developed Conceptual models for Victorian grassland systems (White, 2009). It was identified in the pilot program that it is difficult to conceptualise natural ecosystems and that the information on them is fragmented across a range of sources for different purposes and not well integrated; which is essential for making park management decisions (White, 2009). The Marine Conceptual Framework examines the drivers, threats, and management options relevant to Victorian Marine National Parks and Marine Sanctuaries priority values by integrating the available relevant information into conceptual models and maps. Many of the components identified within habitats are common to all marine habitats investigated. Therefore a general marine habitat model and map are given which should be used as the first step in identifying management responses to particular threats. In addition to the general marine habitat, it was decided that conceptual models would be developed for each habitat for a number of reasons: 1) It is more manageable as a resource, allowing us to ‘divide’ up the marine environment into meaningful units to allow inclusion of a greater level of detail than would be possible for the general marine model (while many components for each habitat overlap with those for other habitats there will be some natural assets, threats and drivers that are more or less unique to a given habitat), 2) habitats are things that people can understand and relate to (important for a target audience of park managers that may have different levels of background knowledge and training), 3) the current monitoring program for Marine National Parks and Marine Sanctuaries is currently habitat based. The habitats that are included in this marine conceptual framework include: Seagrass, Mangroves & Saltmarsh, Water Column, Soft Sediments, Estuaries, Subtidal Reefs and Intertidal Reefs. Both intertidal rocky shores and subtidal rocky shores conceptual maps and models are refined from Murshed (2010). Many of the natural assets, indicators and threats included in this marine conceptual framework were the result of a workshop with marine habitat experts (PV, 2011) and this report was compiled using the knowledge of the author and relevant literature including peer-reviewed scientific papers and technical reports. The marine conceptual models and maps can be used by Parks Victoria (PV) management staff, and as a way to illustrate decision making in the management of marine protected areas.

CONTENTS

1. CONCEPTUAL MODELS FOR MARINE ECOSYSTEMS OF VICTORIA

Conceptual models of marine ecosystems of Victoria have been developed for individual habitat types. This allows the marine environment to be split into more meaningful, understandable and manageable units to allow a greater level of detail to be incorporated than would be possible for an overarching model. The current PV monitoring program is currently habitat based so current knowledge will easily be incorporated into these habitat models. Many of the habitats included in this conceptual framework are not discrete in nature for example Saltmarsh and Mangrove habitats are often found together with Saltmarsh occupying the landward coastal edge and Mangroves occupying the seaward coastal edge. Many species use both habitats (e.g. birds roosting and or feeding) interchangeably. Another example of habitats that are not discrete is seagrass beds. Seagrass beds occupy both intertidal and subtidal soft-sediment habitats but due to their importance as ecosystem engineers (modifying conditions and resources for use by other species) they are considered separately in this report to provide simplification (e.g. Mangroves and Saltmarsh).

Conceptual Maps and Models have been created after a literature review on all habitats. The variables included in the models and maps follow those used by A. White in Grassland Concept Frameworks for PV (White, 2009). The definitions of all variables common to all habitats are given first and then each habitat is discussed with relevant models and maps and the definitions of each variable specific to each habitat are given. There may be some repetition for definition of variables, however in many cases the definition of the same variable may differ for different habitats. For example the driver ‘sediment transport’ in a rocky shore habitat is different to ‘sediment transport’ in a seagrass habitat so the specific details will be given for where it differs from the general definition. The literature consulted to develop frameworks for each habitat is listed at the end of this document.

Definitions (amended from White, 2009)

Drivers: The things that determine the distribution of habitats, and the main factors that act in these systems to influence their state or condition e.g. hydrodynamics.

Threat agents: The past and present activities (and other factors) that influence ecosystem structure, function, state or condition e.g. poaching

Threatening processes: The process through which the threats influence system structure, function and state, or condition e.g. species loss and/or population decline as a consequence of poaching

Management responses: Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes. Three management types are given – Active, Mixed and Collaborative/Advisory. Active refers to direct management actions/response undertaken by (and the responsibility of) PV. Mixed refers to management that includes direct action from PV in addition to direct action by other agencies (e.g. DSE, EPA), or as a support to other agencies. Collaborative/advisory management is where PV can take an advisory role (e.g. for planning applications that impact on the marine environment) or assist other agencies indirectly (e.g. contacting relevant agency if a threat is observed/advised to staff by member of the public).

Resulting habitat structure & Indicators: The habitat structure that results from the combination of threats and drivers acting on a system and management responses:

- Includes important habitat components (descriptive), e.g. canopy layer, understorey, benthos cover
- Indicators are given to highlight the sorts of things that we could monitor in order to make an assessment of condition or state of a system.

Natural Assets: PV-defined (PV, 2011) are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect. These overlap with the resulting habitat structure and indicators so are placed within the same layer in the habitat maps.

Conceptual maps: These models include the six layers Drivers, Management Response, Threat Agent, Threatening Process, Habitat Values and Priority Values (as defined above). Each layer contains a number of variables, which make up components of each layer and are taken from the literature on each habitat. The variables within each component are further defined in this report within both the ‘definition common to all habitats section’; and under each habitat where the variable is specific to that habitat.

Conceptual models: These maps have the same components as for the conceptual models, but with links between components to indicate causal relationships. This captures important interactions as we understand them, but does not indicate if the relationship is positive or negative (although strength or nature of the interaction may be explained in accompanying text).

1.1. Overarching management relevant to this conceptual framework

These factors should be kept in mind while undertaking any management and are a tier above the management described in the conceptual frameworks:

Collaborative management

Collaboration with other agencies is often essential to successful management outcomes. This can include information sharing, training workshops, compliance arrangements, general updates, emergency response (e.g. cetacean stranding, marine pollution), catchment management and collaborative projects such as pest removal (e.g. Apollo Bay *Undaria pinnatifida* removal 2010). Agencies include but are not limited to: EPA, DSE, DPI, CMAs, Melbourne Water, Department of Transport, Local Councils, and Committees of Management.

Rigorous risk assessment/modelling

Parks Victoria should keep up to date with proposed works, activities and threats in and affecting the marine environment in areas adjacent protected areas. Marine waters are continuous, so what is carried out in non-protected waters can still have influence protected waters. Examples of this include the construction of jetties and marina’s (altering sediment movement and water flow), dredging (altering turbidity), waste water discharges (potential for toxicity to spread via food web), improvements of litter capture/water quality. PV should be engaged where appropriate in assessing relevant activities and proposals to ensure appropriate risk assessment and modelling is undertaken to incorporate any potential threats or improvements to marine protected areas.

Parks Victoria’s management of its protected area estate is now progressing towards an asset-led approach that sits within a new Adaptive Management Framework. This framework provides logical steps and a range of tools to guide the effective implementation and evaluation of conservation projects. It will assist staff in maximizing the effectiveness and efficiency of projects for maximum conservation gain and most importantly enables a clearer connection to be made between desired conservation outcomes and actions on the ground. As part of this process, PV is more clearly defining its conservation intent for the priority natural assets identified for the parks and reserves, establishing additional objectives for the mitigation of threats to those assets, and developing management and monitoring strategies based on the above objectives. As this process progresses there may be minor amendments to the natural assets, threats and indicators in the conceptual models. Parks Victoria will need to incorporate these changes as part of ongoing work to ensure conceptual models are current and up to date.

1.2. How to use the models and maps

The models and maps can be used where detailed understanding of marine habitats and how particular threats impact them is required.

- The first step is to consult the general marine habitats map which may provide the detail you require, if you want information on a particular habitat you can consult that map first.
- If you want to know the impact of a threat (e.g. litter) find the threat layer in the map.
- Once you have found the threat layer find the appropriate threat (e.g. pollution which includes litter) which will have an accompanying definition if you are unsure if you have found the right threat.
- Next consult the model which uses the same colour codes as in the map to find the threat you are after (e.g. pollution).
- The arrows linked to that box will show the consequences of the threat (threatening process e.g. decline in species health, population decline, loss of species) and the management actions (e.g. community awareness, enforcement/compliance with regulations).
- Knowing the consequences of certain threats can be useful for planning, monitoring (including indicators), prioritising and carrying out management actions (including seasonal management).
- In the conceptual model each variable may be linked to multiple layers including drivers, multiple management options or threatening processes resulting from one threat agent.
- Only the drivers that link to threat agents are linked in the conceptual model, they are provided to illustrate the importance of natural processes on values.
- The accompanying definitions for all the variables within a marine habitat conceptual map/model cite relevant literature (including PV Technical Series) and often explain the links between variables; these sources should be consulted where required.

These models should be used in combination with PV Marine Management Plans.

Note: The Drivers in the models are not linked unless they directly impact a threat e.g. Hydrodynamics can impact the spread of an oil/chemical spill, history of use can impact the incidence of pests, climate change impacts.

2. GENERAL MARINE ECOSYSTEMS (All Habitats)

Victoria's temperate marine environment consists of seven key habitats: Intertidal rocky reefs, subtidal rocky reefs, soft sediments, seagrasses, water column (pelagic), mangroves & saltmarsh (fringing marshes), and estuaries (see Edgar, 2001 for a general introduction on all these habitat types). These habitats were defined from both physical and biological properties following national classification schemes with revisions to describe local level habitats (PV, 2006f). All of these habitats are represented in Victoria's Marine National Parks and Sanctuaries, therefore understanding the way these habitats persist, the values they consist of, and the threats that impact on their function is important for effective management. This conceptual framework simplifies key Victorian marine habitats which are highly complex, to aid management staff in applying appropriate and timely management response, as well as aiding in communication.

2.1. Definitions for General Marine Ecosystem Models and Maps

2.1.1. Drivers

The things that determine the distribution of habitats, and the main factors that act in these systems to influence their state or condition.

Climate

Includes seasonality (Gibbs et al., 1986, Caffey, 1985), rainfall, sea and land temperature, and other meteorological processes. Climate also refers to oceanic-atmospheric climatic patterns of El Nino and La Nina which alter weather conditions over a prolonged period usually resulting in either drought or flood (respectively). El Nino and La Nina can last years and coincide with the shorter-term seasonal cycle (Autumn, Winter, Spring, Summer). Consequences to the marine environment can include increased terrestrial run off in a La Nina cycle, and low freshwater input during El Nino (Lowthion, 1974). In addition to these 'natural' fluctuations in climate, climate change (Whetton et al., 2001) is also included within this variable (indicated as a threat by the red border in the conceptual maps). Climate change can threaten marine habitats through increased storm frequency, increased water and atmospheric temperature, sea level rise, and ocean acidification (as a consequence of carbon pollution, see Brown, 1987, Whetton et al., 2001).

Geology

Includes all sediments and physical substratum such as rock, sand, and mud. The geology of a particular place can impact the habitat both through its physical (e.g. rugosity) and chemical structure (e.g. minerals).

Water quality: Water quality is both a driver and a value in marine ecosystems. As a driver water quality includes salinity, dissolved gases (e.g. oxygen, nitrogen), elemental composition (e.g. nutrients), density and pH (Lowthion, 1974, Gibbs et al., 1986).

Sediment transport

The transport of sediments through the water column by wave action and currents. In the intertidal area sediment can be transported by wind movement during low tide (Denny and Wethey, 2001).

History of use

This variable describes how the area was used prior to current use. This can include the time since protection from fishing or access, whether mining or dredging was carried out, previous fishing pressure, and the risk or incidence of pests or disease due to prior use. Areas with different prior histories may need to be managed differently for conservation outcomes (e.g. recovery period may be longer, some species may be locally lost or rare).

Hydrodynamics

This includes water flow through waves, currents and tides (Denny and Wethey, 2001).

Bathymetry

This includes seafloor topography and depth (Guichard and Bourget, 1998). The bathymetry of many of Victoria’s MPAs has been mapped using multibeam sonar (Ward and Young, 1982) and more recently, gaps in bathymetry in shallow areas of the MPAs have been filled through DSE’s state-wide Future Coasts LiDAR (airborne laser) mapping project (Roberts et al., 2008).

2.1.2. Management

Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes. Three management types are given – Active, Mixed and Collaborative/Advisory

Three types of management have been separated here to allow managers to understand their role in management of a particular threat: Active management, Mixed management and Collaborative management:

- Active management refers to management falling within PV’s direct responsibilities;
- Mixed management includes management that can be done actively by PV staff which will also require work by other agencies; and
- Collaborative management is management undertaken by other agencies where PV may assist through advice and information sharing.

Many aspects of marine management (e.g. within monitoring and research) are also discussed in : Fairweather (1991b); Groffman et. al.(2006) ; Lundquist & Granek (2005), Taylor (2007), Underwood (1995c), and Zann (1995).

Active Management

Refers to direct management actions/response undertaken by PV (and the responsibility of)

For general active management literature see Parks VIC (2003c) and Westcott (2006).

Education & Community awareness

Education can be undertaken by PV staff, contractors and other agencies. Education needs to be accurate, consistent, up to date, and delivered in a manner that is audience appropriate. Education incorporates communication of regulations and cultivating respect and interest in the marine environment. Education can for example include signs, verbal (general interaction with public, organised talks) and written (reports, flyers) communication. Parks Victoria can work in collaboration with friends groups, councils, educational institutions and others to achieve wide reaching education. Engaging the community to be aware of the threats and values of the marine ecosystem is crucial in ensuring continued interest and investment in marine protected areas (Scales, 2006, Alcock, 1991, Blayney and Westcott, 2004, Alcock and Zann, 1996, Alessa et al., 2003, De Young, 1993, Dwyer et al., 1993, Floyd et al., 1997, see Jelinek, 1990, Leigh, 2005, Goffredo et al., 2004, Howe, 2001, Micheli et al., 2004).

Visitor management

Visitor management includes compliance, education, and community liaison in conjunction with knowledge of visitor behaviour such as peak visitation periods. For example during peak periods of visitation on –ground staff can be increased.

Exclusion zones

This includes enforcing current exclusion zones (e.g. sail only area in Swan Bay, (PV, 2006e) and activities (e.g. driving jet skis too close to cetaceans) within Marine National Parks and Sanctuaries. Short-term exclusion zones may also be desirable in response to emerging threats (in collaboration with relevant authorities). An example includes trampling prevention on intertidal reefs (Taylor, 2007). Maintenance/inspection of signs, navigational markers and fencing/bollards/gates are a significant part of maintaining exclusion zones (PV, 2003b).

Mixed Management

Includes direct action from PV in addition to direct action by other agencies (e.g. DSE, DPI, EPA), or as a support to other agencies

Pest & Pathogen management

Pest and Pathogen management includes investigating reports of outbreaks, reducing activities that increase the threat of pest/pathogen spread (through education/enforcement), and working with other agencies (e.g. DSE, DPI) who monitor and detect emerging pest and pathogen related threats and to lessen impacts to ecosystems through containment/removal of threat where possible. Liaison with agencies managing nearby waters is essential to reducing threat of pest and pathogen spread.

Enforcement/Compliance with regulations

Surveillance of human activities and imposing penalties (in partnership with Fisheries in terms of poaching, and EPA in terms of pollution) to enforce regulations including poaching, fossicking, dog access on beaches, vehicle access, anchoring, dumping of rubbish. It is important for PV to communicate with other agencies and be informed of breeches of regulation occurring in nearby waters (e.g. illegal edge fishing of rock lobster, Carey et al., 2007b) which may impact upon the values of MPAs (especially important when examining monitoring results).

Detect emerging threats

Emerging threats and issues can be identified through appropriate surveillance and monitoring undertaken by PV directly (through contractors, PV staff, Sea Search) and in partnership with other agencies such as EPA, DSE, Melbourne Water, CMAs and community partners such as Reefwatch Vic/Reef Life Survey etc. Surveillance and monitoring techniques, analysis, modelling and reporting should be kept up to date and reflect best current practice by amending as necessary (see also overarching management) in consultation with experts) with clear objectives for conservation outcomes. Detection of emerging threats is currently also addressed by filling knowledge gaps through The Research Partners Panel Programs to continually improve the identification and mitigation of threats to conservation values (for additional reading on conservation values see Constable, 1991, Gerber et al., 2005, Gray and Jensen, 1993, Keough and Quinn, 1991, Underwood, 1995b, Fairweather, 1990a).

Collaborative/Advisory Management

Where PV can take an advisory role (e.g. for planning applications that impact on the marine environment) or assist other agencies indirectly (e.g. contacting relevant agency if a threat is observed/advised to staff by member of the public)

Collaborating agencies include: DSE, DPI, Coastal Board, Catchment Management Authorities, Environmental Protection Authority, Department of Transport, Melbourne Water, Tourism Victoria, Minerals and Petroleum Victoria, Councils.

Stormwater management

Work with and share information with councils, Melbourne Water, and other relevant agencies on reducing impacts to the marine environment through better stormwater management (PV, 2006e), for example sharing information about the effects of litter on marine biota.

Catchment management

Work with and share information with CMAs and relevant agencies to improve catchment management (Poore, 1982), and reduce the impacts of land based activities on the MPAs such as nutrient inputs, sedimentation, herbicide, and pesticide input etc. (PV, 2006e). Examples include: revegetating riparian zones to reduce erosion and sediment run-off; improving riverine systems to enable successful migration of fish that spend part of their life in rivers and the marine environment (see Hindell et al., 2008). Where NPs exist in the catchment PV can take more active catchment management e.g. rehabilitating riparian zones.

2.1.3. Threat Agent

The past and present activities (and other factors) that influence ecosystem structure, function, state or condition

For a general review of threats to Victorian marine habitats see Carey et al. (2007a, 2007b).

Pollution

This threat agent includes rubbish, waste (Brown et al., 1990, Burridge et al., 1996), toxicants (Addison et al., 2008a), oil/chemical spills, atmospheric fallout, and carbon pollution. These may enter the marine environment through a range of sources both within and outside the marine protected area such as discarded fishing line/nets, and litter (e.g. via stormwater). Pollution can result in a range of consequences as given in threatening processes including reduced growth/function, habitat loss, poor reproductive output, species loss/population decline and disruption of food web/species interactions (Bishop et al., 1992, Goessler et al., 1997).

Adjacent land and water use

What happens outside marine protected areas in many cases directly influences marine protected areas. This can include dredging, construction, terrestrial run-off, land fill, spoil, stock grazing, and removal of mangroves (among others). These threatening agents can result in a multitude of threatening processes within a marine protected area (as shown by the links in Figure 2, page 8)(see DSE, 2009, Raventos et al., 2006, Bishop et al., 1992).

Disease vectors

This variable includes infected species, which may enter the marine protected area through unwashed boat/personal water craft traffic (diseased species fouling boats), ballast water discharges (both domestic and international shipping), discarded bait/fishing gear, aquaculture, unwashed dive/snorkelling equipment, and through natural species movement (adults, propagules/larvae). Proximity to commercial fisheries/aquaculture/water exchange and an understanding of their procedures to prevent any escape of disease vectors from their facilities and knowledge of their response measures to any outbreaks should be maintained through good communication channels.

Pest adults/juveniles/larvae/propagules

Pest larvae and propagules can be spread by a number of mechanisms including: natural species movement, boating/water craft (fouling), fishing/recreational equipment, ballast water discharges (both domestic and international shipping), aquaculture, aquarium escapes (e.g. letting pets ‘free’). Proximity to commercial fisheries/aquaculture/water exchange and an understanding of the procedures these facilities have in place to prevent any escape of pest larvae/propagules from their facilities and knowledge of their response measures to any outbreaks should be maintained through good communication channels.

Recreation

Some recreational activities can result in a detriment to marine protected areas. Trampling (Brosnan and Crumrine, 1994, Brown and Taylor, 1999) and fossicking can damage sediments and injure/displace species. Recreation involving water craft (e.g. jet skis) and walking of dogs on beaches can be especially disturbing to the marine environment for example through disturbing important shorebird populations or breeding sites and fish feeding behaviour (noise is a major disturbance). Propeller scarring in shallow areas can also cause physical damage to sensitive habitats such as seagrass (pest/disease vector/spread is covered above separately) (for further reading on recreational impacts see Boden and Ovington, 1973, Carlson and Godfrey, 1989, Castilla, 1999, Kavallinis and Pizam, 1994, Kenchington, 1993a, Liddle, 1991). .

Lack of awareness

Lack of awareness is a social threat that can directly impact on the health of the marine environment. One of the most important of these is people not knowing where marine protected areas are and what activities are and are not permitted in parks, as well as the impacts of some activities on natural values. In addition to this, understanding how to look after recreational equipment (e.g. improper hygiene can contribute to marine pest/pathogen spread) and behaving in ways that won't disturb the marine environment are central to reducing threats in marine protected areas. Awareness is important in terms of the public understanding the services provided by the marine environment, understanding how important a healthy marine environment is to their own health, the economy, and how their behaviour away from the marine environment can impact this (e.g. disposal of toxicants, carbon pollution, revegetation etc.). An aware community can also drive change at a larger scale e.g. through lobbying of government/voting for protection etc. and through on-ground activities such as community based monitoring and works (e.g. revegetation of dunes) performed by friends groups to support marine protected area management (see Alcock, 1991, Blayney and Westcott, 2004, Alcock and Zann, 1996, Alessa et al., 2003, Burke, 2001, Gurran et al., 2006, Leigh, 2005, Lothian, 1994, Lothian, 2002).

Illegal activities

Illegal activities include all things banned within Marine Protected areas including: poaching (Carey et al., 2007a, Carey et al., 2007b), removal and collection (Carey et al., 2007b)(e.g. illegal clearing of mangroves in Yaringa)/damage to marine species/habitats, anchoring within non-anchor special protection zones (Widmer and Underwood, 2004), littering (PV, 2005b, PV, 2005a), and discharging waste from vessels (PV, 2006e, PV, 2007b).

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2.1.4. Threatening Processes

The process through which the threats influence system structure, function and state, or condition

For general discussions on processes threatening to temperate marine ecosystems see Fairweather (1990a) and Underwood (1995a).

Eutrophication: The process whereby excessive dissolved nutrients (e.g. Bishop et al., 1992) promote algal blooms, leading to accumulation of decaying plant material, microbial build-up and oxygen depletion (Edgar, 2001). This is not to be confused with seasonal spikes in algal growth which are ephemeral in nature (e.g. *Ulva* spp. growth).

Reduced growth/function: There are many causes of reduced growth and function of marine species (e.g. interruption to metabolic processes such as feeding). If threats that cause this persist over a prolonged period of time or are repeated frequently enough to prevent recovery, the changes to the abundance and population structure of the species can be significant.

Altered hydrology: Some types of nearby construction, changes to rivers/stormwater can alter coastal hydrology at a local scale, for example: constructing a jetty, groin or other similar feature. Altered hydrology may also include changes to environmental flow of waterways running into MPAs or areas adjacent to MPAs. This may alter water flow which has flow on effects to the marine protected area in terms of connectivity, food availability, oxygenation, and other water quality parameters such as sediment movement/sediment re-suspension (which can smother organisms and alter nutrient cycling, see Poore, 1982).

Increased turbidity: Nearby dredging, mangrove removal, coastal erosion, storm events, flood events, changes in land based activities or other such sediment mobilising cause can increase turbidity in the water column resulting in lower growth and oxygen production (marine plants) and smothering (e.g. seagrass, sponges).

Habitat loss: The loss of habitat whether biotic or abiotic can occur through a range of threatening agents e.g. ocean warming, overgrazing, pollution, physical disturbance (e.g. trampling, anchor scarring). Habitat loss may be large scale or fragmented, it can also occur naturally through agents such as seasonal change (dieback e.g. *Posidonia* seagrass, sediment shift).

Poor reproductive output: This may occur through disease, disturbance, damage, climate change, poaching and by ‘natural’ causes such as seasonality, changes in population structure, sexual maturity (e.g. size classes) and food availability (through changes to food web such as increased predation and competition for food).

Pest invasion See Alexander (2010b): This variable refers to the invasion of introduced marine pests which may outcompete, prey upon or in another way detrimentally affect species within and making up the habitat. Introduced marine pests include both noxious pests such *Asterias amurensis* (Northern Pacific Sea Star), and *Carcinus maenas* (European Shore Crab, Ross et al., 2004), and introduced species that make up part of the marine habitat but may pose great risk to other species e.g. *Antennella scundaria* (hydroid) and *Deucalion levringii* (red alga). Improving knowledge about the emerging pests, their range, and impact on native marine habitats, species and processes need to be revised throughout time. In addition to pests, some native species can expand their range or expand their population in a way that is detrimental to other biota in the habitat (e.g. *Centrostephanus rodgersii* see Subtidal Habitats).

Sediment degradation: This variable refers to the degradation of sediments within marine habitats which may occur through changes in hydrology, sediment transport, toxicants, increased/decreased nutrients, and physical disturbance (e.g. which results in Coastal Acid Sulphate Soils - Price, 2006). The degradation of sediments within a marine habitat can change the habitat itself, for example propeller scar can remove seagrass creating a fragmented seagrass habitat intermingled by subtidal soft sediment habitats. In some cases toxicants or other methods of sediment degradation may be so severe as to create a barren habitat (no marine life).

Disruption of food web/species interactions: Threatening agents such as poaching and pest invasion can disrupt natural food web and species interactions. In the case of introduced pests, their predation on a species within the habitat may increase thereby releasing its prey from predation which could lead to increased effects down the chain. One example is the introduced Northern Pacific Sea Star (*Asterias amurensis*) which predates on bivalves (in addition to many marine invertebrates) which filter the water column for plankton; if predation on bivalves is high enough the decline of mussels can result in turbid water which may detrimentally impact on the settlement and growth of other species (e.g. spatfall, algae) resulting in a change to the community. Poaching can also alter food webs and species interactions, studies into fishing rock lobsters has been linked to changes in trophic cascades such as: increased numbers of sea urchins and an increase in urchin barrens in subtidal marine reefs. (Talman and Keough, 2001, see Alexander, 2010b)

Population loss/species decline: Species may be lost/decline in numbers from a habitat or location due to a range of threats such as poaching, pest invasion (Alexander, 2010b), pathogens (e.g. abalone virus), overabundant native species or range expanding species (e.g. climate change impacts on range expansion of the urchin *Centrostephanus rodgersii*) and habitat loss. This can alter the community structure within a habitat/location and result in a loss of net biodiversity. This variable may occur in addition to the variable Disruption of food web/species interactions.

2.1.5. Resulting Habitat Structure

The habitat structure that results from the combination of threats and drivers acting on a system and management responses

For a general summary of the habitat structure within Victorian Marine Parks and Marine Sanctuaries see Parks VIC (2006f).

Abiotic Habitats

This includes structures occurring above, below and within the substrate; substrate type and condition (soft/hard/mineralogy) and the structural form of substrates (crevices, arches, flat, loose substrate, rugosity, relief). These habitats can be used by species for anchoring, burial and burrowing, reproduction (egg attachment), feeding and other behaviours. Abiotic habitats can also include dead biota e.g. broken shells, empty invertebrate casings.

Biotic Habitats

This includes habitats made up of living organisms such as mussel/barnacle beds, seagrass (including rhizomes), root structures of mangroves, saltmarsh and seagrass, canopy forming algae, algal holdfasts, benthic invertebrates, and any other animal or plant that creates a habitat for other species to occupy. These biotic habitats may be persistent through time or irregular in availability e.g. seagrass dieback during winter. See Edgar (2001).

2.1.6. Natural Assets

PV-defined (PV, 2011), are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect. These overlap with the resulting habitat structure and indicators so are placed within the same layer in the habitat maps.

For reviews on priority values in Victorian marine habitats see Carey et al. (2007a) Environment Conservation Council report (ECC, 2000), all PV Marine Natural Values studies, and Westcott (2006) and PV management plans.

Nutrient cycling

This includes the cycling of chemicals such as nitrate, phosphate, carbon (through food webs) and nutrient regeneration (where organic matter derived from decomposing organisms release nutrients, Arrigo, 2005, Castro and Huber, 2008, Boon and Cain, 1988).

Ecosystem services

The services the marine environment provide for humans include: Provisioning services such as food, water, building materials and pharmaceutical compounds; Regulating services such as regulation of climate, waste processing and protection from storms and floods; Cultural services such as recreation, aesthetic and spiritual benefits; Supporting services such as photosynthesis, soil and sand formation (Duffy and Smith, 2006, ABS, 2004).

Marine biota

This refers to all marine species within the marine ecosystem from bacteria through to marine mammals and birds (Christianou and Ebenman, 2005).

Migratory, Rare/Threatened species

This refers to species of conservation concern including locally or regionally significant species, species at the extremes of their distribution and those listed on: Flora and Fauna Guarantee Act (FFG, 1988), Environment Protection and Biodiversity Act (EPBC, 1999), Victorian Rare or Threatened Species (VROTS), RAMSAR.

Biodiversity

This variable refers to the value of maintaining good levels of marine biodiversity (variety of marine species) within a marine ecosystem (Bulling et al., 2006, Coleman et al., 1997, Ferns et al., 2000).

Water quality

Both a social (for recreation, aesthetics) and environmental value (ecosystem health), water quality needs to be maintained to a minimum of EPA standards (as set out in SEPP and ANZECC guidelines). The quality of marine/estuarine waters includes chemistry, clarity, and temperature integrity (Poore, 1982).

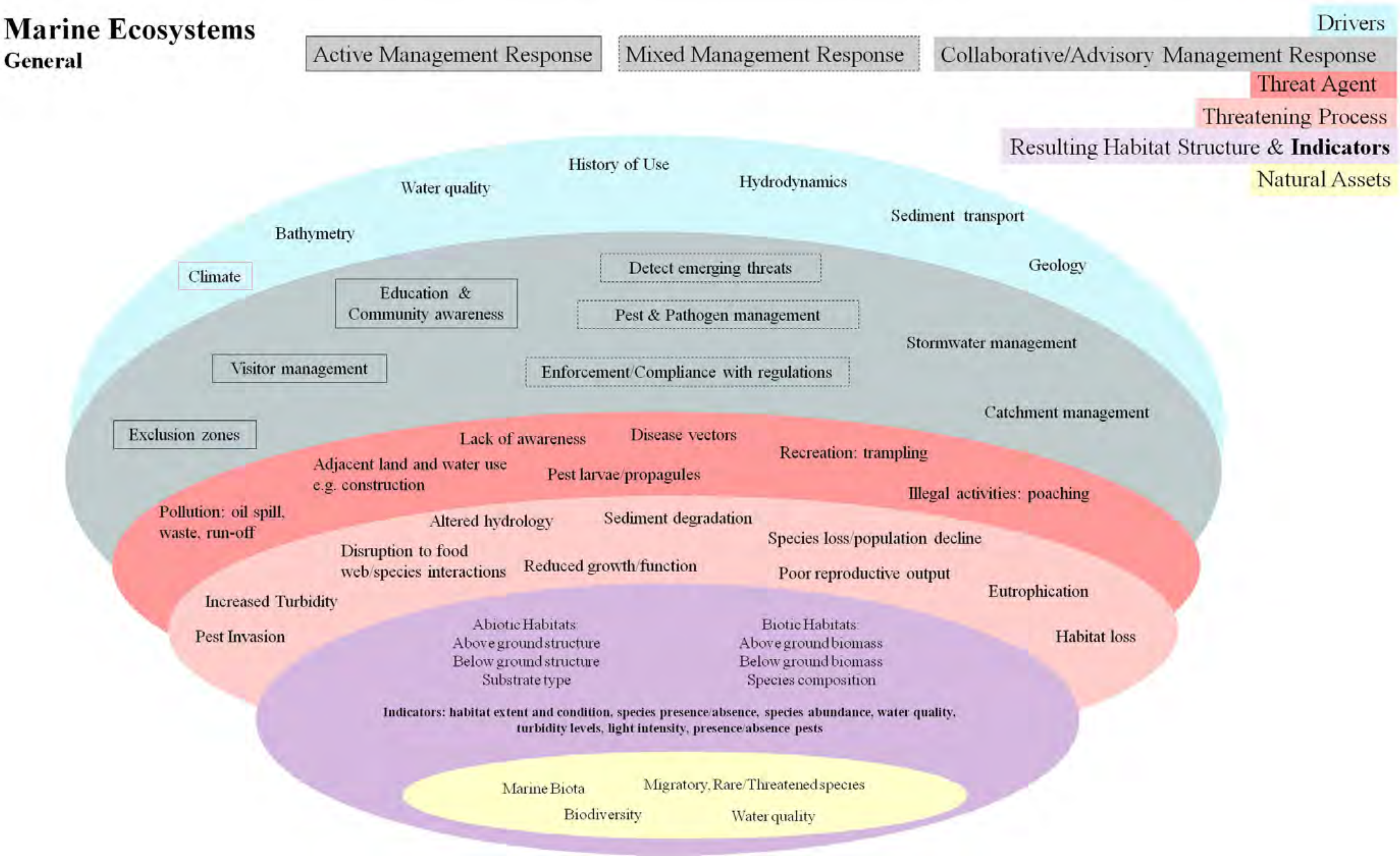


Figure 1 Conceptual Map of General Marine Ecosystem in Victorian Marine Protected Areas

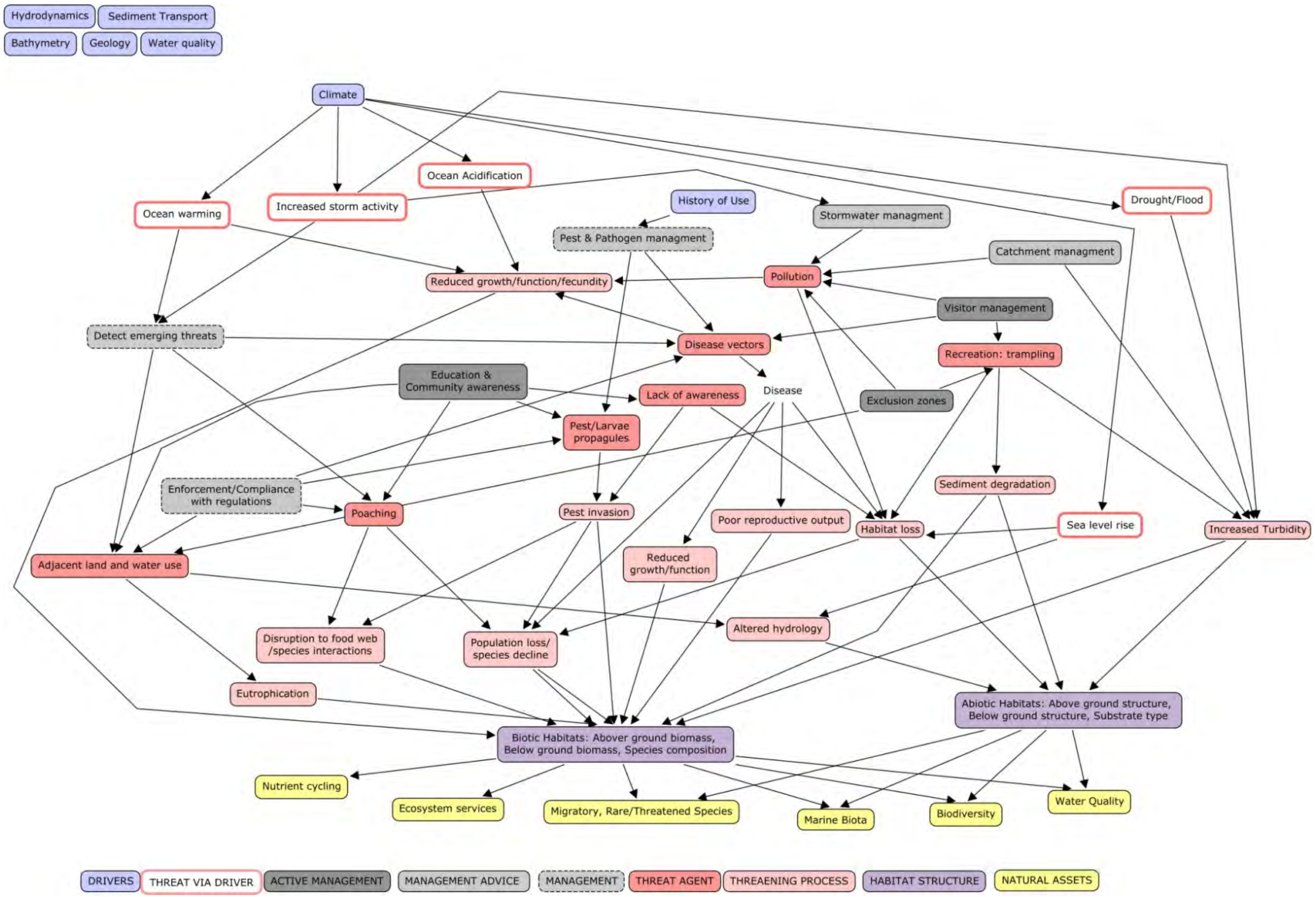


Figure 2 Conceptual Model of General Marine Ecosystem in Victorian Marine Protected Areas

3. SEAGRASS

Broad-leafed seagrass bed with pot bellied seahorse (Corner Inlet Marine National Park) ©Mark Norman

Habitat forming seagrasses found in Victoria include the intertidal species *Zostera muelleri* (Jacobs and Les, 2011)*,* and several subtidal species: Z*ostera nigricaulis* (Jacobs and Les, 2011), *Amphibolis antartica*, and *Posidonia australis* (Warry and Hindell, 2009)*.* These subtidal seagrasses can create continuous or patchy areas, which can differ in their ability to stablise sediments, shade the understorey, provide structure for invertebrates and algae and reduce water movement. Additional species found within Victoria's marine waters include *Halophila australis* (often recorded as H. ovalis, Blake and Ball, 2001), *Lepilaena marina* (Listed as threatened under the Flora and Fauna Guarantee Act 1988, Warry and Hindell, 2009), *Lepilaena cylindrocarpa*, *Ruppia maritima*, *Ruppia tuberosa* and *Ruppia polycarpa* (the latter five recorded in Swan Bay, Warry and Hindell, 2009).

The importance of seagrass in the marine environment is most commonly perceived as their ability to create canopies that create favourable habitats for other species (such as commercial important fish e.g. King George Whiting, Robertson, 1977, Robertson, 1983), although all species of Victorian seagrass contribute ecosystem services such as nutrient cycling (Bulthuis et al., 1984, Hemminga et al., 1991), primary productivity and habitat (even if they don't create a canopy) for other species (such as a substrate for invertebrates/algae to attach in areas made up of soft sediment, Watson et al., 1984). The intertidal seagrass *Zostera muelleri* supports a high abundance of invertebrates making it a particularly important habitat for shorebird foraging (Howard and Lowe, 1984).

Seagrasses decline in abundance due to a range of factors including seasonal fluctuations; and some areas have undergone substantial loss e.g. Corner Inlet, Westernport Bay (suggestions as to why include proximity to river outputs as a consequence of sedimentation/nutrient enrichment, Bearlin et al., 1999, Short and Neckles, 1999, Morris et al., 2007, Waycott et al., 2009). Current research is underway investigating the resilience of seagrasses in Port Phillip Bay to inform current knowledge gaps which will lead to improved management options in this area.

Seagrasses are found in the following Victorian Marine National Parks and Marine Sanctuaries: Churchill Island MNP, Corner Inlet MNP, French Island MNP, Mushroom Reef MS (*Amphibolis*), Jawbone MS (*Zostera* spp.), Point Addis MNP, Port Phillip Heads MNP, Wilsons Promontory MNP and Yaringa MNP (PV, 2011); small patches are also present in other MNPs and MSs.

For an in depth review on Seagrasses in Victoria focusing on Port Phillip Bay please see Warry & Hindell (2009) and for Western Port Bay see Keough et al. (2012).

3.1. Definitions specific to Seagrasses

3.1.1. Drivers

The things that determine the distribution of habitats, and the main factors that act in these systems to influence their state or condition

Climate

A detailed account of the proposed effects of climate change on seagrasses is given by Short and Neckles (1999).

- Climate change – seagrass ecophysiology can be affected by increased water temperature (expected to increase with warming oceans) which can lead to the denuding of seagrass meadows (Ralph, 1998, Holmes et al., 2007) the increased success of pest invasions and competitive species from warmer temperate areas.
- Flooding whether due to seasonality, La Nina patterns or increased storm activity (e.g. changes in catchment flow and inputs) from climate change, can lead to seagrass loss (Campbell and McKenzie, 2004) as a result of shading (turbid water), reduced water quality, and increase water flow (Holmes et al., 2007).

- Air Temperature extremes (intertidal seagrass): intertidal seagrass (*Zostera muelleri*) is subject to tidal inundation, increased air temperature during tidal exposure could result in tissue damage to plants resulting in a decline in plant health and productivity.
- Sea level rise – seagrass distribution is depth limited (Duarte, 1991, Warry and Hindell, 2009, Holmes et al., 2007) as sea level rises seagrass will need suitable substrate to attach to. If shores are backed by unsuitable substrate, seagrasses may be squeezed out and lost.

Bathymetry

As for sea level rise (above), seagrasses are depth/light limited.

Water quality

The water quality parameters that drive seagrass distribution and growth include: nutrient regimes and content (Bulthuis et al., 1984, Hemminga et al., 1991), turbidity (Bulthuis et al., 1984) and light availability (Ralph et al., 2007), salinity (as summarised in Warry and Hindell, 2009), temperature (Holmes et al., 2007), pH (as summarised in Warry and Hindell, 2009), and mixing (Short and Neckles, 1999).

History of Use

The previous use of an area (and areas adjacent) can be very important for determining seagrass health and distribution within an area. Proximity to rivers and drains can reduce seagrass through a combination of flow, sediments, nutrients and turbidity (Keough et al., 2012). Time since exposure to pollution such as sewage and chemical wastes can also determine the current health and density of seagrass in an area. Previous exposure to anchoring and other physical damage (e.g. trawling) can also influence current day seagrass health and distribution.

Sediment transport

This factor is linked to both hydrodynamic energy and sediment structure (see Hydrodynamics and Geology below). Burial and erosion within seagrass beds can affect their distribution, although seagrasses are generally understood to act as sediment sinks (see Bulthuis et al., 1984 for Victorian investigation), an ability that increases with size of the bed (as discussed in Warry and Hindell, 2009).

Hydrodynamics

Seagrass distribution can be influenced by water flow and energy, and seagrasses themselves can influence currents and water flow. Hydrodynamics also influences the dispersal of pollution (e.g. oil spill), and seeds, larvae, and eggs of species found within seagrass beds. Hydrodynamics also covers the effects of tides on seagrass; this is most relevant to the intertidal seagrass *Zostera muelleri* (as summarised in Warry and Hindell, 2009).

Geology

Sediment and substrate (e.g. for *Amphibolis antartica*) composition (e.g. silicates, grain size etc.) influences the distribution of seagrass. The geomorphology of the seabed also influences wave action and water flow which affects the distribution of seagrass (seagrass is generally found in more sheltered environments, see Williams and Grosholz, 2008).

3.1.2. Management

Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes. Three management types are given – Active, Mixed and Collaborative/Advisory

All management of Marine National Parks and Marine Sanctuaries is documented in the PV Management Plans. The plans that contain seagrass specific management are: Barwon Bluff, Bunurong, Corner Inlet, Eagles Nest, Jawbone, Mushroom Reef, Port Phillip Heads, Pt Addis, Pt Cooke, Pt Danger, Ricketts Point, and Western Port Bay (PV, 2003d, PV, 2003a, PV, 2005c, PV, 2005b, PV, 2005a, PV, 2006e, PV, 2006b, PV, 2007g, PV, 2007f, PV, 2007b, PV, 2007a, PV, 2007e)

Active Management

Refers to direct management actions/response undertaken by (and the responsibility of) PV

Education & Community awareness

This refers to the importance of public education and making the community aware of the function of seagrasses and the impacts human behaviour has on seagrass (Holmes et al., 2007, Dunton and Schonberg, 2002, Alfaro et al., 2006). Community education can also aid more directly in management through community monitoring programs like Seagrass Watch (Alper, 1998) or Sea Search (Koss et al., 2005a, Stevenson and Pocklington, 2011).

Visitor management

Visitor management that applies specifically to seagrass habitats includes making visitors aware of the sensitivity of seagrass habitats and how they can change their behaviour to prevent damage: e.g. using alternative access points, responsible water vehicle use and cleaning gear to prevent pest/disease spread (PV, 2007g).

Exclusion zones

Special protection areas exist at Mud Islands and Swan Bay during bird breeding season (RAMSAR) when a 5 knot speed limit for vessels is in place to prevent disturbance to migratory shorebirds (PV, 2007g). Vehicles are excluded from accessing intertidal areas except at a designated boat ramp (PV, 2007g). Temporary exclusion zones may be put in place in conjunction with research (e.g. *Hormosira* trampling exclusion trial, (Taylor, 2007), pollution or pest or disease outbreak (as deemed by responsible agencies e.g. EPA, DSE).

Mixed Management

Includes direct action from PV in addition to direct action by other agencies (e.g. DSE, EPA), or as a support to other agencies

Pest & Pathogen management

Pest and Pathogen management across the state is the primary responsibility of DSE and DPI respectively. Parks Victoria can undertake direct management through education of the public, maintaining good hygiene practices on vessels and infrastructure, and by informing DSE and DPI of any pest or pathogen outbreaks (PV, 2007g). Assistance to DSE and DPI with Pest and Pathogen management in MNPs and MSs can also occur, this may include eradication exercises (see also Williams and Grosholz, 2008).

Enforcement/Compliance with regulations

This includes ranger patrols, issuing warnings and offense notices (e.g. for poaching, dogs in MNP), interacting with the public to let them know the regulations and best practises (e.g. slower vessel speed limits around cetaceans). Parks Victoria can also assist other agencies such as EPA by informing them of pollution if informed by the public or observed during patrols. Some poaching may need to be managed in collaboration with DPI (Fisheries) likely on a specific case basis (e.g. Abalone poaching near Melbourne).

Detect emerging threats

Parks Victoria can detect emerging threats through observations on patrol, by receiving information from the public, by running monitoring and educational programs such as Sea Search (Stevenson and Pocklington, 2011), and through collaborations with other government agencies, research institutions, community groups and monitoring programs (e.g. Reefwatch Vic, Reef Life Survey, Earthwatch Vic).

Collaborative/Advisory Management

Where PV can take an advisory role (e.g. for planning applications that impact on the marine environment) or assist other agencies indirectly (e.g. contacting relevant agency if a threat is observed/advised to staff by member of the public)

Stormwater management

Melbourne Water manages most stormwater discharges into marine waters in Port Philip Bay and Western Port (in conjunction with other water authorities, local councils and EPA). Parks

Victoria can aid this management through informing these agencies of any problems related to stormwater observed on patrols or that they have been informed of (e.g. by a member of the public). Parks Victoria may also advise these agencies of how stormwater affects the marine environment (especially through litter) and any progress in management they become aware of that may reduce these effects where appropriate.

Catchment management

Parks Victoria can assist the Catchment Management Authority (or relevant agency) by advising them on the impacts of runoff to the marine environment and ways to improve the catchment for improved water quality and erosion prevention such as encouraged rehabilitation of riparian zones and reduced use of chemicals/fertilizers. Where NPs exist in the catchment PV can take more active catchment management e.g. rehabilitating riparian zones.

3.1.3. Threat Agent

The past and present activities (and other factors) that influence ecosystem structure, function, state or condition

General threats to seagrasses are reviewed in Orth et al. (2007g) and Waycott et al.(2009).

Pollution

This can come from a variety of sources and cause multiple threatening processes including: increased epiphyte growth leading to eutrophication (Gacia et al., 2007), reduced growth and function of seagrass and even seagrass loss from pollutants in the water column and in the sediment. Pollutants in seagrasses can be passed on through the food chain affecting many species.

Oil/Chemical spill

Chemicals and heavy metals can be absorbed into seagrasses through the water and sediments (Roberts et al., 2008, Ward and Young, 1982) which can then inhibit settlement of epifauna, and reduce the survival of grazers. Oil and fuel can impact organisms in multiple ways e.g. burn of seagrass and algae (as a result of hydrocarbons), behavioural response, reduced immunity to disease, mortality (Holdway, 2002)

- Oil and chemical spills are managed by AMSA www.amsa.gov.au at the national level and by Department of Transport at the state level www.transport.vic.gov.au

Adjacent land and water use

Terrestrial run-off (Morris et al., 2007) and proximity to industrial development (Ward and Young, 1982) such as aquaculture, industrial outfalls and coastal construction (Holmes et al., 2007) can impact on the health of seagrasses and their associated organisms. These impacts can include eutrophication through increased epiphyte growth, and changes in hydrology e.g. due to nearby construction of jetties.

Disease vectors

As per General Marine Habitats

Pest larvae/propagules

As per General Marine Habitats. Note that seagrass habitats can be particularly vulnerable to pest invasion as many known pests invade/occupy this habitat type (e.g. *Asterias amurensis*, *Codium*/*Caulerpa* spp.)

Recreation

Recreational boat/water vehicle use can damage seagrass habitats by propeller scour (Moran et al., 2003, Reed and Hovel, 2006) if operators misidentify depth, this physical damage can result in seagrass habitat fragmentation and localised loss depending on the scale of damage done (Reed and Hovel, 2006). Trampling by people, pets, and terrestrial pests impacts intertidal seagrasses such as *Zostera muelleri*, although can also affect *Posidonia australis* during very low spring tides (usually summer). Walking through seagrass beds can damage the seagrass itself and disturb the sediments resulting in loss of seagrass, increased turbidity, sediment damage and loss or damage to species associated with the seagrass habitat (e.g. mesograzers) (Reed and Hovel, 2006, Aberg and Pavia, 1997)

Lack of awareness

Lack of awareness among the community can be highly detrimental to seagrasses especially through behaviours such as propeller scar, anchoring (Moran et al., 2003) and trampling sensitive seagrass habitats, and the spread of pests and pathogens by poor boat/gear hygiene.

Illegal activities

Poaching (Jenkins et al., 1992) can have both direct and indirect impacts to the seagrass habitat by reducing biodiversity, altering species structures and damaging habitats. Other illegal activities include illegal dumping of rubbish or wastes which can affect species through toxicity.

Beach clearing

Beach clearing directly impacts upon seagrass wrack and the habitat this provides for terrestrial, intertidal and shorebird species. Loss of this habitat can reduce the recycling of nutrients (as they break down as wrack), and remove habitat for animals such as sandhoppers which make up the diet of many other species (management of the beach foreshore may vary between MPAs depending on foreshore land protection).

Coastal erosion

Erosion of the coastal foreshore within or adjacent to the MPA results in increased turbidity of the water column through increased sediment loads.

3.1.4. Threatening Processes

The process through which the threats influence system structure, function and state, or condition

Eutrophication

The process whereby excessive dissolved nutrients (e.g. Bishop et al., 1992) promote algal blooms, leading to accumulation of decaying plant material, microbial build-up and oxygen depletion (Edgar, 2001). This is not to be confused with seasonal spikes in algal growth which are ephemeral in nature (e.g. *Ulva* spp. growth).

Reduced growth/function

All threat agents may result in reduced growth and function of seagrass. Reduced function can include (but not be limited to) providing habitat, reproductive function, photosynthesis.

Altered hydrology

Altered hydrology for example through changes in position of river mouth (e.g. and even increases in flooding Campbell and McKenzie, 2004), or building of jetties in nearby waters, can make conditions unsuitable for seagrass persistence and seagrasses may cease to grow in a particular area (see aerial photos of Kororoit Creek entering Altona, Scott Chidgey pers. comm).

Increased turbidity

Increased turbidity can result in decreased growth and even smothering of seagrasses.

Habitat loss

Loss of seagrass can lead to increased turbidity, the release of phosphorus and silicates into the water column (Bulthuis et al., 1984), and the loss of species usually associated with seagrasses e.g. fish (Smith et al. 2008, Smith et al. 2010, Smith et al. 2011) which can have consequences for food webs and important species (see also Campbell and McKenzie, 2004, MacDonald, 1992, Walker and McComb, 2003, Addessi, 1994, Holmes et al., 2007).

Poor reproductive output

Some threatening agents can result in poor reproductive output by seagrasses and their associated species for example chemical interference with reproductive processes (Roberts et al., 2008), disturbance and reduced light availability may cause seagrass to put resources into growth and repair rather than reproduction (Warry and Hindell, 2009).

Pest invasion

Pest invasion can result from the introduction of adult pests, larvae and propagules. Pests can compete for resources with seagrasses e.g. *Caulerpa taxifolia* in South Australia and NSW, or predate upon species associated with seagrasses e.g. *Asterias amurensis* (Williams and Grosholz, 2008)

Sediment degradation

This differs from Increased turbidity and refers to the degradation of sediments within the seagrass habitat either through pollution, species invasion, disturbance (e.g. trampling) or anoxia (most commonly through lack of aeration or eutrophication). Degraded sediments may become unsuitable for seagrass growth (see Warry and Hindell, 2009)

Disruption of food web/species interactions

All threat agents listed can lead to disruption of the food web and species interactions within seagrass habitats (see Robertson, 1983, Eklof et al., 2009, Jenkins et al., 1992, Holmes et al., 2007). An example is altered nutrient regimes changing resource use within the food web (Warry and Hindell, 2009).

Habitat damage/fragmentation

Trampling, propeller scarring, and anchor damage can all physically disturb seagrass habitats resulting in damage and/or fragmentation. Habitat degradation and fragmentation can reduce connectivity of seagrass habitat and affect species interactions such as the feeding of fish from edges of habitat (and survivorship of epifauna) compared with within the habitats (PV, 2007g, Smith et al., 2008, Smith et al., 2010, Smith et al., 2011) and overall biodiversity.

3.1.5. Resulting Habitat Structure and Indicators

The habitat structure that results from the combination of threats and drivers acting on a system and management responses - see review by Duffy (2006)

Fish and invertebrate nursery/habitat

Temperate seagrass beds have been shown to be an important habitat for invertebrates (Bloomfield and Gillanders, 2005, Robertson, 1984, Edgar, 1990c, Edgar, 1990b, Edgar, 1990a, Orth et al., 1984), fish (Howard, 1985, Pollard, 1983, Smith et al., 2011, Macreadie et al., 2009, Robertson, 1984), and also function as a nursery area for fish that don’t spend their adult life in seagrass (including King George Whiting Robertson, 1977).

Shoot and leaf structure

This provides habitat for other species e.g. coralline algae can attach and grows on Amphibolis antartica leaves (Bramwell and Woelkerling, 1984), reduces water flow (Holdway, 2002) and can be food for some species including swans (PV, 2006e) and invertebrates (Edgar, 1990b).

Wrack

Wrack is the marine debris commonly found on the tide line of beaches, it is usually made up of detached seagrass, algae and other dead or senescing marine fauna (commonly sponges, urchin tests etc.). Seagrass wrack has been found to provide important habitat for intertidal (Olabarria et al., 2010) and terrestrial invertebrates (eaten by shorebirds), terrestrial fauna and fish in the surf zone (Lenanton and Caputi, 1989). Wrack has even been shown in some places to facilitate dune formation (Hemminga and Nieuwenhuize, 1990) and saltmarsh restoration (Chapman and Roberts, 2004).

Root/Rhizome structure

Roots are an important part of seagrass production (Duarte et al., 1998). Both roots and rhizomes stablise sediments, provide habitat for some interstitial fauna (Orth et al., 1984) and sequester carbon (Duarte et al., 1998).

Sediments

Seagrasses are known to stabilise sediments and act as sediment sinks (Bulthuis et al., 1984). Seagrass growth can also alter sediments through detrital nutrient additions and increased biodiversity of invertebrates (such as polychaetes) which can lead to sediment filtering and finer sediments (Decho et al., 1985).

3.1.6. Natural Assets

PV-defined (PV, 2011), are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect. These overlap with the resulting habitat structure and indicators so are placed within the same layer in the habitat maps. Also see marine natural values study (Plummer et al., 2003).

Nutrient cycling

Seagrasses have been shown to cycle nutrients (Walker et al., 2001, Orth et al., 2006) via absorption into leaf and shoot tissue which is made available to other species via the food web through detritus due to seasonal dieback.

Ecosystem services

Seagrasses provide valuable ecosystem services (Orth et al., 2006, Waycott et al., 2009) including habitat provision, food and nutrient cycling, carbon sequestration and oxygen production (Warry and Hindell, 2009).

Fish and invertebrate communities

Important fish (e.g. King George Whiting) and invertebrate communities (e.g. crustaceans, bivalves, sponges) occur within and depend on seagrasses (Watson et al., 1984, Jenkins et al., 1992, Holmes et al., 2007, Howard, 1985, Pollard, 1983, Smith et al., 2011, Macreadie et al., 2009, Robertson, 1984, Walker et al., 2001).

Threatened/Valuable species

This refers to species of conservation concern including locally or regionally significant species, species at the extremes of their distribution and those listed on: Flora and Fauna Guarantee Act (FFG, 1988), Environment Protection and Biodiversity Act (EPBC, 1999), Victorian Rare or Threatened Species (VROTS), RAMSAR. In seagrass habitats these species include (but are not limited to) pipefish, seahorses and seadragons (Syngnathids); and even some commercially important juvenile fish (Robertson, 1977, Jenkins et al., 1992, Holmes et al., 2007).

Shorebird/shore invertebrate foraging

Intertidal seagrass beds are important feeding areas for migratory and local birdlife (Howard and Lowe, 1984), Western Port Bay is an important area for migratory birds as part of RAMSAR (in addition to RAMSAR sites within Port Phillip Bay and Corner Inlet) with many visiting seagrass habitats (Loyn, 1978, Holmes et al., 2007).

Swan food

The native black swan (*Cygnus atratus*) is an important inhabitant of Victorian seagrass beds eating both seagrass and epiphytic algae living on the seagrass (Eklof et al., 2009).

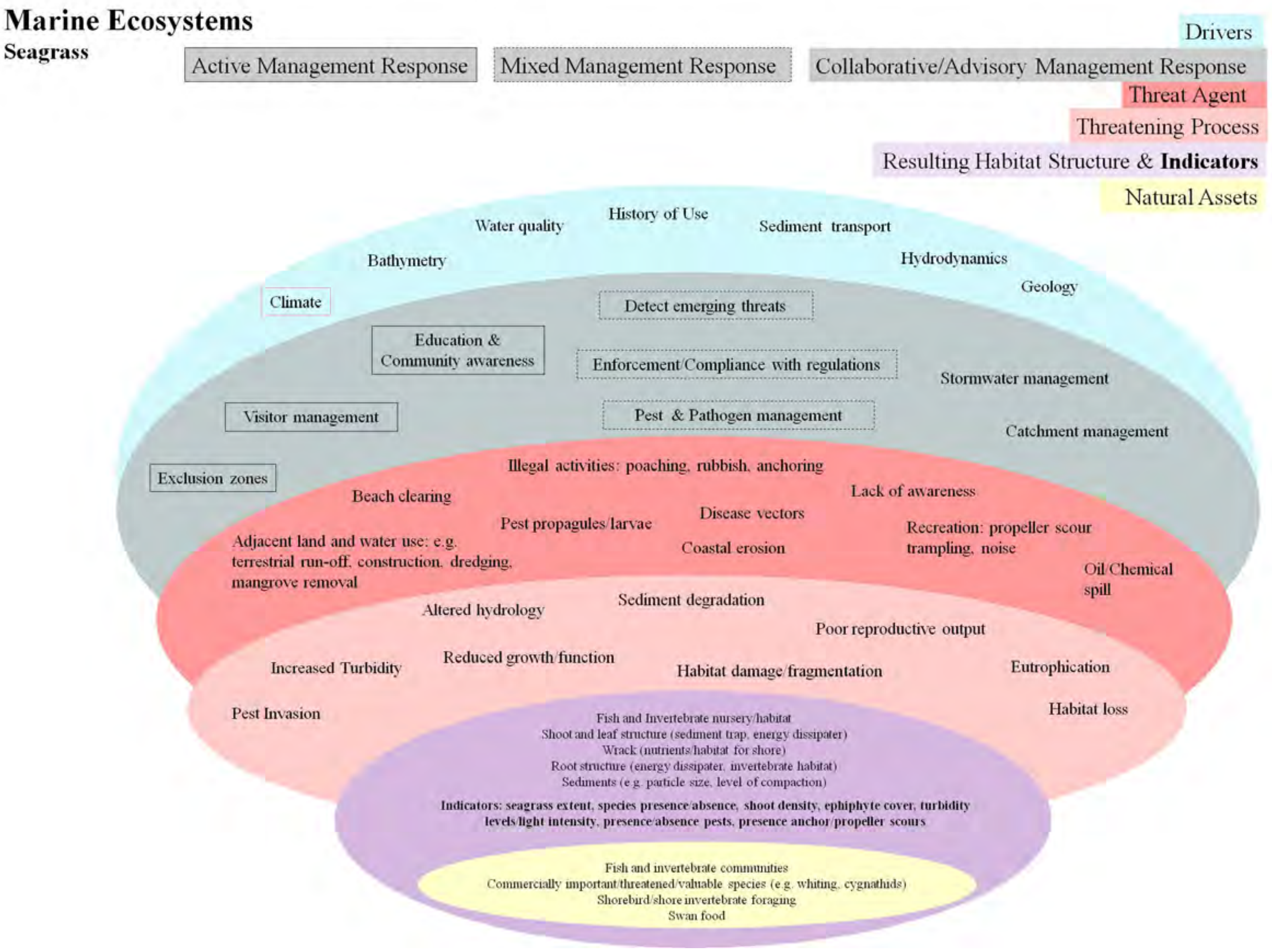


Figure 3 Conceptual Map of Seagrass Habitats in Victorian Marine Protected Areas

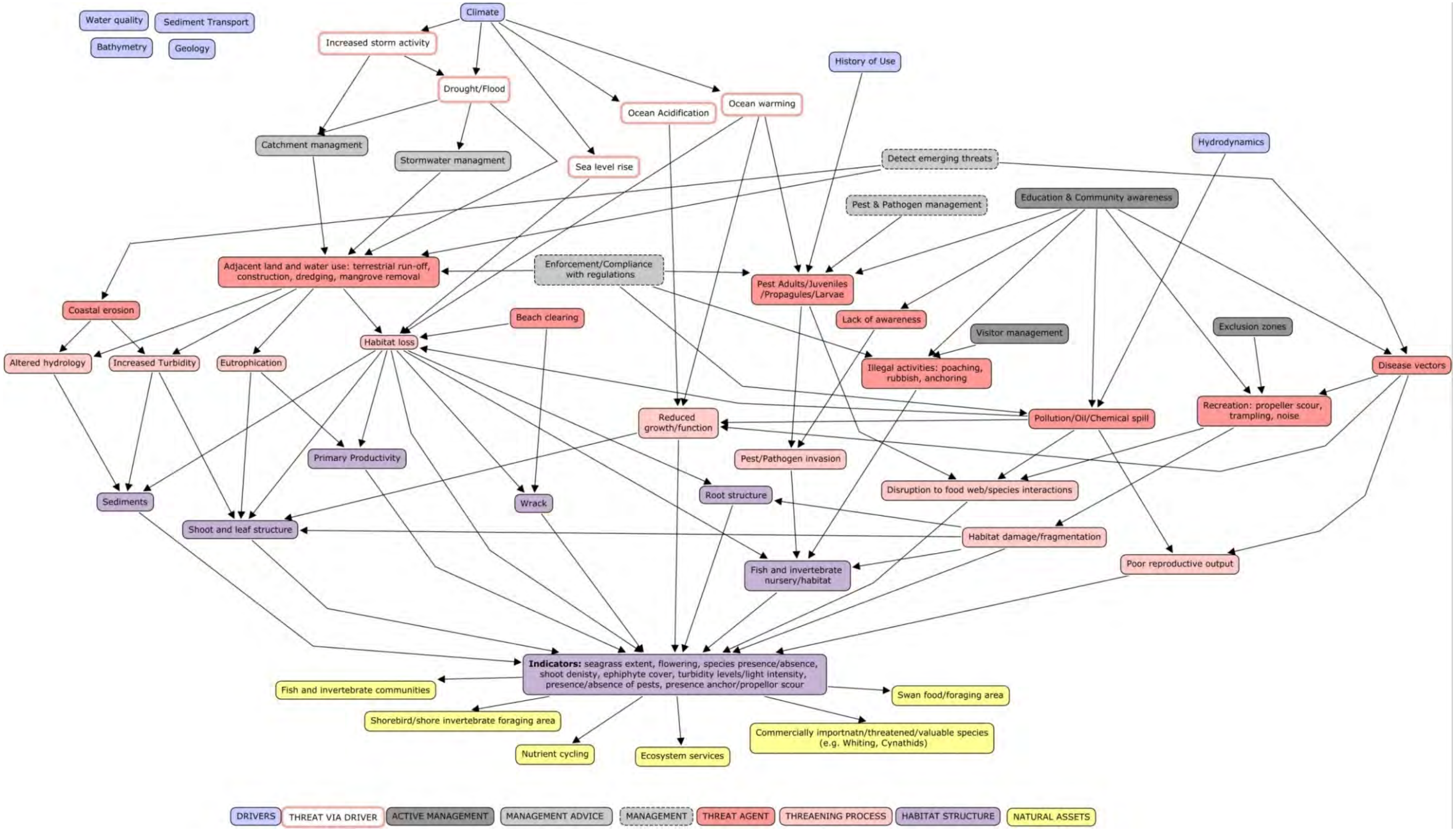


Figure 4 Conceptual Model of Seagrass Habitats in Victorian Marine Protected Areas

4. MANGROVES AND SALTMARSH

Saltmarsh at Mud Islands (Port Phillip Bay Marine National Park) © Mark Rodrigue

Mangroves and Saltmarshes (described as Coastal Wetlands in Boon et al., 2011) fringe the coastline in parts of Victoria. Only one mangrove species exists in Victoria, the white or grey mangrove *Avicennia marina* ssp. *australasica* and this mangrove makes up the Ecological Vegetation Class (EVC) 140 (Boon et al., 2011). Mangrove habitats in Victoria are important for migrating bird life (under RAMSAR), they protect the coastline from erosion, and provide habitat for a number of terrestrial invertebrates, and marine life including invertebrates and fish life (Harty, 2010). Mangroves are generally found in the east of the state, with the Barwon River Estuary being their most westerly location (the most southerly distribution of mangroves in Australia occurs in Corner Inlet) (Harty, 2010). Mangroves (and saltmarshes) were removed from many areas of Victoria (most severely in Corner Inlet) post European settlement for multiple reasons including drainage for pasture, land fill, for soap ingredients and building to name few (Boon et al., 2011, Saintilan and Williams, 1999, Ross, 2000). The consequence in some areas has been severe coastal erosion ((e.g. in the Lang Lang area, T. Ealey pers. comm. and Harty, 2010). Some Victorian mangroves are actually expanding to areas where they haven’t previously been recorded and tend to be expanding landwards rather than seawards (reasons include depth, sedimentation, nutrient and tidal changes; Harty, 2010, Saintilan and Williams, 1999). This landward expansion of mangroves can threaten saltmarsh habitats by squeezing them out since development landward (e.g. roads, residences) of saltmarshes prevents their retreat onto land (Harty, 2010, Rogers et al., 2005). Coastal saltmarsh habitats in Victoria include the EVCs 9 & 10 (and those described in Boon et al. 2011) and contain high biodiversity of flora, terrestrial vertebrates (e.g. lizards) and invertebrates (e.g. insects) (Boon et al., 2011). Saltmarshes are also important habitat and feeding areas for birds (including the protected Orange Bellied Parrot and multiple birds protected under RAMSAR)(Boon et al., 2011). Saltmarshes are currently threatened (in addition to habitat squeeze)(Schleupner, 2008) by physical damage such as trampling (e.g. stock, vehicles, people and pets) and weed invasion (Boon et al., 2011, Bridgewater and Cresswell, 1999). Both Mangroves and Saltmarshes contribute a range of ecosystem services in addition to their role as important habitats including: primary productivity, functioning as natural water filters, and stabilising coastal land and sediments. Further description of mangroves is available in Stewart and Fairfull (2008) and, Harty (2010). For an in depth review of saltmarshes and mangroves in Victoria see Boon et. al (2011).

4.1. Definitions specific to Mangroves and Saltmarsh

4.1.1. Drivers

The things that determine the distribution of habitats, and the main factors that act in these systems to influence their state or condition

Climate

Natural climate events such as seasonality and El Nino/La Nina weather patterns can alter the distribution, reproduction, and floristics (in the case of saltmarshes) of mangroves and saltmarshes.

Climate change:

- Sea level rise (Rogers et al., 2005): this most dramatically affects saltmarsh, especially in areas where no landward migration of saltmarsh is possible due to roads, infrastructure or other land use (and where they are outcompeted by landward moving mangroves). This may also affect mangroves in some areas where expansion is not possible due to adjacent land use (called "coastal squeeze" Schleupner, 2008).
- Air Temperature extremes: mangroves and saltmarsh are subject to tidal inundation, increased air temperature during tidal exposure could result in tissue damage to plants and pneumatophores resulting in a decline in plant health and productivity.

- Water Temperature: increased water temperature may affect the plants physiologically altering their distribution, may lead to the increased success of pest invasions and competitive species from warmer temperate areas, and could also alter the behaviour of associated fauna (e.g. grazing on epiphytes).
- Currently *A. marina* ssp. *australica* is the only species of mangrove that extends to the temperate climate in Victoria, with other species common to the tropics and subtropics. Climate change could lead to a distribution change of such species and push *A. marina* ssp. *australica* out in favour of sub-tropical and tropical mangrove species if they cannot move south.
- Increased incidence of fire due to climate change can impact saltmarshes which aren’t fire tolerant (Boon et al., 2011).
- Increased extremes in weather conditions (e.g. increased storms) can affect catchment related inputs which may lead to increased pollution from run-off and/or sedimentation, and cause erosion of sediment.

Geology

Mangroves and saltmarshes occupy soft sediments including sand, silt and mud. The mineralogy of these sediments can influence the distribution of these habitats. A major problem for both mangroves and saltmarsh is the incidence of acid sulphate soils (Price, 2006) which are caused by disturbance of the sensitive sediments they occupy. These soils can be toxic to plant life.

Water Quality & Depth

Water quality that influences the health and productivity of both mangroves and saltmarshes includes nutrients, chemicals, toxicants, oxygenation and clarity. Saltmarshes (and more so mangroves) are tidal so depth is important for their distribution.

Sediment transport

Mangroves (like seagrasses discussed earlier) stabilise sediments through the structure of their trunks, roots (including pneumatophores) and branches. Coastal wetlands have been shown to stabilise sediments not just from the marine environment but also from the terrestrial environment, as they are filtered across the habitat before reaching marine waters.

History of Use

The distribution and health of mangrove and saltmarsh habitats are highly influenced by what has happened both in and adjacent to the habitats and in the catchment. Previous clearing and destruction of mangroves and saltmarshes (Saintilan and Williams, 1999) can alter conditions to an extent that it prevents restoration and rehabilitation. Some saltmarsh areas were subject to shell-grit and salt crust mining disturbance prior to protection which in some locations has prevented restoration (Boon et al., 2011).

Hydrodynamics

Mangroves and saltmarshes are common in sheltered environments with low wave energy. Hydrodynamic changes (by natural or anthropogenic causes) can alter the distribution of these habitats.

Bathymetry

The topography of the seafloor where mangroves and saltmarsh exist is generally non-complex gently sloping areas. Due to the ability of mangroves to trap sediment they create much of their own bathymetry. See also water depth (above).

Salinity

Mangroves and saltmarshes are highly specialised salt-tolerant plants (e.g. waxy leaves). Excess salinity mostly impacts upon saltmarshes, especially in areas that are rarely inundated with tides. Dried out saltmarsh soils can become hypersaline causing toxic conditions for some flora, and resultant impacts on dependent fauna.

4.1.2. Management

Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes. Three management types are given – Active, Mixed and Collaborative/Advisory. See Harty (2004), Bridgewater and Cresswell and (1999) PV Management Plans (2002, PV, 2003d, PV, 2003a, PV, 2005a, PV, 2007g, PV, 2007b) for management of mangrove and saltmarshes in temperate Australia.

All management of Marine National Parks and Marine Sanctuaries is documented in the PV Management Plans. The plans that contain mangrove and saltmarsh specific management are: Corner Inlet, Jawbone, and Western Port Bay (PV, 2003d) (PV, 2005a, PV, 2007b).

Active Management

Refers to direct management actions/response undertaken by PV (and the responsibility of)

Education & Community awareness

Educating the community about the importance of mangroves and saltmarsh habitats is vital to changing behaviours that impact upon them (Harty, 2010, Boon et al., 2011). Increasing awareness about the importance of these habitats through communication, and by supporting groups such as the Western Port Seagrass Partnership and Dolphin Research Institute will improve awareness.

Visitor management

Visitor management can include communicating with the public during regular patrols, signage and other forms of communication (e.g. flyers). Active measures also include working with tour and other commercial groups to ensure they adhere to guidelines that prevent disturbance to habitats, and by restricting camping/access numbers to saltmarshes (PV, 2002).

Exclusion zones

Seasonal exclusion zones can be implemented especially to prevent disturbance to wading and shorebird breeding and roosting sites (PV, 2002). These can exclude activities such as horse riding, jet skiing, and hunting (e.g. Corner Inlet Ramsar site) in sensitive areas (PV, 2002). Maintaining these exclusions includes signage, communication with public (in person and media), and through tourism and community groups (PV, 2002).

Mixed Management

Includes direct action from PV in addition to direct action by other agencies (e.g. DSE, EPA), or as a support to other agencies

Pest & Pathogen management

In conjunction with other agencies (e.g. DSE, DPI): remove introduced flora and fauna (e.g. *Spartina* x *townsendii*, rabbits) from saltmarshes (PV, 2002); monitor habitats for signs of pathogens.

Enforcement/Compliance with regulations

In conjunction with other agencies (e.g. DPI, EPA) patrol and enforce regulations (including poaching, littering and pollution). Fencing (e.g. bollards) can also prevent unauthorised access (e.g. boat launching).

Detect emerging threats

Work with other agencies (e.g. EPA) and support community groups (e.g. Waterwatch, Fishcare) to detect emerging threats (through e.g. risk assessment, modelling and monitoring) such as water pollution, disease spread (Greenberg et al., 2006) and low fish abundance.

Facilitate landward migration of plants

In conjunction with DSE, local government, and private landholders allow suitable habitat for the landward migration of saltmarsh (Harty, 2010) and/or other ways of retaining saltmarsh (e.g. adding sediment slurry Slocum et al., 2005) in response to sea level rise. This includes not building seawalls or other roads/properties adjacent to saltmarshes (Harty, 2010).

Collaborative/Advisory Management

Where PV can take an advisory role (e.g. for planning applications that impact on the marine environment) or assist other agencies indirectly (e.g. contacting relevant agency if a threat is observed/advised to staff by member of the public).

Lack of collaborative management has been recognised by Bridgewater and Cresswell (1999) as a threat to conservation of mangrove and saltmarsh habitats.

Stormwater management

Stormwater is managed by Melbourne Water, other water authorities, and in some cases by local councils. Parks Victoria can contribute to stormwater management through communication with these agencies about the impacts of stormwater on saltmarsh and mangrove habitats especially the threat of litter and poor water quality.

Catchment management

The catchment is managed by the relevant Catchment Management Authority and rivers entering Port Phillip and Western Port bays are managed by Melbourne Water (PV, 2007g). Parks Victoria can contribute to catchment management through communication with CMAs and private landholders (where relevant) to make them aware of the effect of the catchment on saltmarsh and mangrove habitats. Healthy riparian habitats and best practise can prevent impacts such as run-off affecting saltmarshes and mangroves. Where NPs exist in the catchment PV can take more active catchment management e.g. rehabilitating riparian zones.

4.1.3. Threat Agent

The past and present activities (and other factors) that influence ecosystem structure, function, state or condition - see also reviews by Edyvane (1999) and Bridgewater & Cresswell (1999)

Adjacent land and water use

Building and disturbance to adjacent land and water can result in altered hydrology, increased freshwater input (Ross, 2000, Boon et al., 2011) or salinity (Molloy et al., 2005), tidal patterns, bathymetry, pollution and loss of saltmarsh habitat through preventing its landward migration (Boon et al., 2011, Ross, 2000, Rogers et al., 2005). Adjacent water use such as overfishing in nearby waters (Bridgewater and Cresswell, 1999) can alter mangrove food webs, species diversity and interactions (Boon et al., 2011).

Disease vectors

In addition to the definition in general marine habitats, disease vectors include terrestrial diseases for vertebrates (Greenberg et al., 2006), mangroves and saltmarsh plants. These may be spread through insects (e.g. mosquitoes), birds and other mobile fauna (Greenberg et al., 2006).

Pest/Weed adults/juveniles/larvae/propagules/seeds

In addition to the definition in general marine habitats, pest and weed larvae/propagules can be spread through wind, and soil transferred by animals, vehicles and humans (Carlton, 2003).

Recreation

Recreational threats include trampling and vehicle use (e.g. dirt bikes)(Kelleway, 2006), launching and irresponsible use of water vehicles, fossicking, noise and irresponsible boat use. All of these recreational practises can result in physical disturbance to sediments and to plants. Noise from people and vehicles can disrupt birds and other wildlife.

Lack of awareness

Appreciation of saltmarsh and mangrove habitats is generally low to non-existent within the community which is a major problem for their conservation (Boon et al., 2011, Harty, 2010). Education programs have had some success with a small portion of the community. Lack of awareness of the value of these habitats is a major problem in locations facing coastal erosion where restoration management have faced opposition (Harty, 2010).

Coastal erosion

Coastal erosion can be both the cause and result of mangrove and saltmarsh loss. As a threat agent, coastal erosion can result in habitat loss as well as increased turbidity and sediment degradation. Coastal erosion can be caused by recreational disturbance, adjacent land use (e.g. grazing, construction, watercourse change), past land use (e.g. to an extent that prevents restoration), flooding and adjacent water use e.g. boats exceeding 5 knot nearshore speed limits create wake which can accelerate erosion of channel banks (disturbing mangroves and saltmarsh (Boon et al., 2011). Mangroves are widely considered to reduce coastal erosion (see Boon et al., 2011 for a detailed description of how mangroves and saltmarsh facilitate stability).

Illegal activities

Illegal activities such as poaching, dumping of rubbish/waste, recreational vehicle use (Kelleway, 2006), illegal construction (e.g. private jetties), trampling (by stock) and pollution (including oil and chemical spill) can all detrimentally impact mangroves and saltmarsh.

4.1.4. Threatening Processes

The process through which the threats influence system structure, function and state, or condition

Eutrophication

The process whereby excessive dissolved nutrients (e.g. Bishop et al., 1992) promote algal blooms, leading to accumulation of decaying plant material, microbial build-up and oxygen depletion (Edgar, 2001). This is not to be confused with seasonal spikes in algal growth which are ephemeral in nature (e.g. *Ulva* spp. growth). Eutrophication in mangrove systems can result in smothering and loss of oxygen to roots (Edyvane, 1999), branches, trunks and sediments.

Reduced growth/function

Physical damage, diseases, nutrient changes, tidal pattern change and toxicity (e.g. from oil spill) can all lead to the reduced growth and or function of mangroves and saltmarshes.

Increased sedimentation

Adjacent land and water use, habitat degradation and sediment disturbance can all lead to increased sedimentation. This can bury pneumatophores, and smother epiphytes (e.g. microalgae).

Habitat loss

Loss of saltmarsh and mangroves occurs due to multiple sources including nutrient, industrial, and thermal pollution; changes in catchment processes, land subsidence, habitat disturbance, pests and disease and a number of indirect sources (e.g. coastal development) (Edyvane, 1999). Habitat loss directly impacts upon the species living in saltmarsh and mangrove habitats and the ecosystem services they provide.

Poor reproductive output

Toxicity, disease and increased grazing can all alter the reproductive output of mangroves and saltmarsh plants. Successful establishment of mangrove seedlings are impacted by sediment properties, cover of macroalgae, and physicochemical conditions (Clarke and Myerscough, 1993). Damage or toxicity to sediments can also detrimentally impact saltmarsh seed banks (Boon et al., 2011).

Pest/weed adults/juveniles/larvae/propagules/seeds

Terrestrial pests (e.g. goats, cattle etc.) can cause damage to inhabitants of saltmarshes and mangroves (e.g. birdlife)(Boon et al., 2011, Molloy et al., 2005) and by trampling sensitive sediments (e.g. foxes, dogs, feral cats)(Molloy et al., 2005, Boon et al., 2011). Weeds can outcompete native saltmarsh species e.g. *Lophopyrum ponticum* (Boon et al., 2011).

Sediment degradation

Degradation of sediments that can affect the health of saltmarsh and mangroves include: sediment compaction (Rogers et al., 2005), sediment disturbance (can expose acid sulphate soils, Price, 2006), sediment pollution (e.g. from oil spill), and sediment composition (including microorganims). Degradation of the sediment can compromise priority natural assets.

Overgrazing

Overgrazing by native species can occur to mangrove and saltmarsh plants e.g. where insect populations are not controlled (e.g. lower bird numbers eating insects), or by invasion/population increase of grazers. Overgrazing can compromise plant health (e.g. delaying reproduction).

Habitat damage/fragmentation

Multiple threat agents can result in damage/fragmentation to mangroves (as described in threat agent). In addition to these same threats, damage and saltmarsh loss/fragmentation can occur due to mangrove encroachment (Saintilan and Williams, 1999, Rogers et al., 2005). Introduced plants such as *Spartina* x *townsendii* can outcompete saltmarsh/mangrove plants isolating habitats (Bridgewater and Cresswell, 1999). Habitat damage and fragmentation can disturb species interactions and reduce connectivity (e.g. reducing macro to micro islands).

Disruption of food web/species interactions

Loss or damage to species in mangrove and saltmarshes can alter the species interactions (e.g. breeding behaviour), and food web interactions both by modifying detritus (drives mangrove and saltmarsh food webs, Boon et. al, 2011) and where other prey or predatory species may have different abundances shifting food webs (e.g. loss of large predators can increase numbers of grazing species).

4.1.5. Resulting Habitat Structure

The habitat structure that results from the combination of threats and drivers acting on a system and management responses

Large and micro-islands

These islands (e.g. at Nooramunga) offer habitat for significant vegetation and fauna, and potentially refuge from anthropogenic influences and pests (PV, 2011, Molloy et al., 2005).

Mangrove trees/canopy habitat

Mangrove trees create habitat for multiple species (e.g. birds, bats) through their trunk, branch (roosting habitats) and leaf structures (insect habitat). They also provide shade to the understorey through their canopy e.g. for intertidal crabs.

Pneumatophores/roots

Pneumatophores can be as dense as 10,000 per tree and provide habitat for a variety of marine invertebrates (e.g. barnacles and gastropods) and algae that are not able to colonise the surrounding soft sediments (Gwyther and Fairweather, 2002). Fish move into the mangrove environment (within roots and pneumatophores) during high tide as a refuge from predators and physical disturbance (Boon et al., 2011).

Saltmarsh shrub habitat/ground cover

Victorian saltmarshes contain a range of species which vary spatially depending on local factors (making up EVCs 9 and 10, see also additional types described in Boon et. al, 2010). Both physical habitat and food resources are provided by the plants making up saltmarshes including: spiders, insects, reptiles, birds and mammals (Boon et al., 2011, Harty, 2010).

Sediments

Sediments accrue around mangroves and saltmarshes and can provide habitat for many interstitial and burrowing marine invertebrates. Sediments are generally muddy in composition (Boon et al., 2011).

4.1.6. Natural Assets

PV-defined (PV, 2011), are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect. These overlap with the resulting habitat structure and indicators so are placed within the same layer in the habitat maps.

Nutrient cycling

Saltmarshes (Laegdsgaard, 2006, Boon and Cain, 1988) transfer oxygen to their roots and subsequently the soil starting the cycling of nitrogen. Mangroves also contribute to sediment nitrogen cycling (Boon and Cain, 1988) through the addition of detrital matter (e.g. leaves).

Ecosystem services

This includes services to fisheries (mangroves function as nursery habitat), services such as bioturbation (e.g. invertebrate detritivores), carbon sequestration, and coastal protection from erosion and waves (as summarised in Boon et al., 2011), attenuating nutrient run-off through water purification (Bridgewater and Cresswell, 1999, Boon et al., 2011). Primary production by mangroves (at Victorian latitude) has been calculated at 2 tonnes per hectare per year (Boon et. al 2010).

Habitat island refuges

See large and micro-islands above.

Saltmarsh EVCs and Estuarine Wetlands

Saltmarsh EVCs 9 and 10 are significant for biodiversity and habitat provision (Ross, 2000), additional categories are recommended by Boon et al. 2011 including estuarine wetlands.

Mangrove EVC

The mangrove EVC 140 comprises the mangrove species *Avicennia marina* ssp. *australica* (Ross, 2000, Boon et al., 2011). Components of this habitat and its role are described in resulting habitat structure above.

Terrestrial and marine biota

Many terrestrial and marine biota live in saltmarsh and mangrove habitats including fish (Smith and Hindell, 2005), birds (Loyn et al., 2001), reptiles, insects, and spiders (Laegdsgaard, 2006); see also Boon et al. (2011) and references therein for further detail on biota.

Threatened species

This refers to species of conservation concern including locally or regionally significant species, species at the extremes of their distribution and those listed on: Flora and Fauna Guarantee Act (FFG, 1988), Environment Protection and Biodiversity Act (EPBC, 1999), Victorian Rare or Threatened Species (VROTS), RAMSAR. In mangrove habitats these species include the Orange Bellied Parrot, the Swamp skink and the Lewin’s rail (PV, 2011, Boon et al., 2011).

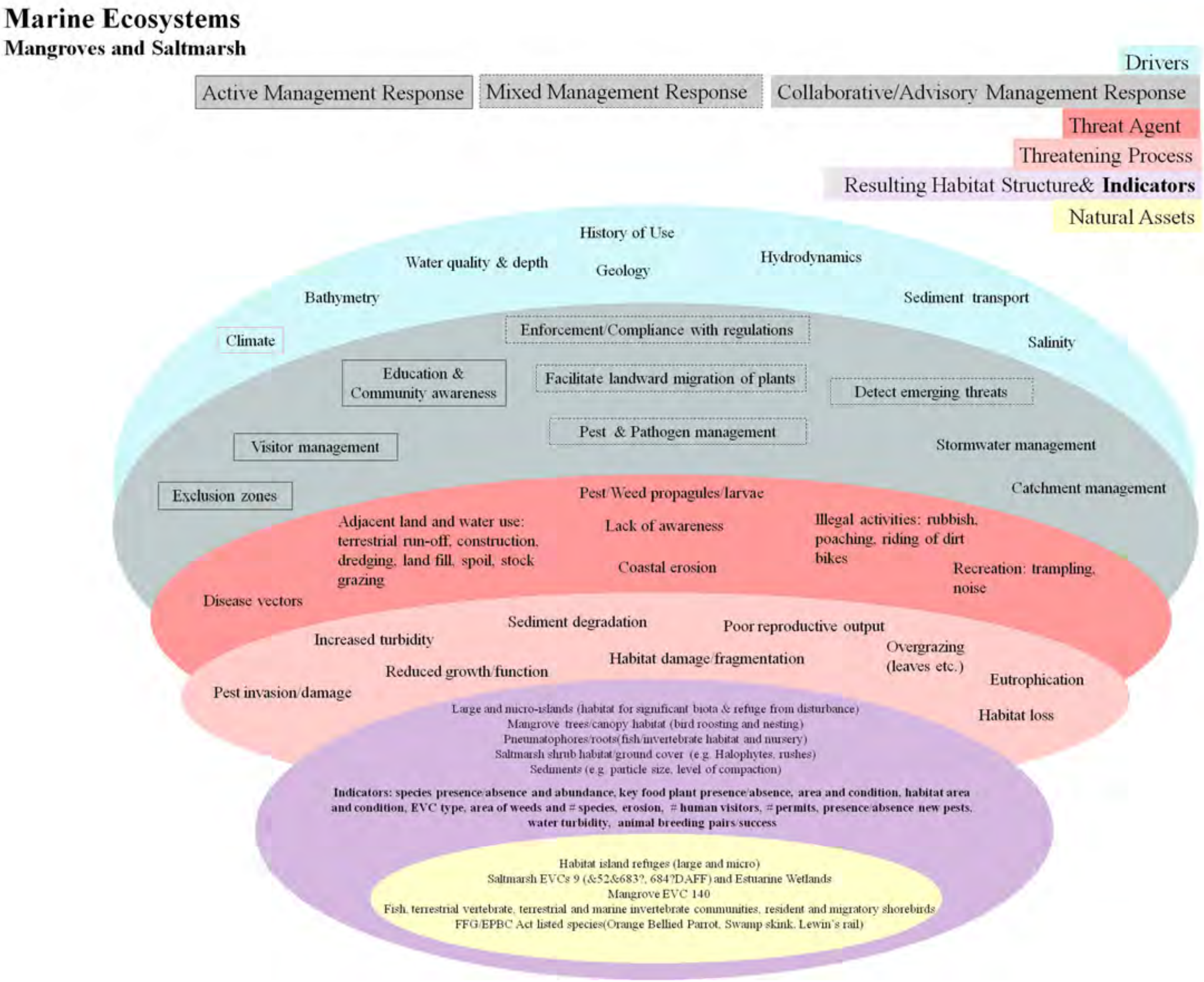


Figure 5 Conceptual Map of Mangroves and Saltmarsh in Victorian Marine Protected Areas

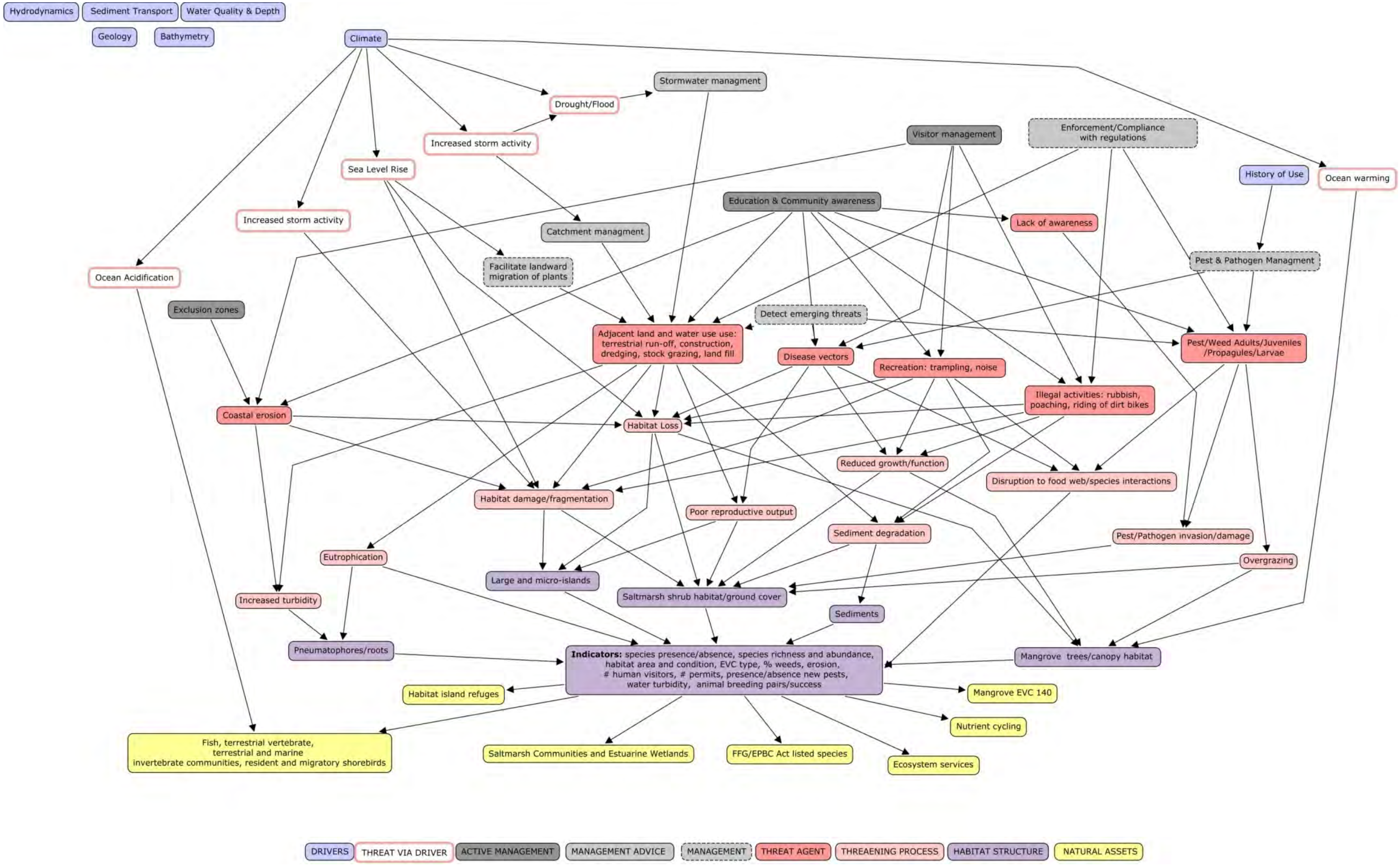
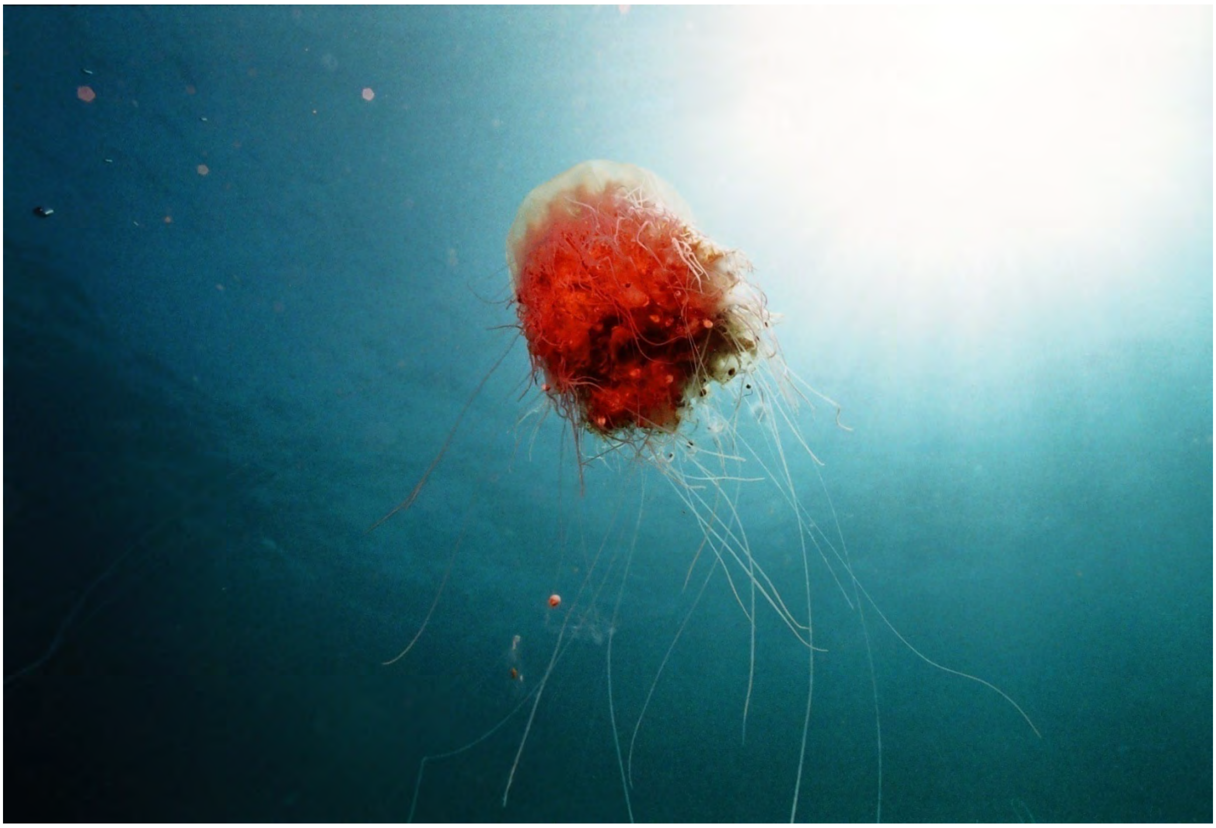


Figure 6 Conceptual Model of Mangroves and Saltmarsh in Victorian Marine Protected Areas

5. WATER COLUMN



Lion's Mane Jellyfish in water column (Beware Reef Marine Sanctuary) © Friends of Beware Reef

The water column (often referred to as the Pelagic zone) comprises all life within open water and the water column above other habitats such as reef and sandy bottom habitats. Important life in the water column includes plankton, nekton, migratory fish, cephalopods, mammals and seabirds. Plankton is the most abundant of organisms in the water column and includes: bacteria, gametes, larvae and marine algae (e.g. single celled diatoms). These make up a source of recruitment, and important food for a wide range of species and the phytoplankton creates a large portion of the earth's oxygen. Larger species common in the Victorian water column include sea jellies (e.g. *Catostylus mosaic*), baitfish (e.g. *Clupeidae/Engraulidae*), and the common dolphin (*Delphinus delphis*) among others. Productivity in the water column is driven by factors including seasonality, water quality, connectivity, light regime, bathymetry and hydrodynamics. The water column habitat is important for connectivity of marine populations (e.g. recruitment success and genetic diversity between reef animal populations that have planktonic reproduction). Some of the threats to the water column include water pollution (e.g. thermal pollution, heavy metal pollution, litter), stratification (e.g. nutrient, temperature, turbidity), and noise pollution (e.g. boat engine noise), and climate change threats such as sea temperature rise, and ocean acidification (can impact upon carbonated plankton such as diatoms). For a general review of the water column see Waite and Suthers (Ch12 in Connell and Gillanders, 2007). Water column habitats are found in all Victorian Marine National Parks and Marine Sanctuaries (PV, 2003d, PV, 2003a, PV, 2005c, PV, 2005b, PV, 2005a, PV, 2006e, PV, 2006b, PV, 2007g, PV, 2007f, PV, 2007b, PV, 2007a, PV, 2007e, PV, 2007c, PV, 2006g, PV, 2006c, PV, 2006d, PV, 2006a, PV, 2007d).

5.1. Definitions specific to Water Column

5.1.1. Drivers

The things that determine the distribution of habitats, and the main factors that act in these systems to influence their state or condition

Climate

Natural climate events such as seasonality (e.g. migration of blue whales, seasonal fluxes of schooling fish) and El Nino/La Nina weather patterns (if water column habitat is close enough to coast to be influenced by flood/drought) may alter biodiversity and reproduction in the water column.

Climate change (Sarmiento et al., 2004):

- Water Temperature: ocean warming (Hobday et al., 2006) can affect currents (e.g. changes in East Australian Current, Ridgway, 2007), and increased sea surface temperatures may also lead to changes in plankton such as increased plankton blooms (Hobday et al., 2006), and the increased success of pest invasions and competitive species from warmer temperate areas.
- Wind change (e.g. as a result in increase in storms/extreme weather) can affect upwellings (e.g. Bonney upwelling in western Victoria, Butler et al., 2002a, Bakun, 1990, Barth et al., 2007, Hsieh and Boer, 1992, Nieblas et al., 2009) leading to changes in species patterns and productivity.
- Ocean acidification may have major impacts on calcified biota in the water column (e.g. diatoms and zooplankton).

Water Quality

An important aspect of water quality (especially on whales, Gill et al., 2011) is water temperature variation through upwelling (e.g. Bonney upwelling in western Victoria, Butler et al., 2002a, Bakun, 1990, Barth et al., 2007, Hsieh and Boer, 1992, Nieblas et al., 2009). Upwellings can drive productivity (increased phytoplankton biomass) enhancing biodiversity (and flow-on effects up the food chain) and species abundance/interactions in the water column. Nutrient levels, oxygenation and stratification influence water quality.

Connectivity

The connectivity of the water column is important for recruitment, food supply (Fancett and Jenkins, 1988), and movement of marine organisms. Threats to connectivity can have detrimental impacts to species occupying the pelagic and benthic areas of the marine environment.

History of Use

Distance to pollution source, previous degradation, and oil/fuel/chemical spills prior to protection or nearby MNP/MS can impact on the health of the water column and the time it may take for recovery. This is most relevant to water columns where low/slow flushing rates occur.

Hydrodynamics

This includes water flow through wave action, tides, upwellings and currents (Denny and Wethey, 2001).

Bathymetry

This influences upwelling (shape of the coastal shelf) can drive hydrodynamics and determine habitat availability of the water column.

Light penetration

Light penetration at sub-surface and through the deeper layers of the water column can influence both plankton growth and species behaviour (e.g. species will alter behaviour in response to altered light regime – nocturnal patterns etc.). Light penetration may also be influenced by turbidity (Carey et al., 2007b), flotsam (e.g. large aggregations of sea jellies, litter) and even to a lesser extent changes in cloud cover (likely to be stochastic).

5.1.2. Management

Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes. Three management types are given – Active, Mixed and Collaborative/Advisory.

All management of Marine National Parks and Marine Sanctuaries is documented in the PV Management Plans. The plans that contain water column specific management are: Barwon Bluff, Bunurong, Corner Inlet, Eagles Nest, Merri, Jawbone, Mushroom Reef, Port Phillip Heads, Pt Addis, Twelve Apostles & The Arches, Pt Cooke, Pt Danger, Ricketts Point, and Western Port Bay, Beware Reef, Cape Howe, Marengo, Point Hicks (PV, 2003d, PV, 2003a, PV, 2005c, PV, 2005b, PV, 2005a, PV, 2006e, PV, 2006b, PV, 2007g, PV, 2007f, PV, 2007b, PV, 2007a, PV, 2007e, PV, 2007c, PV, 2006g, PV, 2006c, PV, 2006d, PV, 2006a, PV, 2007d).

Active Management

Refers to direct management actions/response undertaken by PV (and the responsibility of)

Education & Community awareness

Support education on the impacts of behaviour in the marine environment on the water column focusing on noise, pollution, pest/pathogen spread, interaction with wildlife, vehicle regulations (PV, 2005b).

Visitor management

In addition to general marine habitats communicate with visitors (boat users) to make them aware of specific behaviours that impact on the water column (e.g. noise, litter, driving boats too close to cetaceans, seals and seabirds). Liaison with surfing groups/tourism operators regarding events, water quality, and visitor numbers (PV, 2005b).

Exclusion zones

Enforce via patrols and signage sail power only restriction zone in Pt Danger MS (PV, 2005b). Enforce via patrols, signage and education speed restrictions of water vehicles at distance to: shore (possible increased turbidity), other vessels (reduce collision risk PV, 2005b).

Mixed Management

Includes direct action from PV in addition to direct action by other agencies (e.g. DSE, EPA), or as a support to other agencies

Pest & Pathogen management

In relation to shipping and boat use work with other agencies (e.g. EPA Waste Management Policy 2004) to prevent or minimise risk of pest/pathogen spread (PV, 2005b). This includes maintaining PV vessels, gear and infrastructure (e.g. buoys) to prevent marine pest/pathogen incursions (PV, 2005b). Work in collaboration with DSE on prevention, and also eradication programs where required.

Enforcement/Compliance with regulations

In addition to general marine habitats, enforce and/or support other agencies to enforce compliance with and education on regulations for vessel and human interaction with marine mammals (e.g. speed and distances, PV, 2005b). Support EPA to encourage responsible waste disposal by vessels by providing/maintaining waste receiving/pump out facilities at marinas (PV, 2005b).

Detect emerging threats

Work with other agencies to detect (and respond where necessary) emerging threats such as point-source pollution, oil spill (Response plan to deal with Wildlife affected by and Oil Spill, CNR 1994)(PV, 2005b), port operations, cetacean stranding/entanglements (Victorian Cetacean Contingency Plan)(PV, 2005b), loss of key species in nearby waters (e.g. wrasse, rock lobster: work with Fisheries to help interpret monitoring data for MPAs).

Collaborative/Advisory Management

Is where PV can take an advisory role (e.g. for planning applications that impact on the marine environment) or assist other agencies indirectly (e.g. contacting relevant agency if a threat is observed/advised to staff by member of the public).

Stormwater management

Work with and share information with local councils, Melbourne Water, other water authorities and relevant agencies on reducing impacts to the marine environment through better stormwater management (PV, 2006e), for example sharing information about the effects of litter on marine biota.

Catchment management

Work with and share information with CMAs and relevant agencies to improve catchment management (Poore, 1982), and reduce the impacts of land based activities on the MPAs such as nutrient inputs, sedimentation, herbicide, and pesticide input etc. (PV, 2006e). Where NPs exist in the catchment PV can take more active catchment management e.g. rehabilitating riparian zones.

5.1.3. Threat Agent

The past and present activities (and other factors) that influence ecosystem structure, function, state or condition

Pollution

Includes litter, heavy metals, oil spill, petrol spill, other chemical spills, illegal dumping of sewerage/litter from vessels (SEPP and ANZECC guidelines are the current regulations on pollution), most water pollution is managed by the EPA, Melbourne Water (in Port Phillip Bay) or in the case of oil/chemical spills the Department of Transport (PV, 2006e).

Adjacent land and water use

Loss of key species (e.g. edge fishing, Carey et al., 2007b, may impact species interactions/recruitment/foraging within MPA), dredging, building, and shipping can all detrimentally impact the water column in the marine protected area e.g. by introducing pollutants, disturbing species (e.g. noise), altering channels which can change hydrology.

Pathogen/disease vectors

These can be introduced via movement of ballast discharge (if not done correctly or at sufficient distance from MPA, Waste Management Policy, EPA 2004), discarded fishing gear/bait, unwashed recreational equipment and vessels (PV, 2006c).

Pest adults/juveniles/larvae/propagules

Can be introduced to a park via natural movement, movement of ballast discharge (if not done correctly or at sufficient distance from MPA, Waste Management Policy, EPA 2004), discarded fishing gear/bait, unwashed recreational equipment and vessels.

Noise

Loud noise from vessels, people, industry (e.g. shipping, port operations), and construction can impact species behaviour and interactions (e.g. as discussed by Jung and Swearer, 2011). This can be especially evident in species using echolocation such as dolphins (PV, 2011).

Vessel collision with animals

There is a risk of water vessel collision with animals from shipping, boating, and personal water craft. This can result in injury or death to animals e.g. seals (Carey et al., 2007b).

Lack of awareness

Awareness could prevent many threats to the water column. Many human behaviours both inside and outside of a MPA can detrimentally impact MPA natural assets (e.g. litter, noise) and raising awareness within the community can lead to behaviour change thereby reducing the incidence of these threats (Roggenbuck, 1992).

Illegal activities

Illegal activities in MPAs such as poaching and pollution can be detrimental to MPA natural assets such as maintaining biodiversity. Pollution to the water column including water pollution (heavy metals etc.) and litter (especially fishing line which can entangle and small plastics which can be ingested) can damage the health of many species living in the water column.

Coastal erosion

Coastal erosion can lead to an increase in water turbidity (Carey et al., 2007b) which can affect the foraging behaviour of mobile species (Granqvist and Mattila, 2004), and light penetration for phytoplankton, and can impact upon underlying benthic ecosystems (PV, 2011).

Catchment inputs and discharges

Inputs from the catchment and discharges (e.g. stormwater) can cause pollution of MPAs through the introduction of nutrients (e.g. from agricultural run-off) and chemicals (e.g. from road run off and agricultural pesticides/herbicides) into the water from run-off (Carey et al., 2007a).

5.1.4. Threatening Processes

The process through which the threats influence system structure, function and state, or condition

Eutrophication

The process whereby excessive dissolved nutrients (e.g. Bishop et al., 1992) promote algal blooms, leading to accumulation of decaying plant material, microbial build-up and oxygen depletion (Edgar, 2001). This is not to be confused with seasonal spikes in algal growth which are ephemeral in nature (e.g. *Ulva* spp. growth). Severe eutrophication can lead to fish kills.

Reduced growth/fecundity/function

Climate change (as change in sea surface temperature) has been shown to affect the fecundity of many seabirds (mostly timing of breeding) with positive and negative impacts on the little penguin common to Phillip Island (Cullen et al., 2009). Reduced growth/fecundity and/or function can result from multiple threatening agents (e.g. pollution leading to reduced feeding success), and can result in the loss of priority natural assets such as connectivity and biodiversity.

Increased turbidity

Reduced clarity in the water column as a result of increased turbidity can lead to the disruption of feeding and species interactions especially in species that rely on sight (e.g. Granqvist and Mattila, 2004).

Pest invasion

The invasion of marine pests can lead to increased competition for resources (e.g. competition for prey), competition for habitat (less room for foraging/interacting), and even species loss (direct predation) (both in and outside the MPA, e.g. foxes prey upon penguins while on land, Carey et al., 2007b).

Disruption of foraging/species interactions

Disruption of foraging behaviour and other species interactions such as breeding can occur as the result of a range of threats e.g. marine pest invasion, increased turbidity, stratification of the water column (nutrient/thermal) and pollution.

Disruption to food web

This can result from the loss or increase of species within the marine food web (poaching or via loss of adjacent key species. For example removal of small fish (e.g. anchovy) from a park may reduce the breeding population and cause flow on effects to other species that predate upon them in the short-term and in following seasons. Disruption to the productivity of phytoplankton (e.g. light pollution, toxicants) can severely disrupt pelagic food webs as they are the base of the food chain (Connell and Gillanders, 2007).

Population decline

Lack of food, disruption of species interactions, poaching, removal by marine pests, and health decline (disease, injury) of species can all lead to a decline in the population of species inhabiting the water column (Carey et al., 2007b).

Disease/pathogen spread/infection

Resulting from disease/pathogen vectors, this can lead to reduced health, disruption to species interactions (including breeding and feeding) and even death (reducing populations).

Injury/death to animal

Tangling in litter, ingestion of litter/pollutants, and being struck by water vessels can all lead to the injury or death to marine animals (including birds, fish and mammals).

Reduced primary productivity

Loss of phytoplankton can break down the food web (Connell and Gillanders, 2007).

5.1.5. Resulting Habitat Structure and Indicators

The habitat structure that results from the combination of threats and drivers acting on a system and management responses

Resident planktonic and pelagic species

Seals (Australian, PV, 2006c), penguins and other seabirds (PV, 2006c), resident fish (may be loosely reef associated by spend most of their time in water column, PV, 2006c), zooplankton, phytoplankton, and sea jellies (Fancett and Jenkins, 1988).

Migratory pelagic species (where they spend a key part of the their life cycle in the MPAs or have important breeding or haul out sites in the MPAs)

Whales (Southern Right, Humpback, Killer, Blue (at Discovery Bay MNP, PV, 2006c, PV, 2006g)), dolphins, (bottlenose and common at Pt Nepean, Gill et al., 2011), Australian and New Zealand fur seals (PV, 2006c), some species of fish e.g. Great White Sharks, Herring Cale (PV, 2006c), planktonic larvae/gametes that disperse across large distances.

Water quality and nutrient content

Clarity (important for maintaining benthic and water column productivity), nutrients/micronutrients, temperate extremes, and salinity (PV, 2011) must all be at healthy levels (within SEPP/ANZECC guidelines) to allow maintenance of other priority natural assets.

Primary Productivity

In this habitat productivity is primarily from phytoplankton in the water column and on the water surface (Connell and Gillanders, 2007).

5.1.6. Natural Assets

PV-defined (PV, 2011), are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect. These overlap with the resulting habitat structure and indicators so are placed within the same layer in the habitat maps.

Nutrient cycling

This occurs though the pelagic food web. From phytoplankton utilizing nutrients from the water for growth, that then act as the base of the food web, they cycle continues as detritus/waste from higher organisms is released back to the water column providing nutrients for further phytoplankton growth.

Ecosystem services

Includes primary productivity (below), and broader ecosystem services such as maintenance of climate, supply of larvae and genetic diversity to species occurring outside of MPAs that may be used for a range of purposes.

Iconic species

Includes sharks (e.g. Great White), whales (e.g. Blue Whales in Discovery Bay) and dolphins ((e.g. bottlenose and common, PV, 2006g, Gill et al., 2011, PV, 2006c), seals and seabirds. This also refers to species of conservation concern including locally or regionally significant species, species at the extremes of their distribution and those listed on: Flora and Fauna Guarantee Act (FFG, 1988), Environment Protection and Biodiversity Act (EPBC, 1999), Victorian Rare or Threatened Species (VROTS), RAMSAR.

Primary productivity

In this habitat productivity is primarily from phytoplankton in the water column and on the water surface (Connell and Gillanders, 2007).

Acoustic integrity

An area without human introduced noise (e.g. construction, shipping) allows for natural acoustic interaction between marine organisms (PV, 2011).

Connectivity

Good connectivity ensures food availability (Fancett and Jenkins, 1988) genetic diversity, migration, dispersal, nutrient fluxes and good levels of reproductive success (PV, 2011).

Water quality

Clarity (important for maintaining benthic and water column productivity), nutrients/micronutrients, temperature extremes, and salinity (PV, 2011) must all be at healthy levels (within SEPP/ANZECC guidelines) to allow maintenance of other priority natural assets.

Foraging habitat

These areas need to be maintained in good condition to ensure they remain suitable habitat and foraging areas for many pelagic species (PV, 2011).

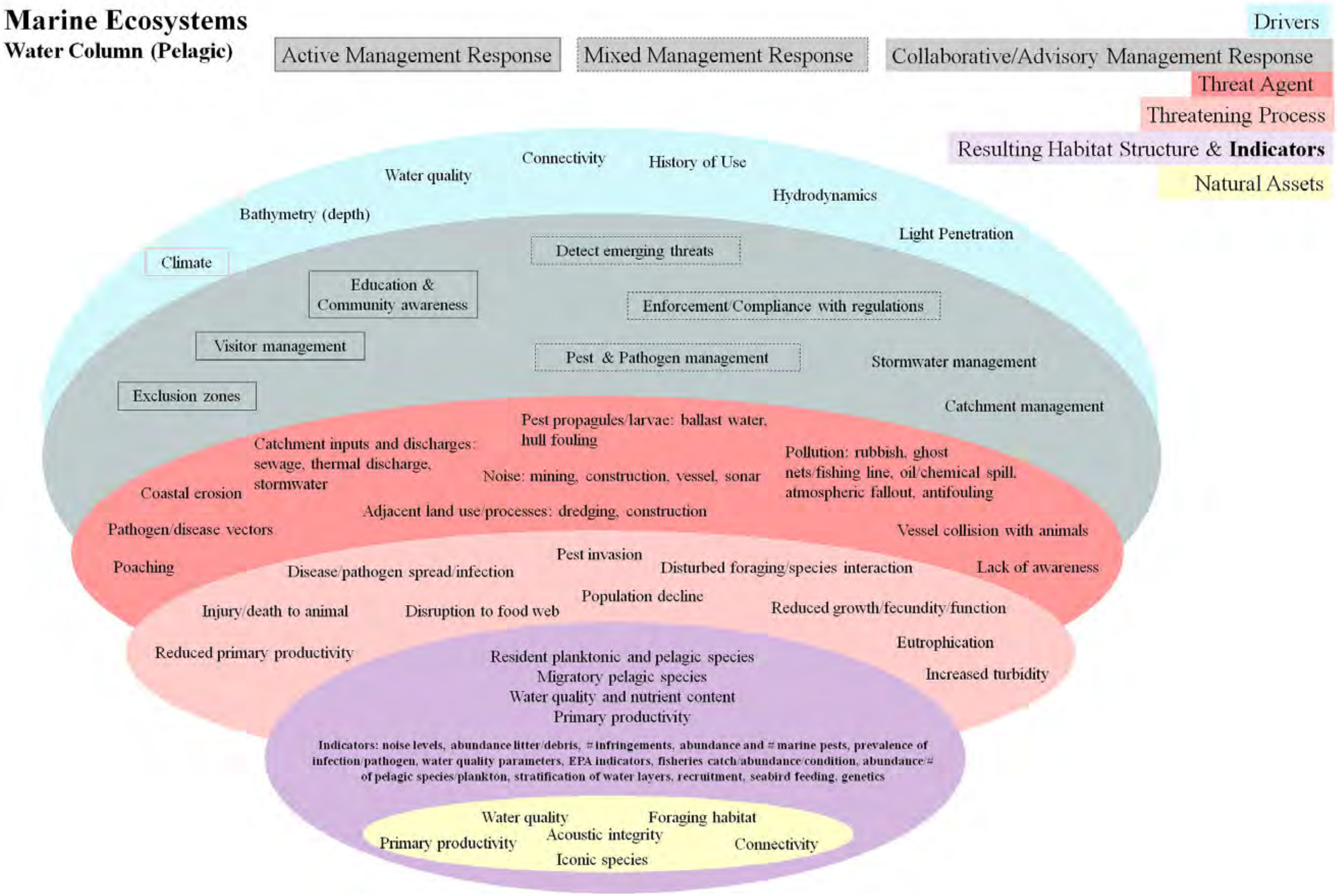


Figure 7 Conceptual Map of Water Column in Victorian Marine Protected Areas

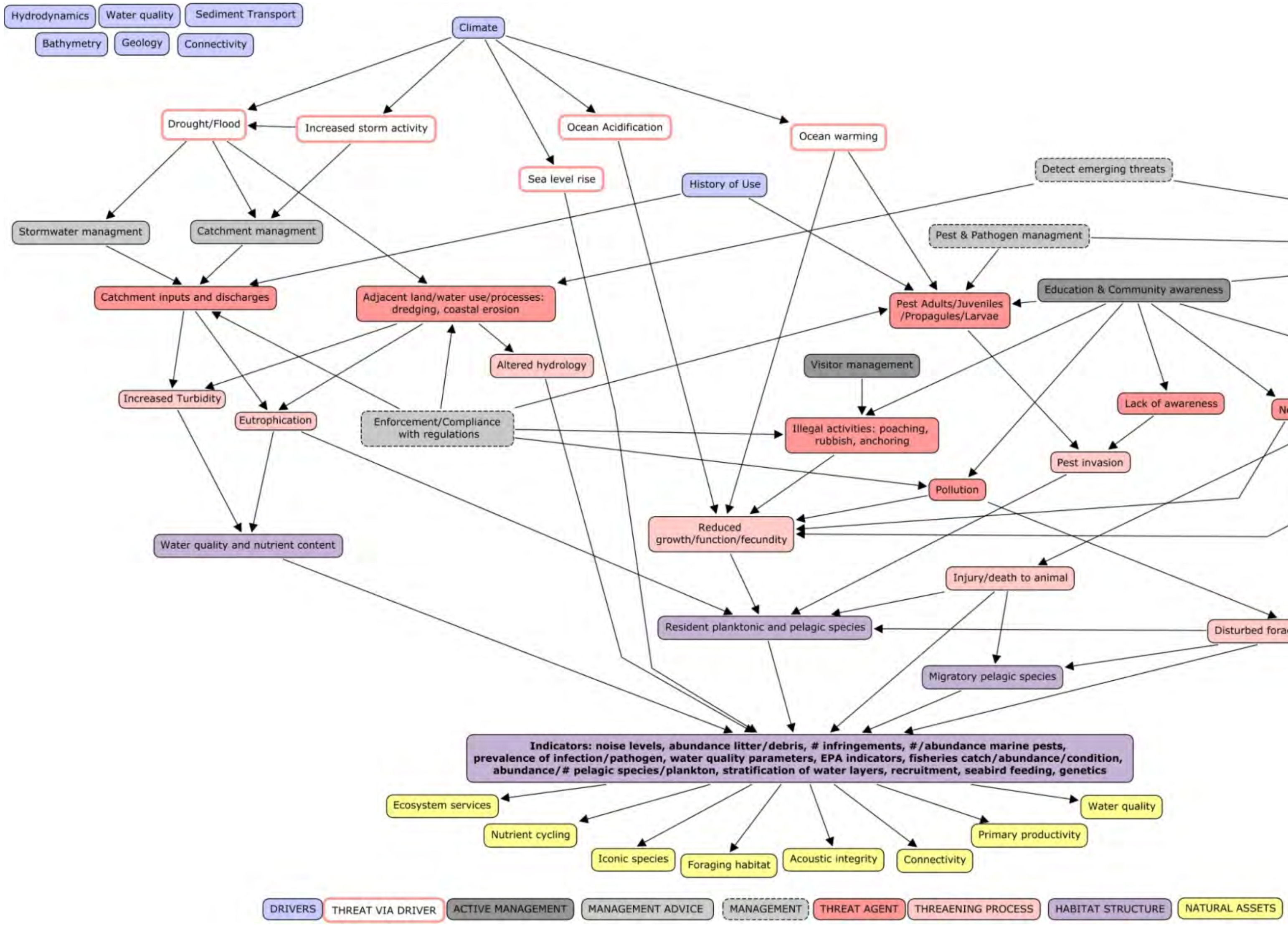


Figure 8 Conceptual Model of Water Column in Victorian Marine Protected Areas

6. SOFT SEDIMENTS

Exposed Mud flat (Churchill Island Marine National Park) © Parks Victoria

This marine habitat includes intertidal and subtidal benthic areas made up of soft sediments (mud, silt, shell grit, and sand). The species occupying this habitat include species that live on the sediment benthos (e.g. sea pens, soft coral, microphytobenthos, waders and shorebirds, sting rays, bottom dwelling fish, burrowing cephalopods etc.), infauna (organisms that live within the sediment) and meiofauna (organisms that live between the sediment grains). Although technically seagrass and mangroves are soft-sediment habitats they have been considered individually in this report as they make up their own significant habitat types.

The major ecosystem services of soft sediments include primary production by microphytobenthos and nutrient cycling (e.g. ghost shrimp, *Callianassa*, as bioturbators of shallow mud). Threats to soft sediment habitats include pollutants from oils, chemicals, agricultural run-off (fertilizers, pesticides/herbicides), illegal activities (e.g. bait pumping, dumping of spoil), disturbance (e.g. propeller scour and trampling), and coastal erosion (additional sediments).

Soft sediment habitats are important feeding grounds for migratory (e.g. many RAMSAR species) and resident shorebirds that feed on the variety of polychaetes (e.g. Capitellids), crustaceans (e.g. amphipods, crabs) and molluscs (e.g. bivalves) living on and within soft-sediments (Keough et al., 2012). Benthic fish including flat head, flounder, rays and skates are common in soft sediment habitats as are burying cephalopods such as dumpling squid (*Euprymna tasmanica*) and the southern sand octopus (*Octopus kaurna*). Soft sediment habitats around found in all Victorian Marine National Parks and Marine Sanctuaries PV, 2006 #1088}(PV, 2006g, PV, 2007a, PV, 2006e, PV, 2005b, PV, 2007b, PV, 2005c, PV, 2006d, PV, 2006c, PV, 2007d).

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6.1. Definitions specific to Soft Sediments

6.1.1. Drivers

The things that determine the distribution of habitats, and the main factors that act in these systems to influence their state or condition

Climate

Natural climate events such as seasonality and El Nino/La Nina weather patterns can alter species assemblages for example from increased flooding entering the marine environment bringing pollutants, sediment and lowering salinity.

Climate change (see Brown, 1987, Whetton et al., 2001):

- Increased water temperatures (for instance from global warming) can detrimentally impact upon soft-sediment species (e.g. on flat fish, Lowthion, 1974). Water temperature increase may also lead to the increased success of pest invasions and competitive species from warmer temperate areas.
- Sea level rise can impact upon intertidal soft-sediment habitats and beaches, especially where there is no-where for them to retreat due to adjacent land use (called "coastal squeeze" Schleupner, 2008).
- Air Temperature extremes: this can impact upon intertidal assemblages (e.g. soldier crabs) by stressing their physiology and reducing their foraging capacity.
- Ocean acidification: this can impact on infauna and benthic invertebrates
- Increased extreme weather (e.g. storms): this can result in sediment re-suspension and movement, and changes in catchment related inputs which could lead to altered nutrient and sediment loads.

Water Quality

Salinity and temperature of the water column can impact upon species assemblages (e.g. high temperature and salinity negatively impact upon flat fish, Lowthion, 1974), turbidity of the water can impact upon the resident species assemblages (e.g. predator foraging and light for benthic algae). Increased nutrients and pollutants (e.g. heavy metals, pesticides) also decrease water quality.

History of Use

Past pollution, catchment practice and history, erosion and incidence of marine pests can all influence the current community composition and its ability to be rehabilitated.

Hydrodynamics

The hydrodynamics (see Denny and Wethey, 2001) can influence the community assemblage found in an area e.g. sponges that require faster water movement for filter feeding, and microphytobenthos that require low levels of water movement and mixing to allow persistence.

Bathymetry

The depth and shape of the seabed (Guichard and Bourget 1998) can influence the hydrodynamics of a particular area (e.g. intertidal/subtidal) resulting in different site-specific soft-sediment habitats.

Light Penetration

Light penetration occurring in the habitat can directly impact upon the resulting benthic species assemblage. Many locations with muddy or silty sediments may be subject to higher levels of water turbidity (Carey et al., 2007b) which can result to a shaded benthic environment and alter benthic community structure and dynamics (Jumars and Nowell, 1984) for microphytobenthos and potentially bottom dwelling fish.

6.1.2. Management

Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes. Three management types are given – Active, Mixed and Collaborative/Advisory.

All management of Marine National Parks and Marine Sanctuaries is documented in the PV Management Plans. The plans that contain soft sediment specific management are: Twelve Apostles & The Arches, Merri, Barwon Bluff, Bunurong, Corner Inlet, Eagles Nest, Jawbone, Port Phillip Heads, Pt Addis, Pt Cooke, Pt Hicks, Ricketts Point, Cape Howe and Western Port Bay (PV, 2006a, PV, 2006g, PV, 2007a, PV, 2006e, PV, 2005b, PV, 2007b, PV, 2005c, PV, 2006d, PV, 2006c, PV, 2007d).

Active Management

Refers to direct management actions/response undertaken by (and the responsibility of) PV

Education & Community awareness

Support education on the value of soft sediment habitats and how to minimise threats such as anchor damage, propeller scarring, erosion from trampling and boat wake, and other pollution sources. Signage at boat launching areas, and leaflets at fishing supplies stockists can assist education of some community members. Education through groups such as the Marine Discovery Centre and Dolphin Research Institute can also assist with improved community awareness. See also (Scales, 2006, Alcock, 1991, Blayney and Westcott, 2004, Alcock and Zann, 1996, Alessa et al., 2003, De Young, 1993, Dwyer et al., 1993, Floyd et al., 1997, Jelinek, 1990, Leigh, 2005, Goffredo et al., 2004, Howe, 2001, Micheli et al., 2004):

Visitor management

Ways of managing visitors (James 2000) can include the provision of boat launching areas, signage and taped off areas of beach to prevent physical and noise disturbance caused by people, dogs and jet skis to breeding birdlife (e.g. hooded plovers and other shorebirds and waders, Weston, 2003).

Exclusion zones

These can include areas such as in Swan Bay where anchoring is not permitted to prevent anchor disturbance (PV, 2006e). Fencing on sand dunes and at water access points can prevent intertidal disturbance (e.g. disturbance of burrowing penguins).

Mixed Management

Includes direct action from PV in addition to direct action by other agencies (e.g. DSE, EPA), or as a support to other agencies.

Pest & Pathogen management

Pest and Pathogen management includes investigating reports of outbreaks, reducing activities that increase the threat of pest/pathogen spread (through education/enforcement), and working with other agencies (e.g. DSE, DPI) who monitor and detect emerging pest and pathogen related threats and to lessen impacts to ecosystems through containment/removal of threat where possible. Liaison with agencies managing nearby waters is essential to reducing threat of pest and pathogen spread.

Enforcement/Compliance with regulations

Surveillance of human activities and imposing penalties (in partnership with Fisheries in terms of poaching, and/or EPA in terms of pollution) to enforce regulations including poaching (e.g. fishing, bait pumping) fossicking, dog access on beaches, vehicle access, anchoring in exclusion zones, and dumping of rubbish.

Detect emerging threats

Emerging threats and issues can be identified through appropriate surveillance and monitoring undertaken by PV directly (through contractors, PV staff, Sea Search) and in partnership with other agencies such as EPA, DSE, Melbourne Water, CMAs and community partners such as Birdlife Australia. Surveillance and monitoring techniques, analysis, modelling and reporting should be kept up to date and reflect best current practice by amending as necessary (see also overarching management) in consultation with experts, with clear objectives for conservation outcomes. Detection of emerging threats is currently also addressed by filling knowledge gaps through The Research Partners Panel Programs to continually improve the identification and mitigation of threats to conservation values (for additional reading on conservation values see Constable, 1991, Gerber et al., 2005, Gray and Jensen, 1993, Fairweather, 1990a, Keough and Quinn, 1991, Underwood, 1995b).

Collaborative/Advisory Management

Where PV can take an advisory role (e.g. for planning applications that impact on the marine environment) or assist other agencies indirectly (e.g. contacting relevant agency if a threat is observed/advised to staff by member of the public).

Stormwater management

Work with and share information with councils, Melbourne Water, and other relevant water authorities and agencies on reducing impacts to the marine environment through better stormwater management (PV, 2006e), for example sharing information about the effects of litter on marine biota.

Catchment management

Work with and share information with CMAs and relevant agencies to improve catchment management (Poore, 1982), and reduce the impacts of land based activities on the MPAs such as nutrient inputs, sedimentation, herbicide, and pesticide input etc. (PV, 2006e). Examples include: revegetation of riparian zones and sand dunes to reduce erosion and sediment run-off. Where NPs exist in the catchment PV can take more active catchment management e.g. rehabilitating riparian zones.

6.1.3. Threat Agent

The past and present activities (and other factors) that influence ecosystem structure, function, state or condition

Pollution

In addition to general pollution types (e.g. oil spills, chemical spills, nutrient run-off), sediments can accumulate toxins such as heavy metals (Carey et al., 2007b). Preventing these entering soft-sediment habitats is a priority.

Adjacent land and water use

What happens outside marine protected areas in many cases directly influences marine protected areas. This can include dredging, construction, terrestrial run-off, land fill, spoil, stock grazing, and removal of shore vegetation (among others). These threatening agents can result in a multitude of threatening processes within a marine protected areas (see DSE, 2009, Raventos et al., 2006, Bishop et al., 1992).

Pathogen/Disease vectors

In addition to the definition in general marine habitats, disease vectors include terrestrial diseases for birds (Greenberg et al., 2006). These may be spread through insects (e.g. mosquitoes), birds and other mobile fauna (Greenberg et al., 2006).

Pest adults/juveniles/larvae/propagules

Pest larvae that have led to introductions of marine pests in Victoria include the bivalves *Corbula gibba* (Talman and Keough, 2001), *Musculista senhousia (*Asian Mussel), *Theora lubrica* (East Asian Bivalve); the European fan worm (Currie et al., 2000), the Northern Pacific Seastar and a range of colonial invertebrates (Cohen et al., 2000). These can be dispersed to Victorian waters by shipping (e.g. sea chests, hull fouling; Coutts et al., 2003).

Lack of awareness(see James, 2000)

Improved community awareness can mitigate many of the threats to soft-sediment habitats including using correct access points, and not disturbing biota. Improvements to the condition of habitats can be assisted by an aware and actively involved community (e.g. Great Ocean Road Coast Committee).

Illegal activities

Poaching (e.g. fishing, bait-pumping; James, 2000), pollution from vessels and anchoring (and other physical damage) in no-anchor areas all contribute to the loss and damage of marine life within soft-sediment habitats.

Disturbance

Disturbance to soft sediment habitats includes noise disturbance (e.g. to waders and shorebirds); physical damage such as trampling (James, 2000), propeller scar, anchoring and boat wake close to shore (which can cause erosion of sediments).

Coastal erosion

Erosion of the coast can occur through unrestricted or illegal trampling and use of off-road vehicles (James, 2000). The loss of coastal vegetation can also cause erosion as sediments are subjected to transport from high winds/storms (this can be mitigated somewhat by revegetation work).

6.1.4. Threatening Processes

The process through which the threats influence system structure, function and state, or condition

Eutrophication

The process whereby excessive dissolved nutrients (e.g. Bishop et al., 1992) promote algal blooms, leading to accumulation of decaying plant material, microbial build-up and oxygen depletion (Edgar, 2001). This is not to be confused with seasonal spikes in algal growth which are ephemeral in nature (e.g. *Ulva* spp. growth).

Reduced growth/fecundity/function

Physical damage, noise/disturbance, diseases, nutrient changes, tidal pattern change and toxicity can all lead to the reduced growth and or function of soft sediment biota.

Disruption to sediment transport/turbidity

Adjacent construction (James, 2000), boat wake causing localised erosion, pollution and proximity to terrestrial inputs (creeks, drains etc.) can disturb the transport of sediment within a soft sediment habitat and lead to increased turbidity.

Sediment/geomorphological feature damage

Physical disturbance from propeller scars, dredging or erosion can lead to the damage of sediments (e.g. compaction) and geomorphological feature damage. This can lead to these features and their associated becoming locally lost.

Pest invasion

Several marine pests have invaded Victoria’s soft sediment habitats including the European fan worm (Currie et al., 2000), northern pacific sea star (Cohen et al., 2000) and the exotic bivalves *Corbula gibba* (Talman and Keough, 2001), *Theora lubrica* and *Musculista senhousia*. These pests can impact upon the biota in soft sediment habitats through predation on resident species, and competition for resources (e.g. impact of exotic clam on local scallops, Talman and Keough, 2001).

Disease/pathogen spread/infection

Pathogen and disease vectors can lead to the incidence of disease, local spread and infection of biota within soft sediment habitats (Carey et al., 2007b).

Disruption of food web/species interactions

All threat agents listed can lead to disruption of the food web and species interactions within soft sediment habitats whether by altered resource availability, loss of individuals or loss of species functions.

Population loss/species decline

All of the threat agents listed can lead to population loss and species decline. An example is by trampling on intertidal areas killing intertidal crabs (James, 2000) or abandonment of nests by shorebirds.

6.1.5. Resulting Habitat Structure

The habitat structure that results from the combination of threats and drivers acting on a system and management responses

Geomorphological features

Examples of important geomorphological features include: Portsea Hole, Swan Bay, and Mud Islands (PV, 2011, Carey et al., 2007b, PV, 2006e).

Intertidal muddy soft sediment (ParksVIC 2011)

This is an important habitat for infauna (e.g. bivalves, marine worms, Heislers and Parry, 2007, Butler and Bird, 2010) and benthic biota (e.g. demersal fish, microphytobenthos) as well as an important feeding area for shorebirds and waders (Loyn, 1978, PV, 2002, PV, 2003d, PV, 2003a).

Intertidal sandy soft sediment

This is an important habitat for infauna (e.g. bivalves, marine worms; Butler and Bird, 2010, Heislers and Parry, 2007) and benthic biota (e.g. demersal fish, Parry et al., 1995) as well as an important coastal bird feeding area (Loyn, 1978, PV, 2002, PV, 2003d, PV, 2003a, PV, 2011)

Shallow subtidal soft sediment

This is an important habitat for invertebrates (Heislers and Parry, 2007, Butler and Bird, 2010, Coleman et al., 1997, Poore and Rainer, 1974), shorebirds, demersal fish (Parry et al., 1995), microphytobenthos and nutrient cycling (PV, 2011).

Deep subtidal soft sediment

This is an important habitat for invertebrates (Heislers and Parry, 2007, Poore and Rainer, 1974), demersal fish (Parry et al., 1995) and high species diversity (Coleman et al., 1997, PV, 2011).

6.1.6. Natural Assets

PV-defined (PV, 2011), are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect. These overlap with the resulting habitat structure and indicators so are placed within the same layer in the habitat maps.

Nutrient cycling

This includes the cycling of chemicals such as nitrate, phosphate, carbon (through food webs) and nutrient regeneration (where organic matter derived from decomposing organisms release nutrients, Arrigo, 2005, Castro and Huber, 2008, Boon and Cain, 1988). An example of nutrient regeneration on soft sediment intertidal areas is wrack (Olabarria et al., 2010).

Ecosystem services (Duffy and Smith, 2006)

This includes nutrient cycling (above), productivity (microphytobenthos), and water clarification (e.g. by filter feeders).

Waders

Birds that feed predominantly in intertidal soft sediment areas (Connell and Gillanders, 2007).

Shore/Coast birds (PV, 2003d)

Birds (resident and migratory) that are occupy coastal habitats (including dunes e.g. Penguins) e.g. Hooded Plovers, Cormorants.

Microphytobenthos

Microalgae that live upon the sediment surface (Connell and Gillanders, 2007).

Rhodoliths

Specific to Pt Addis MNP (PV, 2005b) a type of red encrusting algae that form ball-like structures on the sea bed.

Fish

Demersal fish (Parry et al., 1995) that occupy soft sediment habitats include: flat fish (e.g. Flounder, Flathead), rays and skates and stargazers.

Invertebrate biota

Invertebrates that occupy the benthic and interstitial habitat (Connell and Gillanders, 2007), including burrowing animals and infauna such as: molluscs (e.g. brachiopods, Steele-Petrovic, 1975), worms, crustaceans (crabs, shrimp) and echinoderms.

Species diversity

There is high species richness in Victorian soft sediment habitats (Coleman et al., 1997) including vertebrates, invertebrates and algal biota.

Rare/Threatened species

This refers to species of conservation concern including locally or regionally significant species, species at the extremes of their distribution and those listed on: Flora and Fauna Guarantee Act (FFG, 1988), Environment Protection and Biodiversity Act (EPBC, 1999), Victorian Rare or Threatened Species (VROTS), RAMSAR.

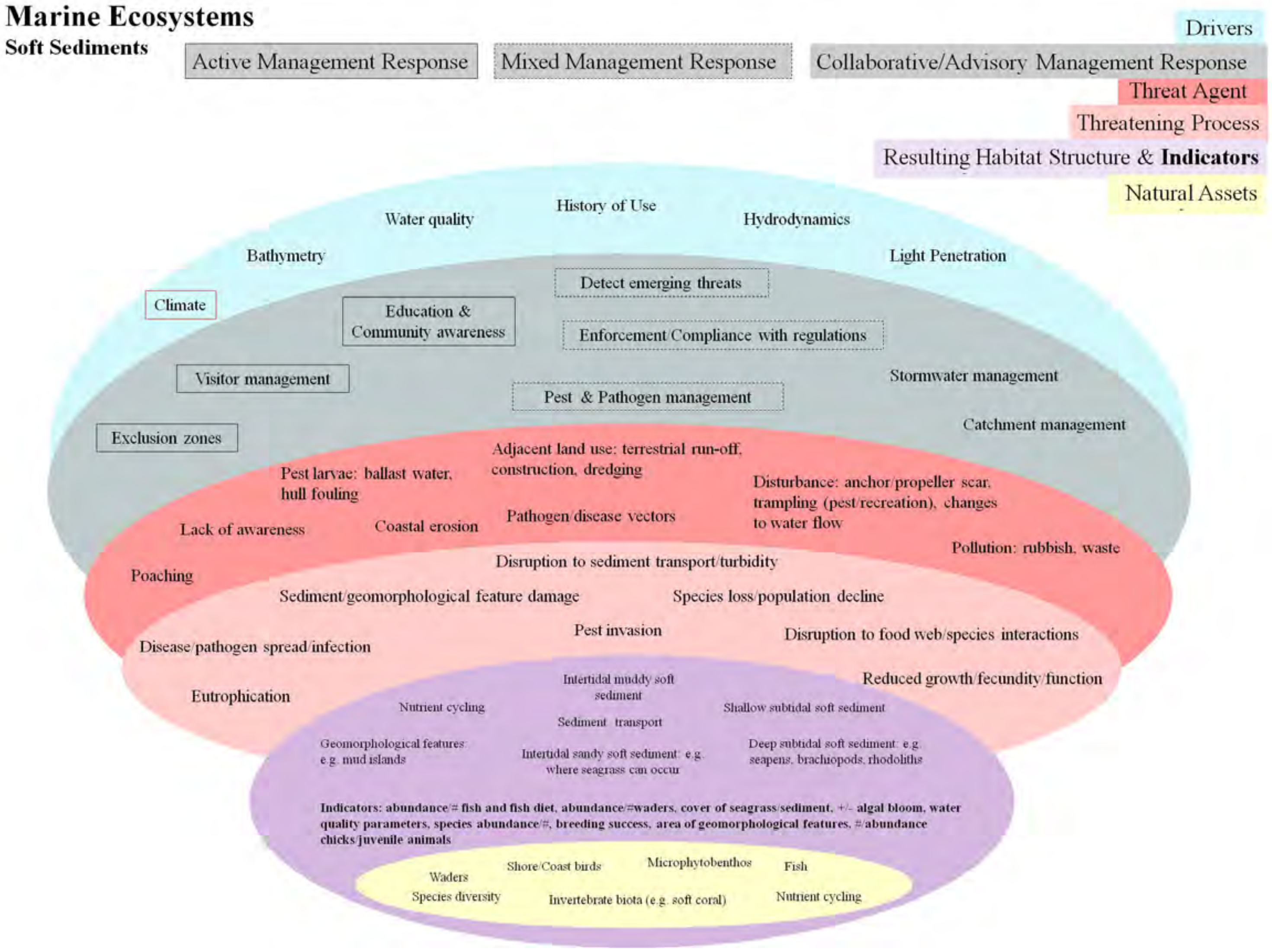

Figure 9 Conceptual Map of Soft Sediments in Victorian Marine Protected Areas

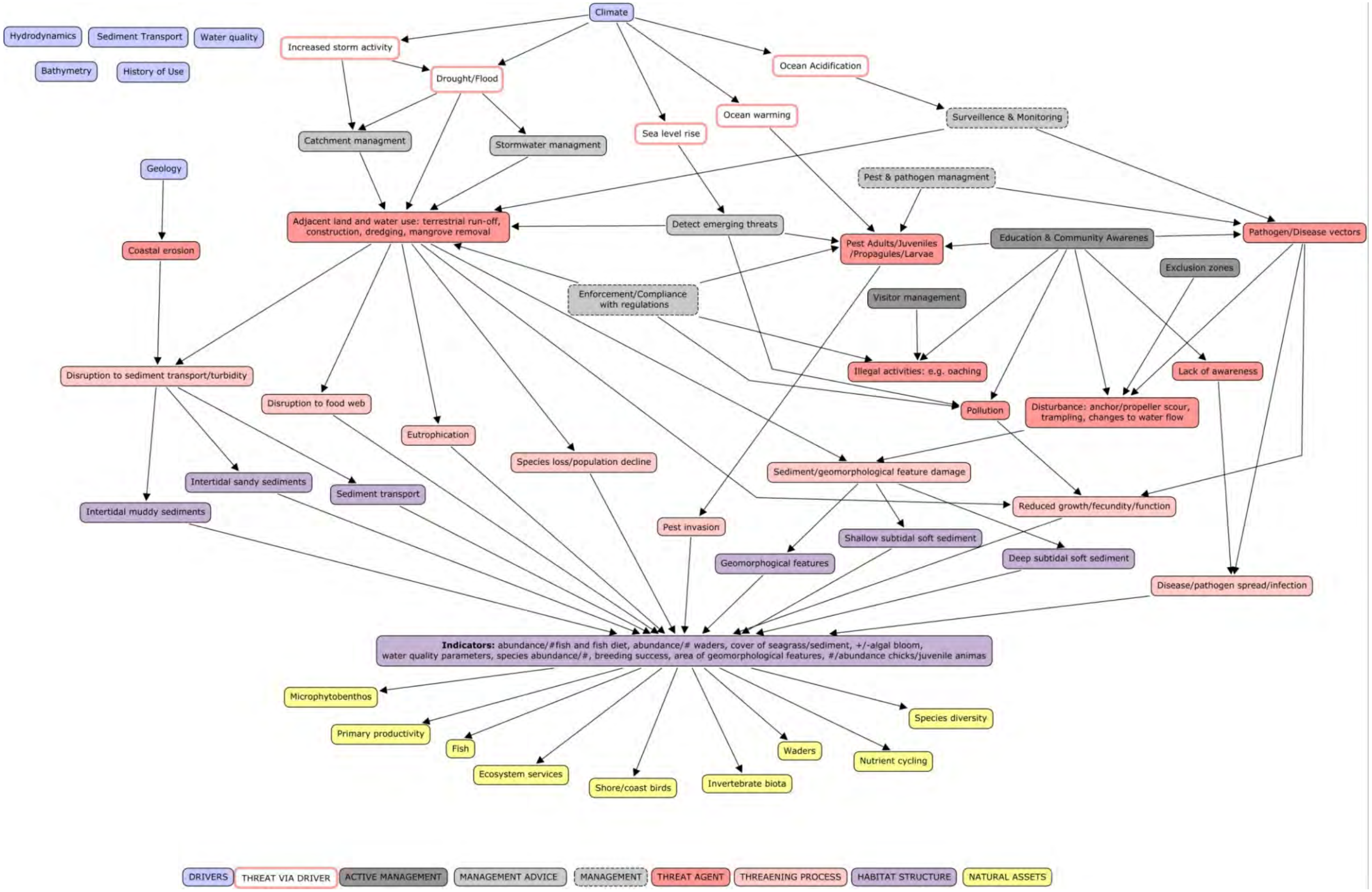

Figure 10 Conceptual Model of Soft Sediments in Victorian Marine Protected Areas

7. ESTUARIES

Estuaries have a range of forms, most readily recognised as where freshwater creeks or rivers drain into the sea. In this framework estuaries are considered as an amalgam of the habitats: soft sediment, mangroves & saltmarshes, and water column. Estuaries are likely to be the first point where land based (esp. catchment/stormwater) threats such as litter; sediment and nutrient run-off are identified in the marine environment. Due to their position at the land/sea interface they are first to suffer the consequence of toxicity and pollution coming from upstream which can have detrimental impacts on the health of this habitat resulting in eutrophication, toxicity or smothering. Connectivity between freshwater and the marine environment is probably the most important feature of estuaries in addition to the fauna adapted to their often brackish water condition. Seasonal and artificial opening and closing of estuaries is one important influence that has specific management protocols (Barton and Sherwood, 2004) and can heavily influence both water conditions (salinity, nutrient levels) and connectivity. Examples of estuarine fauna include: marine worms and polychaetes (Arundel, 2003), bivalves (Matthews, 2006), gastropods and crustaceans (Poore, 1982) and estuarine fish including black bream (*Acanthopagrus butcheri*, Hindell et al., 2008), gobies, mullet (e.g. *Aldrichetta forsteri*), estuary perch (*Macquaria colonorum*) and many others (as listed in Barton and Sherwood, 2004). Estuaries are found in Merri Marine Sanctuary and Western Port Bay (PV, 2007d, PV, 2003d).

7.1. Definitions specific to Estuaries

7.1.1. Drivers

The things that determine the distribution of habitats, and the main factors that act in these systems to influence their state or condition

Climate

Natural climate events such as seasonality and El Nino/La Nina weather patterns can alter species assemblages for example from increased flooding entering the marine environment bringing pollutants, sediment and lowering salinity.

Climate change (see Brown, 1987, Whetton et al., 2001):

- Increased water temperatures (for instance from global warming) can detrimentally impact upon estuarine fauna. Water temperature increase may also lead to the increased success of pest invasions and competitive species from warmer temperate areas.

- Sea level rise can impact upon intertidal soft-sediment habitats and beaches, especially where there is no-where for them to retreat due to adjacent land use (called "coastal squeeze" Schleupner, 2008).
- Air Temperature extremes: this can impact upon intertidal assemblages (e.g. soldier crabs) by stressing their physiology and reducing their foraging capacity.
- Increased extreme weather events can alter catchment related inputs e.g. increased drought can increase salinity due to lowered freshwater input and evaporation in estuaries which can impact upon recruitment (e.g. black bream in Gippsland Lakes, Jenkins et al., 2010); and large infrequent rain pulses can add nutrients and sedimentation into estuaries.
- Ocean acidification can impact upon calcified estuarine organisms.

Water Quality

Salinity (Jenkins et al., 2010) and temperature of the water column can impact upon species assemblages, turbidity of the water can impact upon the resident species assemblages (e.g. predator foraging and light for benthic algae), nutrient loads and toxicants (Keough et al., 2012) in the water can reduce water quality.

Sediment transport

This can be from the catchment and delivered by rivers, streams and creeks. It can also be from river/stream/creek bank and dune/tidal flat (de Jonge and van Beusekom, 1995) erosion being moved around estuarine waters through freshwater movements (especially during/after rain) and by sea due to wind/current/tide.

History of Use

Past management of the estuary and the catchment inputs can be important to driving its current health. Previous construction, artificial closing/opening of the estuary mouth, and pollution delivered into the estuary can impact its current state and recovery ability post-protection.

Hydrodynamics

The hydrodynamics (see Denny and Wethey, 2001) can influence the community assemblage found in an area e.g. water movement (filter feeding invertebrates require fast water movement for feeding, and microphytobenthos require low levels of movement to prevent disturbance), and stratification (affecting fish recruitment, Jenkins et al., 2010). Freshwater inputs, flows and marine flows (e.g. mouth opening, see below) are important factors in estuarine hydrodynamics.

Bathymetry

The depth and shape of the seabed (Guichard and Bourget 1998) can influence the hydrodynamics of a particular area resulting in different habitat types (e.g. seagrasses, mangroves, soft sediment assemblages.

Connectivity

This includes connectivity of the waters within the estuary to the ocean and up the catchment. For example diadromous fish can start their life cycle many kilometres away even in other states up the catchment and the connectivity of these waterways can impact the life cycle and subsequent abundance of these species.

Mouth opening

Natural and artificial (Barton and Sherwood, 2004) mouth opening can alter estuaries. Many small estuaries naturally close and open throughout the year due to sediment movement and water flow. This can alter the salinity and oxygen concentration of the water (including stratification) within the estuary (Barton and Sherwood, 2004) thereby affecting species composition.

Light penetration

Estuaries can be subject to high sediment and detritus loads from the catchment altering light intensity (via turbidity, Carey et al., 2007b), to the water column and benthic environment below. Light penetration at sub-surface and through the deeper layers of the water column can influence both plankton (and other flora) growth and species behaviour.

7.1.2. Management

Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes. Three management types are given – Active, Mixed and Collaborative/Advisory.

All management of Marine National Parks and Marine Sanctuaries is documented in the PV Management Plans. The plans that contain estuary specific management are: Merri, Western Port Bay (PV, 2007d, PV, 2003d).

Active Management

Refers to direct management actions/response undertaken by (and the responsibility of) PV

Education & Community awareness

Support education on impacts to estuarine habitats including noise, pollution, pest/pathogen spread, stormwater runoff, interaction with wildlife and vehicle regulations (PV, 2005b).

Visitor management: In addition to general marine habitats communicate with visitors (e.g. boat users) to make them aware of specific behaviours that impact on estuaries (e.g. noise, litter, erosion, marine pest spread). Liaison with school groups/tourism operators regarding events, water quality, and visitor numbers (PV, 2005b).

Exclusion zones

Enforce via patrols, signage and education speed restrictions of water vehicles at distance to: shore (possible increased turbidity/wake induced erosion) and other vessels (reduce collision risk, PV, 2005b). Seasonal exclusion zones can also be implemented to prevent disturbance to wading and shorebird breeding and roosting sites on the banks of estuaries (PV, 2002).

Mixed Management

Includes direct action from PV in addition to direct action by other agencies (e.g. DSE, EPA), or as a support to other agencies

Pest & Pathogen management

Pest and Pathogen management includes investigating reports of outbreaks, reducing activities that increase the threat of pest/pathogen spread (through education/enforcement), and working with other agencies (e.g. DSE, DPI) who monitor and detect emerging pest and pathogen related threats and to lessen impacts to ecosystems through containment/removal of threat where possible. Liaison with agencies managing nearby waters is essential to reducing threat of pest and pathogen spread in MPAs.

Enforcement/Compliance with regulations

Surveillance of human activities and imposing penalties (in partnership with Fisheries in terms of poaching, and/or EPA in terms of pollution) to enforce regulations including poaching, fossicking, dog access on intertidal areas, dumping of rubbish, point source pollution/discharges, responsible waste disposal of vessels (PV, 2005b).

Detect emerging threats

Work with other agencies (e.g. EPA) and support community groups (e.g. Waterwatch, Fishcare) to detect emerging threats (through e.g. risk assessment, modelling and monitoring) such as water pollution, disease spread (Greenberg et al., 2006), loss of key species . Also work with other agencies in response to outbreaks of point-source pollution, oil spill (Response plan to deal with Wildlife affected by and Oil Spill, CNR 1994, PV, 2005b).

Facilitate landward migration of plants

In conjunction with DSE, local government, and private landholders allow suitable habitat for the landward migration of saltmarsh (Harty, 2010) and/or other ways of retaining saltmarsh (e.g. adding sediment slurry Slocum et al., 2005) in response to sea level rise where these occur near estuaries. This includes not building seawalls or other roads/properties adjacent saltmarshes (Harty, 2010).

Collaborative/Advisory Management

Where PV can take an advisory role (e.g. for planning applications that impact on the marine environment) or assist other agencies indirectly (e.g. contacting relevant agency if a threat is observed/advised to staff by member of the public)

Stormwater management

Work with and share information with councils, Melbourne Water, and other water authorities and relevant agencies on reducing impacts to the marine environment through better stormwater management (PV, 2006e), for example sharing information about the effects of litter on marine biota.

Catchment management

Work with and share information with CMAs and relevant agencies to improve catchment management (Poore, 1982), and reduce the impacts of land based activities on the MPAs such as nutrient inputs, sedimentation, herbicide, and pesticide input etc. (PV, 2006e). Examples include: revegetation of riparian zones and sand dunes to reduce erosion and sediment run-off. Where NPs exist in the catchment PV can take more active catchment management e.g. rehabilitating riparian zones.

7.1.3. Threat Agent

The past and present activities (and other factors) that influence ecosystem structure, function, state or condition

Pollution

This includes rubbish, waste (Brown et al., 1990, Burridge et al., 1996), toxicants (e.g. pesticide/herbicides and heavy metals), and oil/chemicals. These pollutants may enter the marine environment through a range of sources both within and outside the marine protected area such as discarded fishing line/nets, and litter (e.g. via stormwater).

Adjacent land and water use

What happens outside marine protected areas in many cases directly influences them. This can include dredging, construction, terrestrial run-off, land fill, spoil, stock grazing, and removal of shore vegetation (among others).

Pathogen/disease vectors

In estuarine habitats, water vessels, discarded fishing gear/bait and proximity to aquaculture/water exchange area may be sources of pathogen/disease vectors (PV, 2006c).

Pest/weed adults/juveniles/larvae/propagules/seeds

Pests may be spread through ballast discharge (if not done correctly or at sufficient distance from MPA, Waste Management Policy, EPA 2004), discarded fishing gear/bait, unwashed recreational equipment and vessels, and natural spread from existing infestations. This includes marine, terrestrial pests (e.g. foxes trampling exposed mudflats/mangrove sediments) and terrestrial weeds (e.g. saltmarsh weeds).

Recreation

Recreational threats include trampling (on intertidal areas), launching and irresponsible use of water vehicles (e.g. passing too close to shore can cause wake induced erosion), fossicking and noise (PV, 2011, Carey et al., 2007b). All of these recreational threats can result in physical disturbance to sediments and to benthic biota. Noise from people and vehicles can disrupt birds and other wildlife.

Lack of awareness

Improved community awareness (Burger, 1998) through education can mitigate many of the threats to estuarine habitats including using correct access points, and not disturbing biota. Improvements to the condition of habitats can be assisted by an aware and actively involved community (e.g. Waterwatch).

Illegal activities

Poaching (including illegal fishing and bait-pumping; James, 2000), stock trampling, pollution from vessels and anchoring in no-anchor areas all contribute to the loss and damage of marine life (and contribute to sedimentation) within estuarine habitats.

Coastal erosion

Coastal erosion can increase sediment load and water turbidity of the water column (Carey et al., 2007b). This can impact benthic biota, particularly flora, through smothering and reduced light (PV, 2011), and mobile predators through reduced predation efficiency (Granqvist and Mattila, 2004).

Catchment inputs and discharges

Nutrients (including fertilizer), sediments, herbicides, and pesticides (PV, 2006e) can reach the estuarine habitat due to run off and through stormwater diversions. These can lead to eutrophication, reduced growth/function of some species.

Noise

Loud noise from vessels, people, industry (e.g. shipping, port operations), and construction can impact species behaviour (mobile and benthic) and interactions (as discussed in Jung and Swearer, 2011). This can be especially evident in species using echolocation such as dolphins and also in shorebirds (PV, 2011).

7.1.4. Threatening Processes

The process through which the threats influence system structure, function and state, or condition

Eutrophication

The process whereby excessive dissolved nutrients (e.g. Bishop et al., 1992) promote algal blooms, leading to accumulation of decaying plant material, microbial build-up and oxygen depletion (Edgar, 2001). This is not to be confused with seasonal spikes in algal growth which are ephemeral in nature (e.g. *Ulva* spp. growth). Severe eutrophication can lead to fish kills.

Reduced growth/fecundity/function

Multiple threat agents can reduce the growth/fecundity and function of estuarine biota. For example changes in salinity stratification and freshwater flow due to climate change can impact upon estuarine fish recruitment (Jenkins et al., 2010).

Habitat damage/fragmentation/loss

Where mangroves/saltmarsh, and seagrass occupy estuarine habitats they can be subject to habitat damage/fragmentation/loss due to a range of disturbances (e.g. physical disturbance from recreation). Soft sediments within estuaries are also subject to damage through propeller scour and boat wake disturbances (PV, 2011).

Pest/Weed invasion

Pest invasion results from the successful spread of pest larvae/propagules. The invasion of introduced marine pests may outcompete, predate upon or in another way detrimentally affect species within estuarine habitats for example the Northern Pacific Seastar (*Asterias amurensis*) and *Caulerpa fragile* in soft sediments (see NIMPIS). Coastal weeds can also impact saltmarsh habitats fringing estuaries such as the grasses *Spartina anglia*, *Spartina x townsendii* and *Lophopyrum ponticium* which outcompete native species (Boon et al., 2011).

Disease/pathogen spread/infection

Disease/pathogen spread/infection can be spread in various ways including infected bait, fishing/boating/recreational equipment in addition to natural spread. Increases in disease are expected to result from climate change (Harvell et al., 2002).

Sediment/geomorphological feature damage

Physical disturbance can lead to the damage of sediments (e.g. compaction) and geomorphological feature damage (PV, 2011). This can lead to these features and their associated becoming locally lost and the exposure of coastal acid sulphate soils.

Disruption of food web/foraging/species interactions

Multiple threat agents can disrupt the foraging interactions (Alfaro et al., 2006) of species in estuarine environments, e.g. when turbidity or noise levels are increased. Loss of species/fragmented habitat can occur due to disturbance or toxicity.

Species loss/population decline

Lack of food, disruption of species interactions, poaching, removal by marine pests, and health decline (disease, injury, toxicity) of species can all lead to a decline in the population or loss of particular species inhabiting estuaries (Carey et al., 2007b).

Reduced primary productivity

Loss of phytoplankton, microphytobenthos, seagrass, and mangroves/saltmarsh can break down the food web (Connell and Gillanders, 2007).

Injury/death to animal

Tangling in litter, ingestion of litter/pollutants, and being struck by water vessels can all lead to the injury or death to marine animals (including birds, fish and mammals e.g. dolphins).

Overgrazing

Overgrazing can occur to mangrove and saltmarsh plants within estuarine habitats where insect populations are not controlled (e.g. lower bird numbers eating insects), by invasion/population increase of grazers or illegal stock grazing. Overgrazing can compromise plant health (e.g. delaying reproduction).

Disruption to sediment transport/turbidity

Adjacent construction (James, 2000), boat wake causing localised erosion, pollution and proximity to terrestrial inputs (creeks, drains etc.) can disturb the transport of sediment within estuaries and lead to increased turbidity.

7.1.5. Resulting Habitat Structure

The habitat structure that results from the combination of threats and drivers acting on a system and management responses

Intertidal muddy soft sediment (ParksVIC 2011)

This is an important habitat for infauna (e.g. bivalves, marine worms, Heislers and Parry, 2007, Butler and Bird, 2010) and benthic biota (e.g. demersal fish, microphytobenthos) as well as an important feeding area for coastal birds and waders (Loyn, 1978, PV, 2002, PV, 2003d, PV, 2003a).

Intertidal sandy soft sediment

This is an important habitat for infauna (e.g. bivalves, marine worms)(Butler and Bird, 2010, Heislers and Parry, 2007) and benthic biota (e.g. demersal fish, Parry et al., 1995) as well as an important coastal bird feeding area (Loyn, 1978, PV, 2002, PV, 2003d, PV, 2003a, PV, 2011)

Shallow subtidal soft sediment

This is an important habitat for invertebrates (Heislers and Parry, 2007, Butler and Bird, 2010, Coleman et al., 1997, Poore and Rainer, 1974), shore birds, demersal fish (Parry et al., 1995), microphytobenthos and nutrient cycling (PV, 2011).

Large and micro-islands

These islands (e.g. at Nooramunga) offer habitat for significant vegetation and fauna, and refuge from anthropogenic influences and pests (PV, 2011, Molloy et al., 2005).

Mangrove trees/canopy habitat

Mangrove trees create habitat for multiple species (e.g. birds, bats) through their trunk, branch (roosting habitats) and leaf structures (insect habitat). They also provide shade to the understorey through their canopy e.g. for intertidal crabs.

Pneumatophores/roots

Pneumatophores can be as dense as 10,000 per tree and provide habitat for a variety of marine invertebrates (e.g. barnacles and gastropods) and algae that are not able to colonise the surrounding soft sediments (Gwyther and Fairweather, 2002). Fish move into the mangrove environment (within roots and pneumatophores) during high tide as a refuge from predators and physical disturbance (Boon et al., 2011).

Saltmarsh shrub ground cover

Victorian saltmarshes contain a range of species which vary spatially depending on local factors (making up EVCs 9 and 10, see also additional types described in Boon et. al, 2010). Both physical habitat and food resources are provided by the plants making up saltmarshes including: spiders, insects, reptiles, birds and mammals (Boon et al., 2011, Harty, 2010).

Resident planktonic and pelagic species

Seals (Australian)(PV, 2006c), penguins (PV, 2006c), resident fish (e.g. Banded Morwong PV, 2006c), zooplankton, phytoplankton, and sea jellies (Fancett and Jenkins, 1988).

Migratory pelagic species

Diadromous fish, dolphins, (bottlenose and common, Gill et al., 2011), some species of fish e.g. Herring Cale (PV, 2006c), and planktonic larvae/gametes that disperse across large distances.

7.1.6. Natural Assets

PV-defined (PV, 2011), are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect.

These overlap with the resulting habitat structure and indicators so are placed within the same layer in the habitat maps.

Nutrient cycling

This includes the cycling of chemicals such as nitrate, phosphate, carbon (through food webs) and nutrient regeneration (where organic matter derived from decomposing organisms release nutrients, Arrigo, 2005, Castro and Huber, 2008, Boon and Cain, 1988).

Ecosystem services

Estuaries provide important ecosystem services (Barbier et al., 2011, ECC, 2000) such as filtering riverine inputs (Durr et al., 2011), primary productivity, nursery areas(e.g. estuarine macrophytes, Arundel et al., 2009) and nutrient cycling.

Primary Productivity

Plants associated with estuaries that are primary producers include seagrass (Loyn, 1978), mangroves, saltmarsh, phytoplankton, and microphytobenthos (Cook et al., 2009).

Connectivity

Includes riverine connectivity for diadromous fish, and connectivity of the water column for recruitment, food supply (Fancett and Jenkins, 1988) and movement of marine organisms.

Foraging habitat

This can include seagrass (Loyn, 1978), soft sediment benthos (e.g. for shorebirds) and mangrove habitat (roots and pneumatophores).

Microphytobenthos

Microalgae that live upon the sediment surface (Connell and Gillanders, 2007, Cook et al., 2009).

Acoustic integrity

An area without human introduced noise (e.g. construction, shipping) allows for natural acoustic interaction between marine organisms (PV, 2011) e.g. fish (as discussed by Jung and Swearer, 2011).

Migratory, Rare/Threatened/Iconic species

This refers to species of conservation concern including locally or regionally significant species, species at the extremes of their distribution and those listed on: Flora and Fauna Guarantee Act (FFG, 1988), Environment Protection and Biodiversity Act (EPBC, 1999), Victorian Rare or Threatened Species (VROTS), RAMSAR.

Species diversity

Estuaries maintain high species diversity due to the multiple habitat types they incorporate (mangrove/saltmarsh, pelagic, soft sediment) including species from multiple taxonomic groups including invertebrates (Poore, 1982), fish (Platell and Freewater, 2009), marine mammals, birds and plants.

Water quality

Salinity (Jenkins et al., 2010) and temperature of the water column can impact upon species assemblages, turbidity of the water can impact upon the resident species assemblages (e.g. predator foraging and light for benthic algae), nutrient loads and toxicants (Keough et al., 2012) in the water can reduce water quality. Quality must all be at healthy levels (within SEPP/ANZECC guidelines) to allow maintenance of other priority natural assets.

Habitat island refuges

See large and micro islands above.

Saltmarsh EVCs Estuarine Wetlands, Mangrove EVC

Saltmarsh EVCs 9 and 10 are significant for biodiversity and habitat provision (Ross, 2000), additional categories are recommended by Boon et al. 2011 including estuarine wetlands. The mangrove EVC 140 comprises the mangrove species *Avicennia marina* ssp. *australica* (Ross, 2000, Boon et al., 2011). Components of this habitat and its role are described in resulting habitat structure above

Invertebrates

Includes marine worms and polychaetes (Arundel, 2003), bivalves (Matthews, 2006), gastropods and crustaceans (Poore, 1982).

Fish

Estuarine fish (Platell and Freewater, 2009) found in Victorian estuaries include black bream (Acanthopagrus butcheri, Hindell et al., 2008), gobies, mullet (e.g. *Aldrichetta forsteri*), estuary perch (*Macquaria colonorum*) and many others (as listed in Barton and Sherwood, 2004).

Mammals

Predominantly in saltmarsh areas of estuaries, mammals include: the Heath mouse (*Pseudomys shortridgei),* Swamp Antechinus (*Antechinus minimus*), Broad-toothed rat (*Mastacomys fuscus*), Spot-tailed Quoll (*Dasyurus maculatus*), Large-footed Myotis (*Myotis adversus*) and the Common Bentwing bat (*Miniopterus schreibersii*)(Barton and Sherwood, 2004); dolphins may occasionally venture into estuaries.

Birds

Examples include: the Great Egret (*Ardea alba*), Australasian Bittern (*Botaurus poiciloptilus*), Powerful Owl (*Ninox strenua*)(Barton and Sherwood, 2004).

Reptiles

Includes the Swamp skink (*Egernia corentryi*)(Barton and Sherwood, 2004)

Plants

Includes mangroves, saltmarsh plants, seagrass (e.g. *Ruppia megacarpa*) and algae (microphytobenthos, phytoplankton and macroalgae)(Arundel et al., 2009).

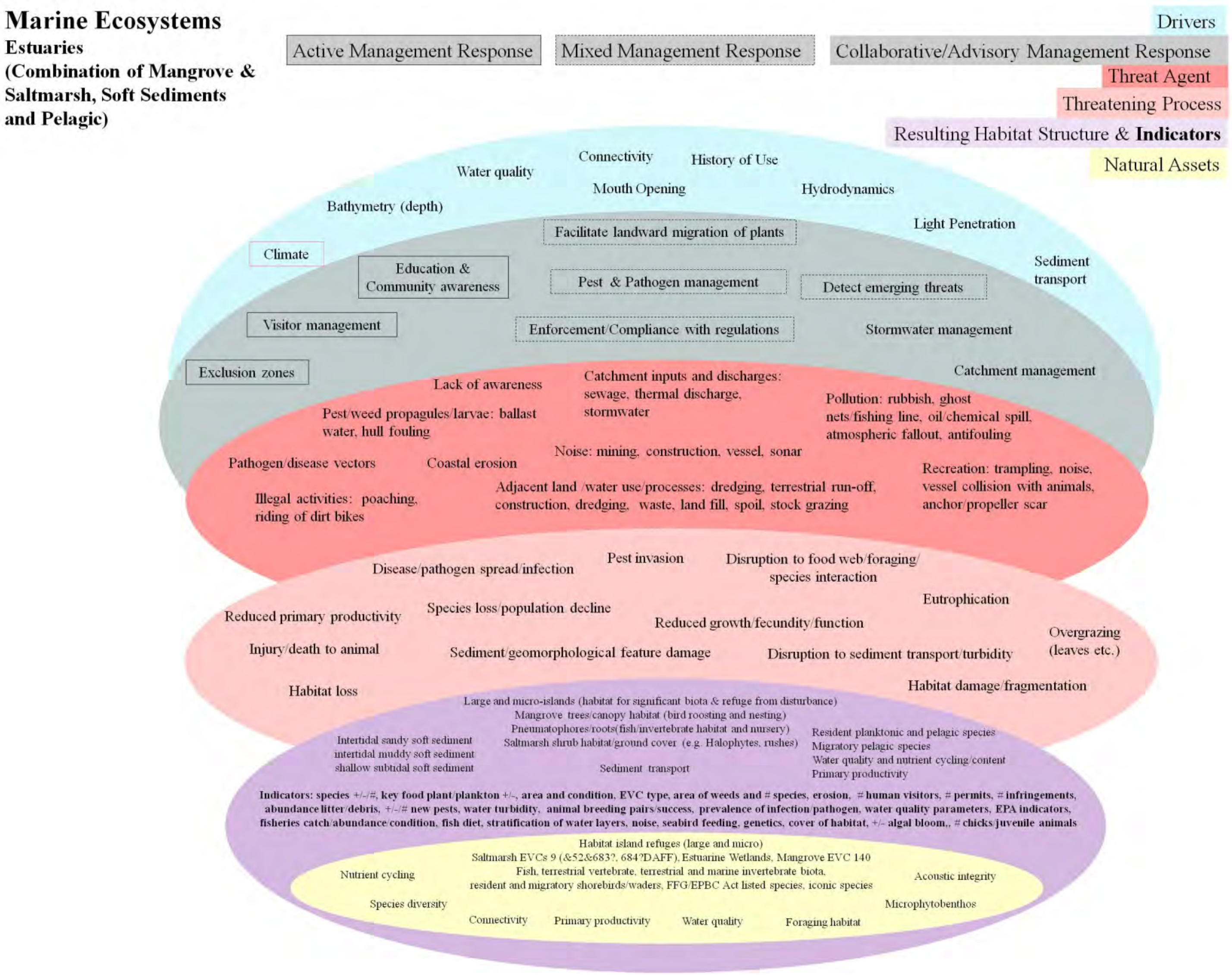

Figure 11 Conceptual Map of Estuaries in Victorian Marine Protected Areas

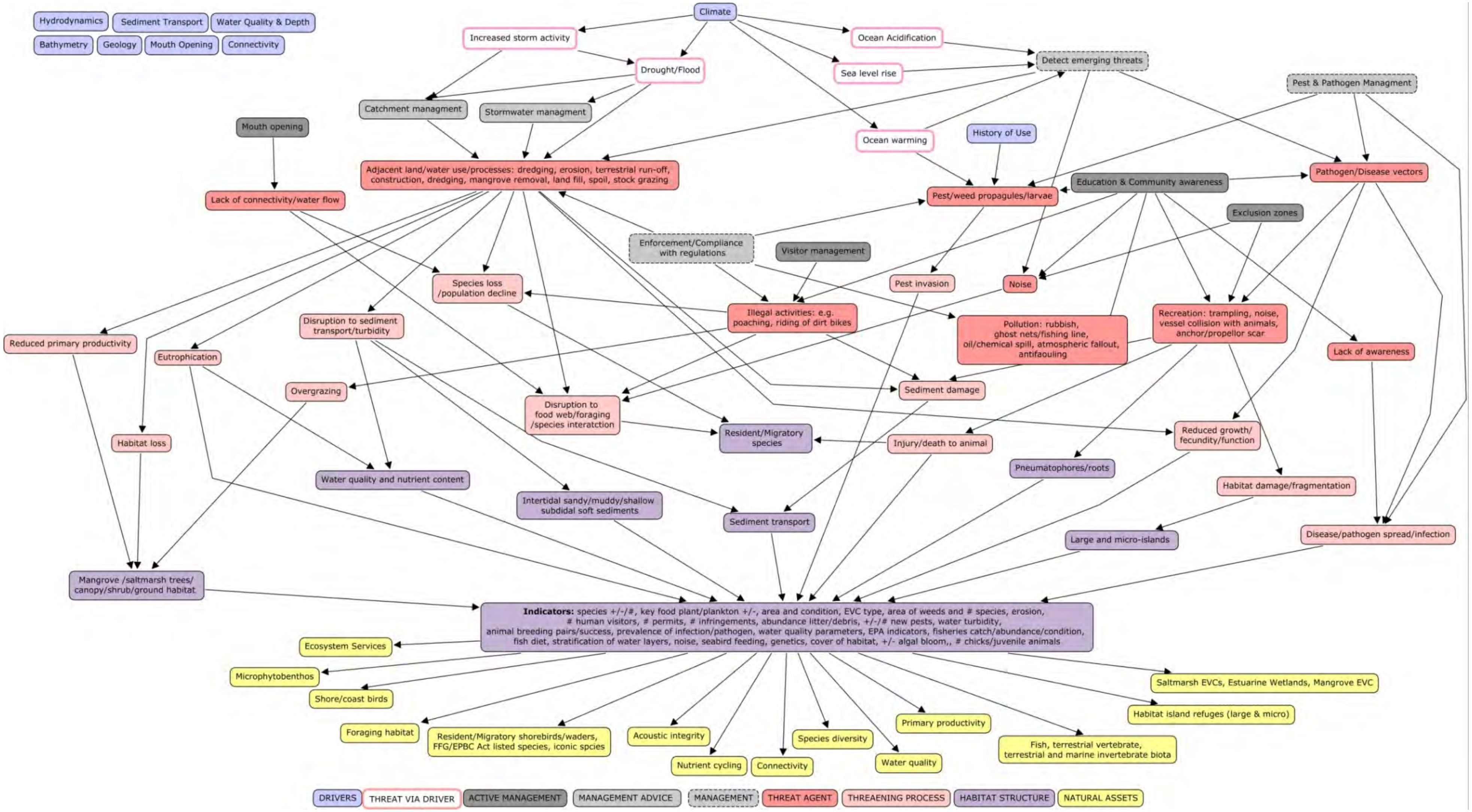

Figure 12 Conceptual Model of Estuaries in Victorian Marine Protected Areas

8. SUBTIDAL REEF

Subtidal Reef (Ricketts Point Marine Sanctuary) © Julian Finn

For the purposes of this report, subtidal reef includes (as per Hutchinson et al., 2010, PV, 2011): shallow reef (2-20m), deep reef (more than 20m) and deep canyons as specific areas owing to their geomorphic features (e.g. Port Phillip Heads). These habitats are highly diverse (Keough and Butler, 1996) providing a surface for attachment of algae and sessile invertebrates. Reefs can be highly complex with gutters, arches, crevices and overhangs which provide multiple sub-habitats for reef associated species. Both complexity and depth can drive species assemblage patterns. Macroalgae is abundant on shallow reefs and provides a multidimensional habitat through increased surface area for associated biota, altering environmental conditions such as flow and light, and providing camouflage for mobile predators and prey. Common macroalgae found on subtidal reefs in Victoria includes *Ecklonia radiata*, *Cystophora* spp., *Sargassum* spp., *Macrocystis pyrifera*, *Caulerpa* spp., and multiple red algae (e.g. *Plocamium* spp.). On deeper reefs multidimensional structure is provided by sessile invertebrates that are adapted to lower light levels such as: ascidians, sponges and in some locations gorgonians (Hutchinson et al., 2010). Algae on deeper reefs are generally limited to low light adapted reds such as encrusting coralline algae (Hutchinson et al., 2010). Subtidal reefs support diverse invertebrate assemblages including echinoderms (seastars and urchins), crustaceans (crabs, rock lobster), molluscs (gastropods, cephalopods), marine worms (e.g. fan worms), cnidarians (anemones, corals); and vertebrates such as fish (e.g. Southern Hulafish, Blue-throat Wrasse). Subtidal Victorian reefs are important for tourism (e.g. recreational snorkelling and scuba diving), ecosystem services (productivity of algae), and as refuge habitat for many commercially important species which may contribute to genetic diversity in reefs outside protected areas. Threats to subtidal reefs include illegal fishing, multiple climate change stressors (acidification, warming waters), pollution, pests and the movement of habitat-modifying species. Further detail on subtidal reefs within Flinders and Central marine bioregions is given in Edmunds et al. (2000a). Marine National Parks and Sanctuaries that have subtidal reef habitats include: Barwon Bluff, Bunurong, Corner Inlet, Jawbone, Mushroom Reef, Port Phillip Heads, Pt Addis, Pt Cooke, Pt Danger, Pt Hicks, Ricketts Point, Cape Howe, Beware Reef, Merri, Twelve Apostles and Western Port Bay (PV, 2003d, PV, 2003a, PV, 2005c, PV, 2005b, PV, 2005a, PV, 2006e, PV, 2006b, PV, 2007g, PV, 2007f, PV, 2007b, PV, 2007a, PV, 2007e, PV, 2006a, PV, 2006g, PV, 2006c, PV, 2006d, PV, 2007d)

8.1. Definitions specific to Subtidal Reefs

8.1.1. Drivers

The things that determine the distribution of habitats, and the main factors that act in these systems to influence their state or condition

Climate

Includes seasonality (Gibbs et al., 1986, Caffey, 1985), rainfall, sea and land temperature, and oceanic-atmospheric climatic patterns of El Nino and La Nina which alter weather conditions over a prolonged period usually resulting in either drought or flood (respectively).

Climate change

- Increased extreme weather events e.g. storm frequency, rainfall pulses influencing catchment inputs.
- Increased water temperature e.g. range expansion of some species (likely on the east coast) may occur as waters warm as has been seen for the benthic sea urchin *Centrostephanus rodgersii* on subtidal reefs (found at Beware Reef in Victoria and extensively on east coast of Tasmania, Edmunds et al., 2010, Waters, 2008).
- Ocean acidification (Brown, 1987, Whetton et al., 2001).

Geology

The geology of a subtidal reef refers to the rock type rock type (e.g. mineralogy and structure, Guidetti et al., 2004) of subtidal rocky reefs. This includes sedimentary (e.g. sandstone) and igneous rock types (e.g. basalt, granite, calcarenite).

Water quality

Water quality is both a driver and a natural asset in marine subtidal habitats. As a driver water quality includes salinity, dissolved gases (e.g. oxygen, nitrogen), elemental composition (e.g. nutrients), and pH (Lowthion, 1974, Gibbs et al., 1986). Upwelling (e.g. Bonney Upwelling western Victoria) can influence water quality during the summer months through increased productivity (Butler et al., 2002b).

Light penetration

The amount of light that reaches the reef can influence the type of biota found (Connell, 2005). Overhangs (Plummer et al., 2003) from reef structure, and turbidity in the water column can also alter light availability (Connell, 2005).

Sediment transport

Sediment transport on reefs can have detrimental impacts such as smothering of sessile species and preventing attachment or successful recruitment of algae and sessile/sedentary invertebrates.

History of Use

This variable describes how the area was used prior to current use. This can include the time since protection from fishing or access, previous fishing pressure, and the risk or incidence of pests or disease due to prior use. Areas with different prior histories may need to be managed differently for conservation objectives (e.g. recovery period may be longer, some species may be locally lost or rare).

Hydrodynamics

Includes water movement such as currents, tides and upwellings which can be affected by nearby structures and wind (Denny and Wethey, 2001).

Bathymetry: Depth and structure (e.g. flat, complex) can drive different subtidal reef assemblages (Plummer et al., 2003).

8.1.2. Management

Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes. Three management types are given – Active, Mixed and Collaborative/Advisory.

All management of Marine National Parks and Marine Sanctuaries is documented in the PV Management Plans. The plans that contain subtidal reef specific management are: Barwon Bluff, Bunurong, Corner Inlet, Jawbone, Mushroom Reef, Port Phillip Heads, Pt Addis, Pt Cooke, Pt Danger, Pt Hicks, Ricketts Point, Cape Howe, Beware Reef, Merri, Twelve Apostles and Western Port Bay (PV, 2003d, PV, 2003a, PV, 2005c, PV, 2005b, PV, 2005a, PV, 2006e, PV, 2006b, PV, 2007g, PV, 2007f, PV, 2007b, PV, 2007a, PV, 2007e, PV, 2006a, PV, 2006g, PV, 2006c, PV, 2006d, PV, 2007d).

Active Management

Refers to direct management actions/response undertaken by (and the responsibility of) PV

Education & Community awareness

Education can be undertaken by PV staff, contractors and other agencies. Education needs to be accurate, consistent, up to date, and delivered in a manner that is audience appropriate. Education incorporates communication of regulations and cultivating respect and interest in the marine environment. Education can for example include signs, verbal (general interaction with public, organised talks) and written (reports, flyers) communication. Parks Victoria can work in collaboration with friends groups, councils, educational institutions and others to achieve wide reaching education. Engaging the community to be aware of the threats and natural assets of subtidal marine habitats is crucial in ensuring continued interest and investment in marine protected areas. Community participation in subtidal monitoring and awareness programs such as Sea Search, Reef Watch Victoria and Reef Life Survey should be encouraged and supported.

Visitor management

Visitor management includes compliance, education, and community liaison. Recreational divers, snorkelers and boat users should be targeted for education on minimal impact visitor behaviour to reduce the risk of disturbance, noise and movement of marine pests (PV, 2003b). Continue to have Parks Victoria registered tour operators that abide by maximum visitor numbers and minimum impact guidelines to reduce reef disturbance (PV, 2003b).

Exclusion zones

This includes enforcing current exclusion zones and activities within Marine National Parks and Sanctuaries. Short-term exclusion zones may also be desirable in response to emerging threats (in collaboration with relevant authorities). Maintenance/inspection of signs, navigational markers and fencing/bollards/gates (PV, 2003b) and education are a significant part of maintaining exclusion zones.

Mixed Management

Includes direct action from PV in addition to direct action by other agencies (e.g. DSE, DPI, EPA), or as a support to other agencies

Pest & Pathogen management

Pest and Pathogen management includes investigating reports of outbreaks, reducing activities that increase the threat of pest/pathogen spread (through education/enforcement), and working with other agencies (e.g. DSE, DPI) who monitor and detect emerging pest and pathogen related threats and to lessen impacts to ecosystems through containment/removal of threat where possible. Liaison with agencies managing nearby waters is essential to reducing threat of pest and pathogen spread. Over-abundant native species and range expanding species are also included in this category for convenience. Of current interest on subtidal Victorian reefs is the spread of the sea urchin *Centrostephanus rodgersii* in the east of the state (found at Beware Reef in Victoria, Edmunds et al., 2010, Waters, 2008). Although native to areas of NSW, this species is not indigenous to Victoria and it can have a major impact on kelp habitats (Ling et al., 2009). Current research is also underway in Port Phillip Bay on the impact of locally increased populations of the indigenous sea urchin *Heliocidaris erythrogramma* (P. Carnell unpublished).

Enforcement/Compliance with regulations

Surveillance of human activities and imposing penalties (in partnership with Fisheries in terms of poaching, and/or Police in terms of pollution) to enforce regulations including poaching, fossicking, dumping of rubbish. It is important for PV to communicate with other agencies and be informed of breeches of regulation occurring in nearby waters (e.g. illegal edge fishing of rock lobster Carey et al., 2007b) which may impact upon the natural assets of MPAs (especially important when examining monitoring results).

Detect emerging threats

Emerging threats and issues can be identified through appropriate surveillance and monitoring undertaken by PV directly (through contractors e.g. SRMP, PV staff) and in partnership with other agencies such as EPA, DSE, Melbourne Water, CMAs and community partners such as Reefwatch Vic/Reef Life Survey etc. Surveillance and monitoring techniques, analysis, modelling and reporting should be kept up to date and reflect best current practice (by amending as necessary in consultation with experts) with clear objectives for conservation outcomes (for case study see Edgar et al., 1997). Detection of emerging threats is currently also addressed by filling knowledge gaps through the Research Partners Panel program to continually improve the identification and mitigation of threats to conservation values (Parks VIC pers. comm.).

Collaborative/Advisory Management

Where PV can take an advisory role (e.g. for planning applications that impact on the marine environment) or assist other agencies indirectly (e.g. contacting relevant agency if a threat is observed/advised to staff by member of the public)

Stormwater management

Work with and share information with councils, Melbourne Water, and other water authorities and relevant agencies on reducing impacts to the marine environment through better stormwater management (PV, 2006e), for example sharing information about the effects of litter on marine biota.

Catchment management

Work with and share information with CMAs and relevant agencies to improve catchment management (Poore, 1982), and reduce the impacts of land based activities on the MPAs such as nutrient inputs, sedimentation, herbicide, and pesticide input etc. (PV, 2006e). Where NPs exist in the catchment PV can take more active catchment management e.g. rehabilitating riparian zones.

8.1.3. Threat Agent

The past and present activities (and other factors) that influence ecosystem structure, function, state or condition

Pollution

This threat agent includes rubbish, waste (e.g. sewerage, Chapman et al., 1995), toxicants (Addison et al., 2008a), oil/chemical spills, atmospheric fallout, and carbon pollution. These may enter the subtidal habitat through a range of sources both within and outside the marine protected area such as discarded fishing line/nets, and litter (e.g. via stormwater). Pollution can result in a range of consequences as given in threatening processes including reduced growth/function, habitat loss, poor reproductive output, species loss/population decline and disruption of food web/species interactions (Bishop et al., 1992, Goessler et al., 1997).

Adjacent land and water use

Adjacent land and water use that can impact subtidal reef natural assets include: dredging, coastal development, terrestrial run-off and nearby fishing pressure (can alter top-down/bottom-up species recruitment and interactions on reefs). These threatening agents can result in a multitude of threatening processes within a marine protected area (see DSE, 2009, Raventos et al., 2006, Bishop et al., 1992).

Disease vectors

This variable includes infected species, which may enter the marine protected area through unwashed boat/personal water craft traffic (diseased species fouling boats), proximity to ballast water discharges (both domestic and international shipping), discarded bait/fishing gear, proximity to aquaculture, unwashed dive/snorkelling equipment, and through natural species movement (adults, propagules/larvae).

Pest adults/juveniles/larvae/propagules

Pest larvae and propagules can be spread by a number of mechanisms including: natural species movement, boating/water craft (fouling), fishing/recreational equipment, ballast water discharges (both domestic and international shipping), proximity to aquaculture, aquarium escapes (e.g. disposal of aquarium plants).

Recreation

Recreation such as diving and recreational boating (Kenchington, 1993b) can result in noise and physical disturbance to subtidal reefs.

Lack of awareness

Lack of awareness is a social threat that can directly impact on the health of subtidal reef habitats. One of the most important of these is people not knowing where marine protected areas are and what activities are and are not permitted in parks. In addition to this understanding how to look after recreational equipment (e.g. improper hygiene can contribute to marine pest/pathogen spread) and behaving in ways that won’t disturb the marine environment are central to reducing threats in marine protected areas. Awareness is important in terms of the public understanding the services provided by subtidal reefs and how their behaviour away from the marine environment can impact this (e.g. disposal of toxicants, carbon pollution, revegetation etc.). An aware community can also drive change at a larger scale e.g. through lobbying of government/voting for protection etc. and through on-ground activities such as community based monitoring (e.g. Sea Search, fish count - Reef Watch Victoria).

Illegal activities

Poaching (e.g. fishing reef fish, collecting abalone and rock lobster) is a major threat to subtidal reef habitat natural assets and can result in disrupted food webs and loss of biodiversity. Another illegal activity that impacts on subtidal reefs is pollution (e.g. chemical and litter disposal).

Habitat modifying species

Species such as sea urchins can modify subtidal habitats such as kelp forests by overgrazing (e.g. Cetrostephanus rodgersii in Cape Howe Marine National Park, Ball and Blake, 2007).

8.1.4. Threatening Processes

The process through which the threats influence system structure, function and state, or condition

Eutrophication

The process whereby excessive dissolved nutrients (e.g. Bishop et al., 1992) promote algal blooms, leading to accumulation of decaying plant material, microbial build-up and oxygen depletion (Edgar, 2001). This is not to be confused with seasonal spikes in algal growth which are ephemeral in nature (e.g. *Ulva* spp. growth). Severe eutrophication can lead to fish kills.

Reduced growth/function

Subtidal species can suffer reduced growth, damage or function due to a range of threat agents including disease (Webster, 2007) and pollution (e.g. King George Whiting, Smith et al., 1999).

Increased turbidity

Increased turbidity in the water column (Connell, 2005) can increase shade to reefs and reduce visibility on the reef which can impact the effectiveness of visual predatory species.

Substratum/Habitat damage/reduction/loss

Substratum and habitat can be reduced or lost due to impacts such as severe storms, climate change, and physical disturbance (e.g. anchor damage).

Poor reproductive output

Toxicity, disease, poaching, climate change and marine pests can all contribute to poor reproductive output in subtidal reef biota.

Pest invasion

Pest invasion through juvenile/adult movement, propagules and larvae can cause a detrimental impact on reef biota through increased competition for resources, habitat modification (Ling, 2008), and consumption (Grosholz et al., 2000) leading to the loss of species, loss of particular size classes of species and loss of overall biodiversity (Ling, 2008).

Disruption of food web/species interactions

Threatening agents such as poaching and pest invasion can disrupt natural food web and species interactions. Introduced pests, disease, pollution, physical disturbance and poaching can alter food webs/species interactions. A study of the effect of poaching was undertaken in Tasmania and found poaching of rock lobsters has been linked to changes in trophic cascades such as: increased numbers of sea urchins and an increase in urchin barrens in subtidal marine reefs (Ling, 2008).

Species loss/Population decline

All threat agents listed can lead to species loss and population decline on temperate reef habitats. Population decline can result from species specific predation or poaching. Species loss can result from disease, toxicity, and competition with pest species.

8.1.5. Resulting Habitat Structure

The habitat structure that results from the combination of threats and drivers acting on a system and management responses. Detailed description of biota in Victorian MNPs and MSs can be found in Edmunds et al. (2000b).

Habitat forming species

This includes kelp (e.g. Ecklonia radiata, Macrocystis angustifolia, O'Hara, 2001), seagrass (Amphibolous antartica, Ferns and Hough, 2002), invertebrates (e.g. corals, sponge gardens) and other mixed algae (e.g. Caulerpa spp., Phyllospora/Cystophora spp., O'Hara, 2001).

Benthic biota

This includes a range of fish (e.g. Wrasse, Leatherjackets, Cardinal fish, draughtboard sharks (deep reef only); Hutchinson et al., 2010, Edmunds et al., 2000b), invertebrates (e.g. sponges, molluscs, crustaceans), macroalgae (e.g. kelp, red foliose algae, coralline algae; Preciado and Maldonado, 2005).

Rock types and structures

The structure (e.g. complex, simple), type (e.g. basalt, sandstone) and availability of rock substratum is important for the settlement and recruitment of biota (e.g. on complex surfaces, Walters and Wethey, 1996).

8.1.6. Natural Assets

PV-defined (PV, 2011), are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect. These overlap with the resulting habitat structure and indicators so are placed within the same layer in the habitat maps.

Nutrient cycling (see Hutchinson et al., 2010)

Algae take up nutrients from the water column and use them for growth. Detritus is produced from reef biota and exported to other habitats (e.g. as food source for nearby soft sediment species).

Ecosystem services (see Hutchinson et al., 2010)

Subtidal reefs provide numerous ecosystem services not limited to but including: protection from beach erosion (wave break).

Fish

Examples include wrasse, morwong, leatherjackets, Herring Cale, Sea Sweep, Scaly Fin among others (Edmunds et al., 2010, Hutchinson et al., 2010).

Invertebrates

Examples include molluscs (e.g. snails, octopus), crustaceans (e.g. lobster, crabs), worms (e.g. fan worms) and echinoderms (sea urchins, sea cucumbers, sea stars), bryozoans (e.g. lace corals), corals (e.g. cold water coral) and ascidians (e.g. sea tulip)(Hutchinson et al., 2010, Edmunds et al., 2010).

Algae

Macroalgae are common on subtidal reefs and include a range of kelps, mixed brown algae, green algae and red algae (usually more common under other algae or on darker areas of reefs) (O'Hara, 2001, Hutchinson et al., 2010, Edmunds et al., 2010).

Habitat forming species

This includes the common kelp *Ecklonia radiata* (Irving et al., 2004) and string kelp *Macrocystis pyrifera* (Hutchinson et al., 2010) and various other habitat forming brown algae.

Biodiversity

Subtidal reefs are diverse habitats species from multiple groups including: seagrasses, algae, corals, bryozoans, ascidians, sponges, crustaceans, molluscs, worms and fish (Hutchinson et al., 2010).

Water quality

Water quality is improved by filter-feeding species (e.g. mussels, worms) that remove particulates from the water column (improving clarity, Gili and Coma, 1998).

Key/rare/threatened/iconic species

This refers to species of conservation concern including locally or regionally significant species, species at the extremes of their distribution and those listed on: Flora and Fauna Guarantee Act (FFG, 1988), Environment Protection and Biodiversity Act (EPBC, 1999), Victorian Rare or Threatened Species (VROTS), RAMSAR. In subtidal reef habitats examples include: rock lobster, blue groper, some species of sea cucumber, sea horses, pipe fish and some shrimp (rare/threatened source: Museum Victoria Port Phillip Bay Database).

Rock formations

This includes caverns, overhangs, arches and simple vertical or horizontal rock formations (PV, 2011).

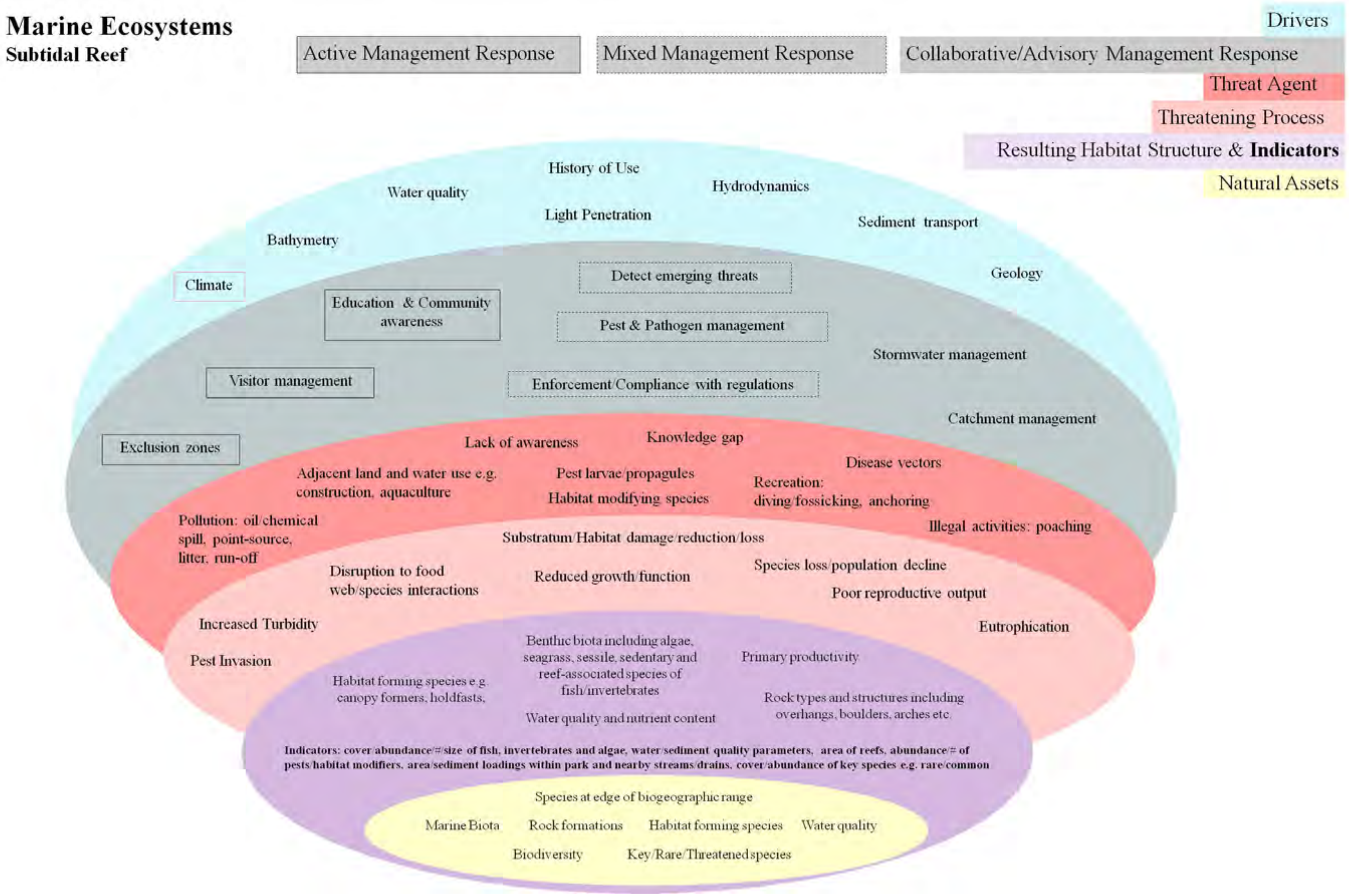

Figure 13 Conceptual Map of Subtidal Reefs in Victorian Marine Protected Areas

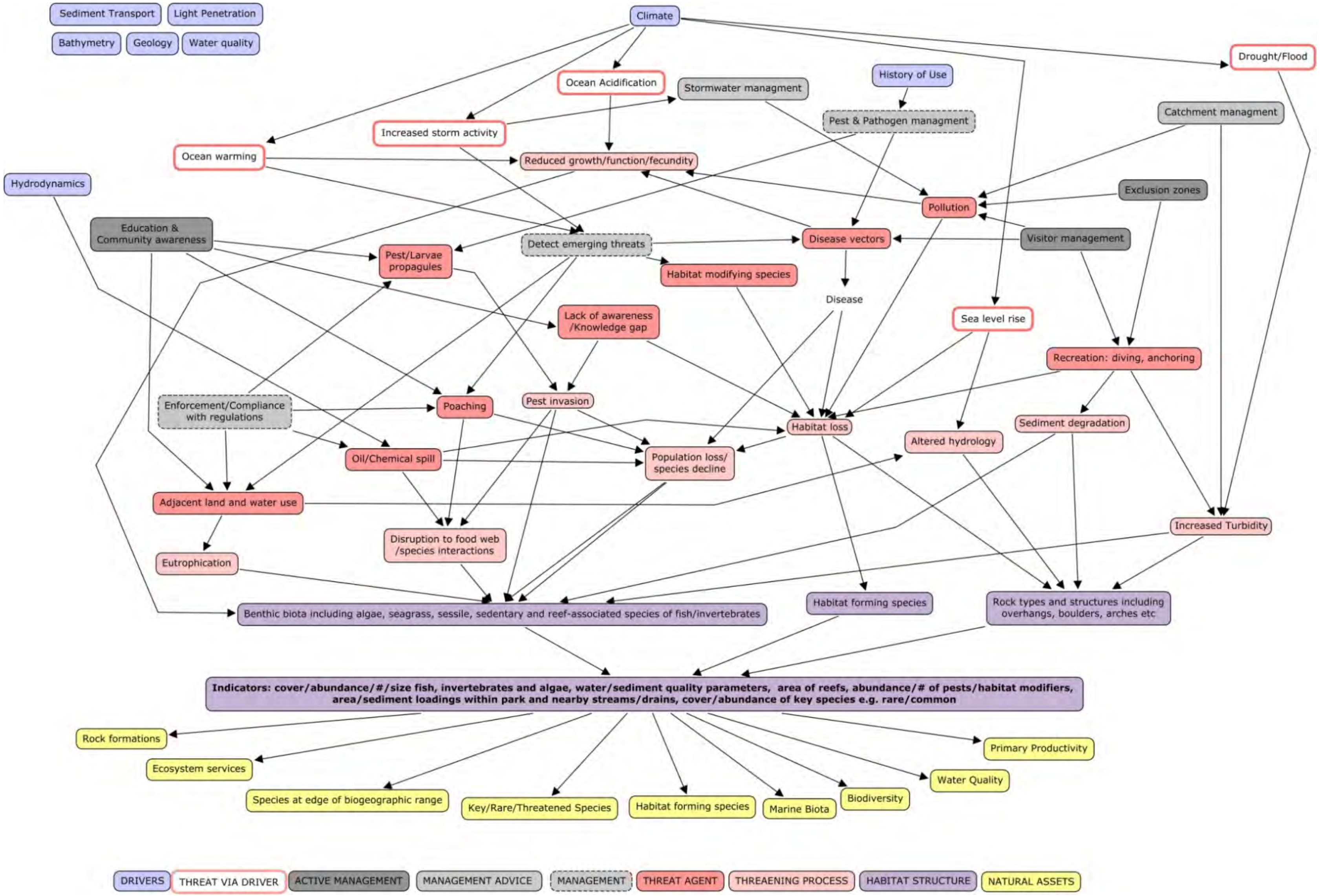

Figure 14 Conceptual Model of Subtidal Reefs in Victorian Marine Protected Areas

9. INTERTIDAL REEFS

Intertidal rocky reef (Mushroom Reef Marine Sanctuary) © Mark Norman

Victorian intertidal reef habitats include rock platforms, boulders, and artificial hard substrates such as rockwalls and breakwaters which are exposed to terrestrial climate during low tide. Tide and exposure to waves are major driving factors for intertidal rocky reef biota as are species interactions (e.g. competition and predation). On reefs exposed to wave action rock pools are common which house some intertidal species along with species more common to the shallow subtidal and even juvenile subtidal species (e.g. Zebra fish, Museum Victoria unpublished data). Most intertidal species have physiological or behavioural adaptations to enable them to withstand exposure to terrestrial climate during tidal exposure (Connell and Gillanders, 2007, Underwood and Chapman, 1995). Many types of flora and fauna can be found on rocky reefs including: cnidarians (e.g. anemones), crustaceans (e.g. barnacles), molluscs (e.g. periwinkles), polychaetes (e.g. tube worms), echinoderms (e.g. seastars), algae, seagrass, blue-green algae, lichens, rock-pool fish and resident bird life that feeds during low tide (Underwood and Chapman, 1995, Edmunds et al., 2004). Additional drivers of intertidal reef habitats include climate (natural seasons and climate change stressors such as sea level rise and increased air temperatures), tides, geology, bathymetry/topography, and hydrodynamics. Intertidal reefs are highly valuable from a social sense for the public, as they are easily accessible during low tide and may be the only interaction people have with marine life, they are therefore common areas for education and tourist visits. Threats to intertidal reefs include recreation (e.g. trampling algae, poaching of invertebrates), disease, pests, pollution, and terrestrial pests (e.g. foxes). A review by Thompson (2002) summarises the current status and discusses the future of intertidal reefs. Marine National Parks and Sanctuaries that include intertidal reef habitats include: Barwon Bluff, Bunurong, Corner Inlet, Cape Howe, Eagle Rock, Beware Reef, Jawbone, Mushroom Reef, Port Phillip Heads, Pt Hicks, Pt Addis, Pt Cooke, Pt Danger, Ricketts Point, and Western Port Bay (PV, 2003d, PV, 2003a, PV, 2005c, PV, 2005b, PV, 2005a, PV, 2006e, PV, 2006b, PV, 2007g, PV, 2007f, PV, 2007b, PV, 2007a, PV, 2007e, PV, 2006d, PV, 2006c, PV, 2006a).

9.1. Definitions specific to Intertidal Reefs

9.1.1. Drivers

The things that determine the distribution of habitats, and the main factors that act in these systems to influence their state or condition

Climate

Includes seasonality (Underwood and Jernakoff, 1984), sea and land temperature, oceanic-atmospheric climatic patterns of El Nino and La Nina which alter weather conditions over a prolonged period usually resulting in either drought or flood (respectively).

Climate change (Chapman and Underwood, 1996)

- Increased extreme weather events e.g. storms (Underwood, 1998, Underwood, 1999)
- Increased temperature (Kirk, 1977) on land (e.g. air temperature) and water (land and water) influencing intertidal reef biota. Can also lead to the increased success of pest invasions and competitive species from warmer temperate areas.
- Ocean acidification can affect calcareous biota including coralline algae and species such as molluscs and crustaceans.
- Sea level rise may have a detrimental impact on intertidal reefs where reef on higher ground isn’t available for intertidal species to occupy

Geology

The rock type of intertidal rocky reefs. This includes sedimentary (e.g. sandstone) and igneous rock types (e.g. basalt, granite, calcarenite).

Tide

Tidal exposure is an important determinant of biota on rocky shores with different species being excluded from areas high on the shore due to prolonged exposure to terrestrial climate

(Chapman and Underwood, 1996, Kelaher et al., 2003, Underwood and Jernakoff, 1984). Time of day and exposure duration can alter patterns of species distribution over time.

Water Quality

The quality of coastal water can impact rocky intertidal species. Poor water quality such as increased nutrient levels can be identified by an abundance of some algal species (e.g. *Ulva* sp., *Ceramium* sp.). Proximity to drains, pipes and estuaries can also impact water quality.

Sediment transport/Erosion

Coastal erosion can increase sedimentation on rocky reefs. Sand scour can reduce the abundance of some species and sedimentation (Schiel et al., 2006, Airoldi, 2003) can smother some species.

History of Use

The previous use of the rocky shore (e.g. activities such as fossicking and collection) prior to protection can influence the species assemblage, recovery and current health of the reef.

Hydrodynamics

Exposure to wave action is a major determinant of intertidal rocky shore species assemblages (Sousa, 1979b, Sousa, 1979a, Underwood and Jernakoff, 1984, Blanchette, 1997, Underwood, 1998, Underwood, 1999).

Bathymetry/Topography

The structure of the rock, slope, gradient and height above mean low water can influence the distribution of biota (e.g. rock complexity, relief; Beck, 2000, Johnson et al., 2003, McGuinness and Underwood, 1986, Underwood and Jernakoff, 1984).

Light conditions

Light conditions on rocky shores refers to shading from overhangs, sloping rock, proximity to cliffs/ledges and structure such as canopy forming seaweed (exposed and in rockpools). Some species will only persist in shady areas (e.g. anemones, some barnacles).

9.1.2. Management

Management actions that aim to eliminate/manage/ameliorate threats and/or threatening processes. Three management types are given – Active, Mixed and Collaborative/Advisory.

All management of Marine National Parks and Marine Sanctuaries is documented in the PV Management Plans. The plans that contain intertidal reef specific management are: Barwon Bluff, Bunurong, Corner Inlet, Cape Howe, Eagle Rock, Beware Reef, Jawbone, Mushroom Reef, Port Phillip Heads, Pt Hicks, Pt Addis, Pt Cooke, Pt Danger, Ricketts Point, and Western Port Bay (PV, 2003d, PV, 2003a, PV, 2005c, PV, 2005b, PV, 2005a, PV, 2006e, PV, 2006b, PV, 2007g, PV, 2007f, PV, 2007b, PV, 2007a, PV, 2007e, PV, 2006d, PV, 2006c, PV, 2006a).

For discussion on management of rocky intertidal shores see Underwood (1993) and Keough and Quinn (1993).

Active Management

Refers to direct management actions/response undertaken by (and the responsibility of) PV

Education & Community awareness

Education can be undertaken by PV staff, contractors and other agencies. Education needs to be accurate, consistent, up to date, and delivered in a manner that is audience appropriate. Education incorporates communication of regulations and cultivating respect and interest in the marine environment. Education can for example include signs, verbal (general interaction with public, organised talks) and written (reports, flyers) communication. Education programs such as rockpool rambles (Marine Discovery Centre, Summer by the Sea program) and monitoring (Sea Search, Koss et al., 2005b) are great ways of educating the public about marine life on rocky shores and the impact of behaviour such as fossicking, collecting (poaching) and trampling (Chapman, 1997, King, 1992, Wosinski, 2002). These education programs also improve community awareness which can lead to improved stewardship and follow on education.

Visitor management

Trampling, fossicking and illegal collection can be detrimental to intertidal marine biota (King, 1992), and managing visitor numbers or restricting access to sensitive areas of reefs can minimise damage during peak seasons. Signs, patrols and interaction with the public can achieve this (PV, 2005c). Also see paper by Fletcher and Frid (1996).

Exclusion zones

Excluding access from areas on rocky shores can minimise disturbance (Castilla, 1999, Castilla and Bustamante, 1989, Castilla and Durán, 1985). Dogs are excluded from intertidal reef areas (e.g. Pt Lonsdale MNP) to prevent trampling damage and disturbance to coastal birdlife (PV, 2003c). Additional short term exclusions such as the “don’t burst my bubbles” trial can help lower disturbance to the intertidal alga *Hormosira banksii* during summer peak periods of visitation (Taylor, 2007).

Mixed Management

Includes direct action from PV in addition to direct action by other agencies (e.g. DSE, EPA), or as a support to other agencies

Pest & Pathogen management

Pest and Pathogen management includes investigating reports of outbreaks, reducing activities that increase the threat of pest/pathogen spread (through education/enforcement), and working with other agencies (e.g. DSE, DPI) who monitor and detect emerging pest and pathogen related threats and to lessen impacts to ecosystems through containment/removal of threat where possible (PV, 2003c). Liaison with agencies managing nearby waters is essential to reducing threat of pest and pathogen spread. Of current interest on intertidal Victorian reefs are the introduced crab *Carcinus maenas* (Ahyong, 2005), algae *Pterocladia capillacea* (Hewitt et al., 2004), *Grateloupia turuturu* (Chapman et al., 2006) and the potential risk/spread of *Codium fragile ssp. tomentosoides* (Alexander, 2010a).

Enforcement/Compliance with regulations

Surveillance of human activities and imposing penalties (in partnership with Fisheries in terms of poaching, and/or EPA in terms of pollution) to enforce regulations including poaching (e.g. collection for bait/food), fossicking, dumping of rubbish, dogs on beach (PV, 2003c). It is important for PV to communicate with other agencies and be informed of breeches of regulation occurring in nearby waters which may impact upon the natural assets of MPAs (especially important when examining monitoring results).

Detect emerging threats

Emerging threats and issues can be identified through appropriate surveillance and monitoring undertaken by PV (PV, 2003c) directly (through contractors e.g. IRMP, PV staff) and in partnership with other agencies (e.g. through research partners program, DSE, university research). Effective monitoring is required to detect emerging threats to intertidal reefs (Hawkins and Hartnoll, 1983, Hawkins et al., 1986, Underwood and Kennelly, 1990) and monitoring methods should continue to be updated to reflect best practice.

Collaborative/Advisory Management

Where PV can take an advisory role (e.g. for planning applications that impact on the marine environment) or assist other agencies indirectly (e.g. contacting relevant agency if a threat is observed/advised to staff by member of the public)

Stormwater management

Work with and share information with councils, Melbourne water, and other relevant agencies on reducing impacts to the marine environment through better stormwater management (PV, 2006e), for example sharing information about the effects of excess nutrients on marine biota.

Catchment management

Work with and share information with CMAs and relevant agencies to improve catchment management (Poore, 1982), and reduce the impacts of land based activities on the MPAs such as nutrient input (Bellgrove et al., 1997, Bellgrove et al., 2010), sedimentation (Airoldi, 2003), herbicide, and pesticide input etc. (PV, 2006e). Where NPs exist in the catchment PV can take more active catchment management e.g. rehabilitating riparian zones.

9.1.3. Threat Agent

The past and present activities (and other factors) that influence ecosystem structure, function, state or condition For general reading on threat agents to intertidal reefs see Crowe et al. (2000) and Costa (2008).

Pollution

This threat agent includes rubbish, waste (e.g. sewerage, Bellgrove et al., 1997, Fairweather, 1990b, Doblin and Clayton, 1995, Kevekordes, 2000, Kevekordes, 2001, Kevekordes and Clayton, 2000), toxicants (Myer et al., 2006), and oil/chemicals (e.g. herbicide, Seery et al., 2006). These may enter the intertidal reef habitat through a range of sources both within and outside the marine protected area such as discarded fishing line/nets, and litter (e.g. via stormwater). Pollution can result in a range of consequences as given in threatening processes including reduced growth/function, habitat loss, poor reproductive output, species loss/population decline and disruption of food webs/species interactions.

Adjacent land and water use

Adjacent land and water use that can impact intertidal reef natural assets include: dredging and dune/coastal erosion (e.g. increased sedimentation, Airoldi, 2003, Schiel et al., 2006), construction, terrestrial run-off and nearby loss of key species (Carey et al., 2007b). These threatening agents can result in a multitude of threatening processes within a marine protected area including changes in biodiversity, species interactions, and species health.

Disease vectors

This variable includes infected species, which may enter the marine protected area through unwashed recreational equipment (e.g. snorkelling equipment), proximity to ballast water discharges (both domestic and international shipping), discarded bait/fishing gear, proximity to aquaculture, and through natural species movement (Carey et al., 2007b).

Pest larvae/propagules

Pest larvae and propagules can be spread by a number of mechanisms including: natural species movement, unwashed recreational equipment, ballast water discharges (both domestic and international shipping), proximity to aquaculture (Carey et al., 2007b).

Recreation

A major source of disturbance on intertidal reefs in Victoria is through recreational activities. Trampling and disturbance through fossicking (e.g. turning over rocks) can stress intertidal biota during low tide affecting their physiology and survival (Erickson et al., 2003, Fletcher and Frid, 1996, Ghazanshahi et al., 1983, Keough and Quinn, 1998, McGuinness, 1987, Pinn and Rodgers, 2005, Povey and Keough, 1991, Casu et al., 2006, Porter and Wescott, 2004) thereby altering biodiversity and species interactions.

Lack of awareness

Lack of awareness is a social threat that can directly impact on the health of intertidal reef habitats (Carey et al., 2007b). One of the most important of these is people not knowing where marine protected areas are and what activities are and are not permitted in parks. In addition to this understanding how to look after recreational equipment (e.g. improper hygiene can contribute to marine pest/pathogen spread) and behaving in ways that won’t disturb the marine environment (i.e. minimising effects of trampling and fossicking) are central to reducing threats in marine protected areas. Awareness is important in terms of the public understanding of the services provided by intertidal reefs and how their behaviour away from the marine environment can impact this (examples of behaviour change can include responsible disposal of toxicants, revegetation of dunes/waterways etc.). An aware community can also drive change at a larger scale e.g. through lobbying of government/voting for protection etc. and through on-ground activities such as community based monitoring (e.g. Sea Search).

Illegal activities

Human collection (De Boer et al., 2002, Durán and Castilla, 1989, Fairweather, 1991a, Keough et al., 1993, Kingsford et al., 1991, Lasiak and Field, 1995) for bait or food (poaching) is the major illegal activity impacting on intertidal reefs and alters biodiversity, disrupts species interactions and contributes to population loss/species decline.

Possible threats (knowledge gap)

Noise: Loud noises from humans, construction etc. may impact upon the behaviour of intertidal biota (e.g. mobile invertebrates retreat into crevices, bird feeding). **Habitat modifying species:** Species such as aggregating bivalves, tubeworms and algae can alter conditions on rocky shores and reduce other available habitats. Currently there are few conspicuous introduced habitat modifying species on intertidal reefs and these have currently not been found in Victorian MPAs (e.g. *Boccardia proboscidae*), but should be reported if found.

Predation by terrestrial pests

Foxes and domestic pets (e.g. dogs and cats) can predate on intertidal animals (Carey et al., 2007b, PV, 2007a).

9.1.4. Threatening Processes

The process through which the threats influence system structure, function and state, or condition

Eutrophication

The process whereby excessive dissolved nutrients (e.g. Bishop et al., 1992) promote algal blooms, leading to accumulation of decaying plant material, microbial build-up and oxygen depletion (Edgar, 2001)**.** This is not to be confused with seasonal spikes in algal growth which are ephemeral in nature (e.g. *Ulva* spp. growth). Further detail on eutrophication on intertidal rocky shores is summarised in Addessi (1994).

Reduced growth/function

Intertidal species can suffer reduced growth, damage or function due to a range of threat agents including disease and pollution.

Increased turbidity/sediment deposition

Increased turbidity and sediment deposition on rocky shores can lead to smothering and scouring of intertidal biota (Schiel et al., 2006, Airoldi, 2003).

Substratum/Habitat damage/reduction/loss

Trampling, storm and other disturbance can lead to damage and death of marine biota and alterations in species composition and distribution (Goodsell and Underwood, 2008, Lilley, 2004, Lilley and Schiel, 2006, Schiel and Lilley, 2007, Keough and Quinn, 1998).

Poor reproductive output

Poor reproductive output can result from pollution (Bellgrove et al., 1997, Doblin and Clayton, 1995), disease, disturbance, predation (e.g. through increased predator population) and species loss.

Pest invasion

Pest invasion results from pest larvae/propagules and adult immigration into the intertidal reef habitat. Pests can disturb and modify the natural species assemblages through predation and competition for resources (Carey et al., 2007b).

Disruption of food web/species behaviour/interactions

Species interactions have been shown to be important determinants of biota distribution and biodiversity on intertidal reefs (Engle et al., 1998, Hawkins and Hartnoll, 1983, Menge et al., 1999, Underwood and Jernakoff, 1981, Worthington and Fairweather, 1989). Invasive pests, pollution, poaching, disturbance and disease can all impact species interactions including food web interactions and behaviour.

Species loss/population decline

The loss of particular species or population decline of one or more species can result from disease, pollution (Hindell and Quinn, 2000, Bellgrove et al., 1997, Brown et al., 1990), poaching (Keough et al., 1993, Roy et al., 2003, Sharpe and Keough, 1998, De Boer et al., 2002), competition/predation and disturbance (Schiel and Taylor, 1999, Keough and Quinn, 1998, Erickson et al., 2003, Beauchamp and Gowning, 1982, Brosnan and Crumrine, 1994, Brown and Taylor, 1999, Casu et al., 2006).

9.1.5. Resulting Habitat Structure

The habitat structure that results from the combination of threats and drivers acting on a system and management responses

Habitat forming species

Intertidal reefs often have conspicuous habitat-forming species such as fucoid algae (Jenkins et al., 1999a, Jenkins et al., 1999b, Jenkins et al., 1999c, Jenkins et al., 1999d, Wright and Jones, 2006, Lilley, 2004, Lilley and Schiel, 2006, Schiel and Lilley, 2007, Schiel, 2006, Schiel and Taylor, 1999). On rocky shores in Victoria this is *Hormosira banksii*. This species modifies conditions allowing species more typically common to fringe and subtidal areas to persist in the intertidal reef habitat (JB Pocklington in prep.). On some shores habitat-forming species can include mussel (e.g. *Brachidontes rostratus* and *Xenostrobus pulex*) beds (Stewart et al., 2007) which can provide habitat for species such as limpets and barnacles. In some locations the cunjevoi *Pyura stolonifera* provides habitat through its structure allowing increased surface area and shaded/sheltered areas for species such as turfing algae and predatory gastropods (J Pocklington pers. obs.).

Benthic biota

Intertidal benthic biota includes a range of invertebrates (e.g. gastropods, cnidarians, echinoderms, crustaceans), algae, lichen and cyanobacteria (Stewart et al., 2007). Intertidal biota are generally physiologically or behaviourally adapted to cope with exposure to terrestrial climate during low tide.

Rock-pool resident fish

Many species of fish occupy rock-pools on intertidal rocky shores such as triple-fins, blennies and gobies (Silberschneider and Booth, 2001, Griffiths, 2003, Costa, 2008). Other fish use the area only during high tide and retreat as it recedes, which may be size related (Faria and Almada, 2006) (Roy et al., 2003).

Rocky types and structure

Type of rock (e.g. basalt, sandstone) and structure including relief, boulders and occurrence of rock-pools and depressions (exposed coasts usually have more rock-pools due to scour) can impact the distribution of intertidal biota (McGuinness and Underwood, 1986, Underwood, 2004).

9.1.6. Natural Assets

PV-defined (PV, 2011), are an explicit statement of the things that PV value in these systems, and therefore the things that management actions aim to influence/protect. These overlap with the resulting habitat structure and indicators so are placed within the same layer in the habitat maps. * denotes not a major asset for this habitat

Nutrient cycling*

Algae takes up nutrients from the water column and is then consumed by multiple grazing invertebrates. Detritus from both the water column and terrestrial deposition (likely wind driven) is utilized as a food source by invertebrates such as crustaceans.

Ecosystem services

Some intertidal algae (*Hormosira banksii* and *Notheia anomala*) has been shown to acquire carbon (Raven et al., 1995), and all marine plants produce oxygen. Intertidal reefs are popular destinations for recreation (Addison et al., 2008b, Barnes et al., 2002, Porter and Wescott, 2004) and often the only marine environment people come into contact with (Connell and Gillanders, 2007).

Shorebirds*

Examples include Oyster catchers, gulls (silver, pacific, kelp), gannets, cormorants (Museum Victoria records) among others.

Fish

Rockpool resident fish and juveniles such as zebra fish, gobies, and blennies (Silberschneider and Booth, 2001, Griffiths, 2003, Costa, 2008).

Invertebrates

Includes a variety of gastropods: such as topshells, turban shells, periwinkles, bivalves and limpets; crustaceans: crabs, shrimp, barnacles; (Schreider et al., 2003, Stewart et al., 2007),

Plants

Lichens (e.g. *Lichena*), Algae (e.g. *Hormosira banksii, Capriola implexa, Ulva* spp.), *Amphibolis antartica* seagrass and occasionally saltmarsh (e.g. *Sarcocornia*) plants (Stewart et al., 2007).

Habitat forming species

Includes the algae: *Hormosira banksii, Durvillaea potatorum* (littoral-fringe)*;* the cunjevoi *Pyura stolonifera;* mussels *Xenostrobus pulex, Brachodontes rostratus* and barnacles such as *Chaemosipho tasmanica* and *Cthalamus antennatus* (Stewart et al., 2007).

Key/Rare/Threatened species

One key species is the habitat-forming canopy alga *Hormosira banksii* which has been shown to be an important habitat for a variety of invertebrates (e.g. gastropods) and algae (Schiel, 2006)*.*

Biodiversity

Multiple species occur on rocky intertidal shores occupying different areas of the shore (Connell and Gillanders, 2007).

Water quality

Water quality is important for ecosystem health and for recreation (PV, 2011).

Migratory, Rare/Threatened species

This refers to species of conservation concern including locally or regionally significant species, species at the extremes of their distribution and those listed on: Flora and Fauna Guarantee Act (FFG, 1988), Environment Protection and Biodiversity Act (EPBC, 1999), Victorian Rare or Threatened Species (VROTS), RAMSAR. For intertidal reef habitats: a biogeographic barrier exists around Wilsons Promontory (and ninety mile beach) and several intertidal reef species can only be found to the east or west of this region (Hidas et al., 2007). Species such as the littoral-fringe bull kelp *Durvillaea potatorum* do not extend into the North East of the state (pers. obs.).

Rock structure

Rock structure on Victorian rocky reefs includes large granite boulders (around Wilsons Promontory), basalt outcrops in the west and flat expansive sandstone platforms in the central and surf coast regions of the state.

Primary productivity*

All plants including lichens, cyanobacteria, algae (including microalgal films and crusts) and seagrass (*Amphibolis antartica* only) are important intertidal primary producers (Connell and Gillanders, 2007).

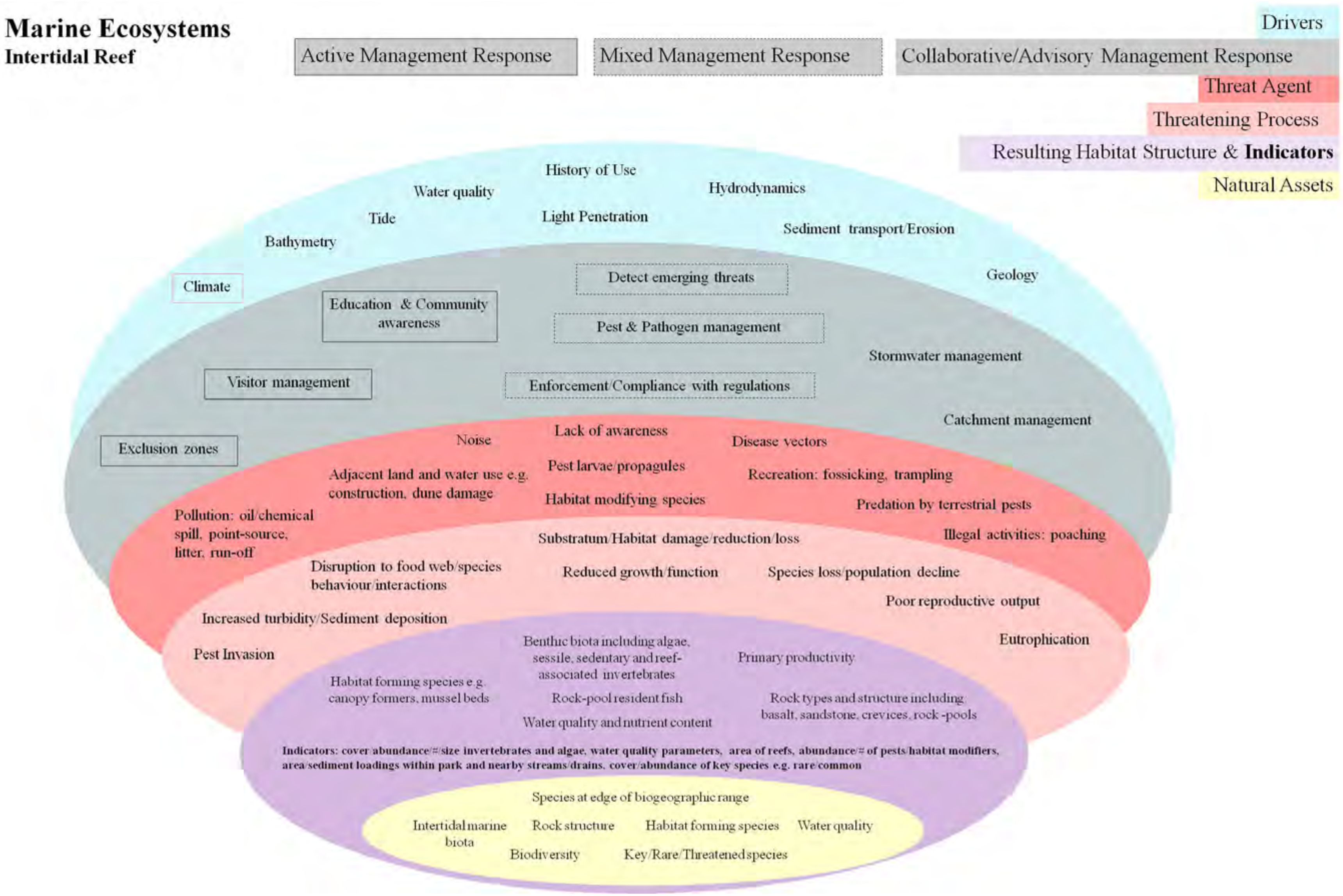

Figure 15 Conceptual Map of Intertidal Reefs in Victorian Marine Protected Areas

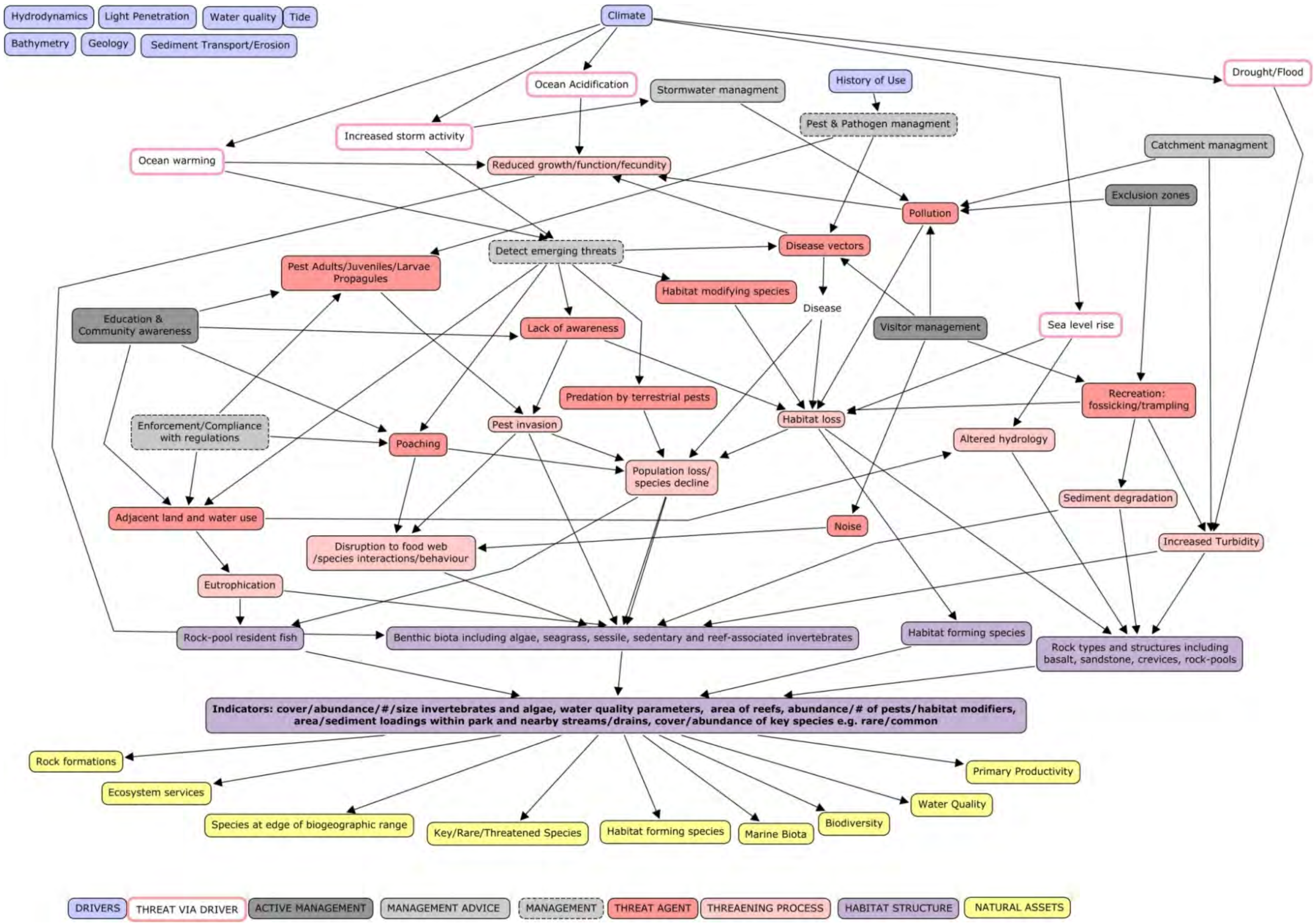

Figure 16 Conceptual Model of Intertidal Reefs in Victorian Marine Protected Areas

10. GLOSSARY

ABS: Australian Bureau of Statistics

AMSA: Australian Maritime Safety Authority

ANZECC: Australian and New Zealand Environment Conservation Council (now National Environment Protection Council)

CMA: Catchment Management Authority

Diadromous: Spending part of their life in freshwater and part in marine waters

DPI: Department of Primary Industry (Victoria)

DSE: Department of Sustainability and Environment Victoria

EIA: Environmental impact assessment

EPA: Environmental Protection Authority, Victoria

EVC: Ecological Vegetation Class, Victoria

Microphytobenthos: Unicellular eukaryotic algae and cyanobacteria that grow within the upper several millimetres of illuminated sediments (e.g. soft sediment seabed), typically appearing only as a subtle (often marbled) brownish or greenish shading (MacIntyre et al., 1996). OR Microscopic benthic algae that live on the soft-sediment seabed.

MPA: Marine Protected Area

MNP: Marine National Park

MS: Marine Sanctuary

PV: Parks Victoria

Poaching: The illegal removal of plants or animals.

RAMSAR: International treaty signed in Ramsar, Iran (1971) for the conservation of wetlands of international importance (includes ‘wise-use’ of wetlands in all member countries and territories); of high relevance to migratory birds.

SEPP: State Environmental Protection Policy

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