ENVIRONMENTAL ASSESSMENT, KARAAF WETLANDS

PATHWAYS
BUSHLAND & ENVIRONMENT

Report to Surf Coast Shire, by Doug Frood (Pathways Bushland and Environment, Marraweeney, Victoria), September 2022.

ACKNOWLEDGEMENTS

The Karaaf is located on the lands of the Wadawurrung People of the Kulin nation. The author acknowledges them as the Traditional Owners of this place and pays respect to their Elders past, present, and future.

The author wishes to extend his appreciation to the staff of Surf Coast Shire for their support for this project, in particular to Robyn Neville, Gabrielle O'Shea and Kate Smallwood. Thank you also to Jamie McMahon of ABZECO Pty Ltd for preparation of the aerial photography for use in the field and digitizing of the mapping information.

EXECUTIVE SUMMARY

The purpose of this assessment was to determine the current extent and quality of existing vegetation at The Karaaf, and identify the impacts resulting from stormwater flows from the western outlets connected to residential development.

88 locally indigenous plant taxa and 91 introduced taxa were recorded from the Karaaf Wetlands. The greater majority of the introduced species are restricted to the drier areas, fringing the saltmarsh system. Most of the saltmarsh which has not been affected by stormwater inputs is relatively weed-free, especially in the areas subject to tidal inundation.

Summary is provided for several taxa included in State-wide rare or threatened species lists and other species considered to be of regional significance are noted. The Bellarine Glasswort Tecticornia sp. (Connewarre) is only known from hypersaline saltmarsh vegetation of western Port Phillip Bay and the Bellarine Peninsula. This relatively recently recognised species does not yet have a formal conservation status, but would meet the requirements for listing under the Flora and Fauna Guarantee as at least 'endangered'. The Karaaf is a stronghold for this species, where it is the dominant species of low, hypersaline saltmarsh shrubland.

Descriptions are provided for the Ecological Vegetation Classes (EVCs) recorded at the Karaaf, including eleven saltmarsh and allied EVCs, as well as the adventive communities occurring in habitat modified by stormwater inputs.

The impacts of stormwater inputs into the wetlands are described and the relevant areas of modified vegetation are mapped. Inflows from stormwater dramatically alter the environmental conditions, particularly where they lead to unnaturally wet conditions over summer. In addition to the ecological shift towards wetland species indicative of less saline habitats in the western section of the reserve, there has been substantial mortality of the succulent shrubby glasswort species which dominate much

of the extent of the Karaaf saltmarsh. Mortality rates of glasswort shrubs were particularly high in the western section of the Karaaf, with broad areas of virtually total stand death evident: It is considered highly probable that, in this area, stormwater inputs have compounded the deleterious effects of ponding in the saltmarsh following estuary closure. Discussion on the factors behind shrub die-off is provided.

As evidenced by the frequent retention of finer branch structures on dead plants, much (but not all) of this impact is relatively recent, apparently within the last few years. Evidence such as the remains of algal growth attached to the stems of dead glasswort shrubs indicates that these plants have been subject to prolonged inundation well above the depth reached by normal tidal inflows. Comparative observations from previous studies indicate that both the extent of dieback of saltmarsh shrubs and the area dominated by species indicative of less saline conditions in the western part of the Karaaf have expanded substantially over the preceding five years.

While saltmarsh plants of the intertidal zones are adapted to regular inundation to a particular depth, sustained and deeper inundation can exceed their tolerances. Species adapted to highly saline conditions can be intolerant of sustained conditions of low salinity, further increasing their vulnerability to freshwater inputs.

Dieback occurs when the saltmarsh experiences prolonged flooding due to closure of the entrance of the Thompson Creek estuary. Impoundment and harvesting of water for agricultural use, in conjunction with climate change may be influencing the natural cycles of stream opening and closure. It is suspected that there is an interaction between the impacts of stormwater inputs and the ponding of water during events of estuary closure. It is recommended that the estuary be maintained in an open condition to assist recovery of the impacted saltmarsh vegetation and that stormwater entry into the Karaaf from adjacent development is prevented. If these stormwater inputs into the wetlands can be eliminated, the development of thresholds (e.g. related to depth or extent and duration of inundation) for subsequent decision-making around artificially opening the Thompson Creek entrance could be a useful tool for minimizing the extent of future dieback events. It is noted that no agency currently holds a permit to artificially open the Thompson Creek estuary mouth, and that this matter would require a review amongst the relevant agencies in terms of the issues of responsibility and the development of relevant protocols and procedures.

It is also noted that water sources for the Karaaf are not confined to stormwater and tidal flows. They also include groundwater, as well as seepage/runoff from more elevated fringing areas outside of the urbanized zone and localised ponding of rainfall in low-lying places during cooler and wetter periods of the year. All of these sources can influence the local characteristics of the vegetation to varying extents.

It is not considered likely that increased tidal flows since 2004 have had any impact in relation to recent dieback of saltmarsh shrubs. Instead, the absence of tidal flows during periods of estuary closure will have influenced the vegetation in parts of the Karaaf where tidal flows may have had a moderating effect on limiting declines in salinity and assisted the drainage of overflow of ponded stormwater from the western side. Normal tidal flows do not appear to reach the low lying areas in the further western section of the Karaaf. However, above a certain level of ponding in these areas, overflow will occur into

Mullet Creek, resulting in some drainage out of the system provided the entrance is open: While this drainage into Mullet Creek will not prevent the impacts of stormwater ponding in areas at elevations below the level of overflow, an open entrance can reduce the extent and depth of ponding which may occur if there are large inputs of stormwater during periods when the entrance of the estuary is closed.

If further damage due to adverse hydrological conditions can be prevented, recovery of the saltmarsh vegetation would be based on natural regeneration. The potential extent of recovery and relevant time frames for this to occur in the areas heavily impacted by stormwater are unclear. However, the chances of this happening are dependent on allowing the relevant areas to dry out. The potential and time for recovery of dieback areas will depend on the extent to which tipping points have been exceeded in areas of total kill of the saltmarsh shrubs, including the capacity for soils to return to salinised condition and the availability of viable seed. Provided suitable hydrological conditions are maintained, recovery is presumed likely for all but the more extreme areas of dieback, provided it is understood that it may take a decade or more for the canopy to mature.

The negative impacts of stormwater inputs on saltmarsh and allied vegetation are considered to far outweigh any potential perceived benefits of maintaining the potential for delivery of additional water into the wetland system at the Karaaf: The more the Karaaf can be insulated from the impacts of adjacent development, the better the chances of maintenance of the existing ecological values and the greater the potential for recovery of currently impacted vegetation.

In summary, the potential for recovery of the vegetation of the more highly impacted areas towards the western end of the Karaaf and any relevant timeframes are unclear - at this stage it is not known whether environmental conditions have passed a tipping point and whether the most impacted areas will continue to support species indicative of brackish wetland into the indefinite future, even if future stormwater inputs are prevented. Just because major impacts have occurred in the recent past does not mean that the rate of recovery from these will be rapid. Elimination of stormwater discharge will however contain the expansion of the impacted zone and optimise the chances of local and broader-scale recovery of the saltmarsh vegetation.

CONTENTS

1. INTRODUCTION

1.1 BACKGROUND

Pathways Bushland and Environment was commissioned by Surf Coast Shire to undertake an assessment of the vegetation of the Karaaf (Map 1). The purpose of this assessment was to determine the current extent and quality of existing vegetation, and identify the impacts resulting from stormwater flows from the western outlets connected to residential development.

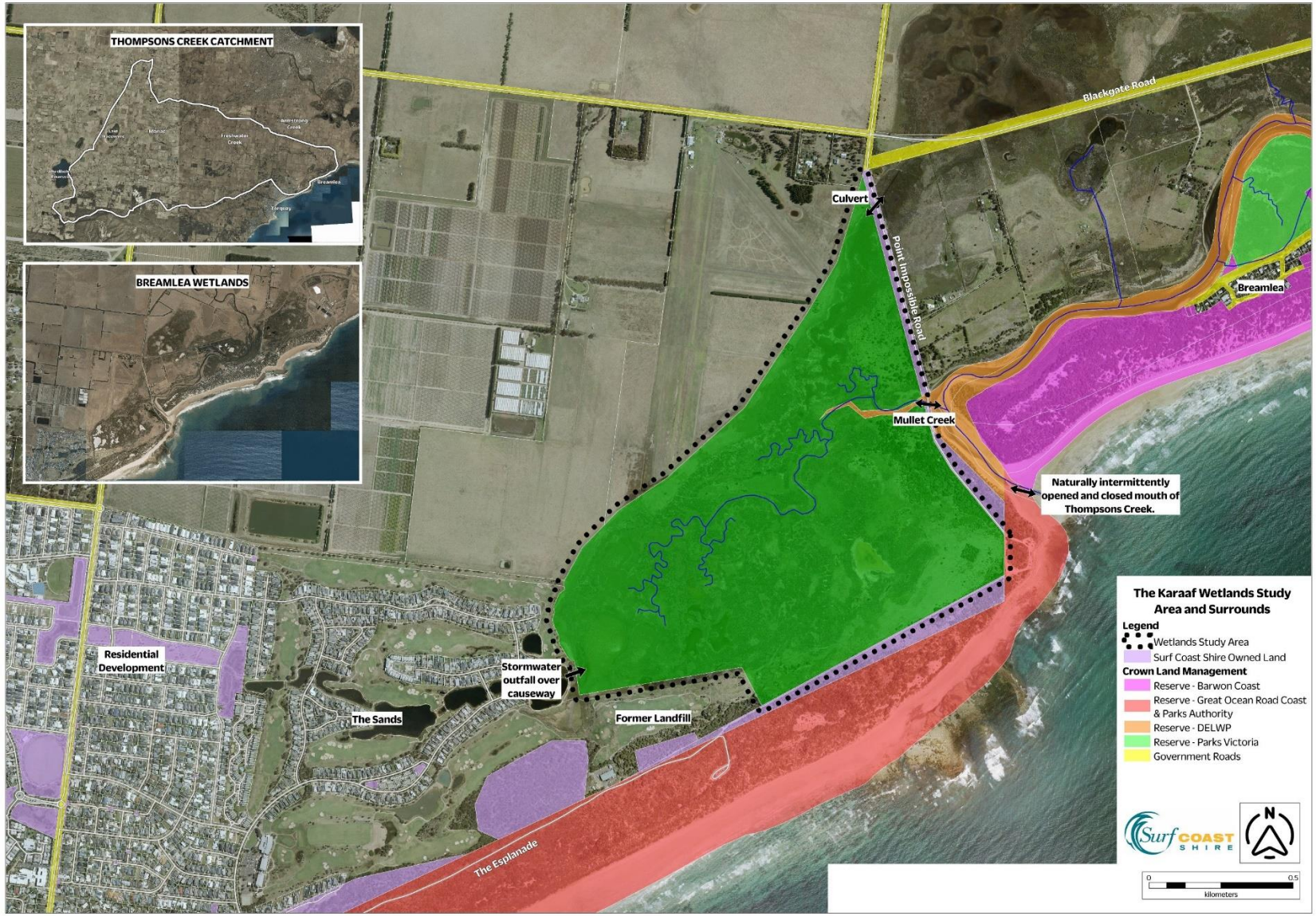
The project brief provides background information as follows:

The Karaaf is a 130 ha site, including approximately 95 ha of saltmarsh vegetation. It is managed by Parks Victoria and has a catchment that straddles two local government areas. The Surf Coast Shire Council (Council) is the stormwater drainage authority for the majority of the Karaaf and Thompson Creek catchments to the north and west of the site. The Karaaf is part of the Thompson Creek estuary and is a subsection of the broader Breamlea Flora and Fauna Reserve saltmarsh system. The Karaaf lies within Wadawurrung Country and is noted to be of high environmental, community and living cultural heritage significance.

The Council is working on a large-scale review on how the stormwater arrangements, under Council's jurisdiction, impact on the Karaaf. Council is working in collaboration with a Project Control Group (PCG) consisting of DELWP, Parks Victoria, Corangamite CMA, Wadawurrung Traditional Owners Aboriginal Corporation (WTAOC), Barwon Water, Great Ocean Road Coast and Parks Authority (GORCAPA) as well as community representatives on this project.

The following report provides a contribution to this review: The Council notes that the results of this assessment will be used to inform the determination of water requirements for the maintenance of ecological values within the Karaaf and an appropriate monitoring program to identify changes in vegetation condition once an infrastructure plan is determined and changes to the freshwater flow rates are implemented.

MAP 1. THE KARAAF WETLANDS STUDY AREA AND SURROUNDS



1.2 PROJECT TASKS AND DELIVERABLES

The brief identifies the following required outputs as components of the Environmental Assessment:

Background literature review

- Review of relevant flora and fauna databases and documentation pertaining to the site. This includes relevant reports, aerial imagery and background documentation for context and review of EVC mapping and vegetation quality data.

Site assessment

- Field identification and mapping of extent of 'weed' species including freshwater sensitive species present within saltmarsh communities.
- Field identification and mapping of areas experiencing dieback due to prolonged and/or infrequent inundation.
- Review of percentage cover of perennial native cover and percentage of exotic cover of vegetation communities (ARI 2017, Fringing vegetation for the index of estuary condition).
- Identification of other important ecological features or field observations relevant to stormwater flows, freshwater intrusion, inundation, infrastructure or land use.

Mapping

- Site plan detailing the location of field observations.

Report Production

- Preparation of a summary report of the assessment, outlining background review, methodology of field assessment and details of field observations including preparation of detailed mapping and submission of GIS layers.

2. REVIEW OF EXISTING INFORMATION

A.S. Miner Geotechnical (2008) described the natural soils in the Sands development adjacent to the Karaaf as silty clays, from bores within the Torquay Group [of Tertiary marine deposits]. These are occurring adjacent to Quaternary (Holocene) age deposits of aeolian materials, comprising coastal and inland dunes with some swamp deposits. Trengrove (1998) described the soils of the saltmarsh as recent estuarine peaty silts overlain in sections with drifts of wind-blown recent calcareous dune sand.

Flora and Fauna records for the Karaaf were extracted from the Victorian Biodiversity Atlas (VBA) of DELWP (2022a). These flora species recorded in the VBA and records of other authors (e.g. Carr *et al*., 2001) were used to augment field observations. A combined list of plant species is included as Appendix 2. Fauna species recorded for the Karaaf in the VBA (comprising mammals and birds) are listed in Appendix 3.

Trengrove (1998) and Carr *et al.* (2001) provided descriptions of the vegetation relevant to parts of the Karaaf. In the EVC descriptions provided in section 3.3 of the following report, the labels used by these authors for the respective vegetation communities are cross-referenced to the Ecological Vegetation

Class (EVC) terminology currently in use in Victoria. Osler *et al*. (2010) provided an overview of estuary vegetation in the Corangamite Catchment Management Authority region. As well as general descriptions of the EVCs, they mapped the EVCs present in the Thompson Creek estuary. These authors also provided vegetation condition assessments, but generally without detailed descriptive information.

Two versions of EVC mapping, from 2010 (Osler *et al*., 2010) and 2017 (Sinclair *et al*., 2020) respectively, were provided by the Surf Coast Shire (SCS). The 2017 mapping allocated values for perennial native cover to the respective EVCs. Further comment on the available vegetation mapping is provided in section 4.1 of the following report.

The construction of the Point Impossible Road across Mullet Creek adjacent to its confluence with Thompson Creek during the 1950s, with only a single pipe under the road, resulted in substantially reduced tidal flows into the Karaaf. Tidal flows into the saltmarsh were effectively restored with the installation of a set of larger inlets in 2004. Billows (2006) investigated ecological responses to the improved tidal flows. Billows (*op. cit*.) cited modelling data by Water Technology (2001) suggesting that the tidal range of the Karaaf wetlands could be increased by as much as 1.37 metres if the new culvert system fully reinstated natural tidal flows, and later in his thesis noting an effective increase of at least 0.87 metres due to the base level of the new culvert being well below that of the preceding inlet. Modelling by Water Technology (2003) predicted the maximum tidal inundation levels prior to the construction of Point Impossible Road as extending around the entirety of the saltmarsh, including to the western boundary. This modelling may have been a little generous, as that would have inundated the hypersaline saltmarsh communities and seasonally inundated claypan habitats that are presumed to have been dry over the summer period and hence outside of the reach of normal tidal inundation.

Billows measured salinities across the Karaaf and within the main channel of the Thompsons Creek estuary, noting variation (during drought conditions) from 3.34 ppt. (fresh) at the golf course discharge point to 48.1 ppt. (hypersaline) at the old ford on Mullet Creek within the Karaaf. Recorded salinities within the Thompsons Creek estuary ranged from 8.9 ppt. to 44.7 ppt. Nutrient and turbidity levels were also investigated: During the study of Billows, levels of both total phosphorous and total nitrogen in the estuary frequently exceeded Victorian EPA estuarine quality objectives – this was suggested to be due to agricultural inputs further up the catchment as well as from waterbirds and washed in wrack. Turbidity levels were consistently low, suggested to be most likely due to low or ceased flow upstream. Floristic changes recorded by Billows after installation of the larger culverts are discussed in Section 5.3.1 of this report. Billows commented that there appeared to be an inverse relationship between the density of crab burrows and percentage plant cover and noted a range of effects of these burrows in relation to aeration of the marsh soils, due to increased conductivity between the marsh and the tidal channel.

Sinclair and Boon (2012) investigated levels of depletion in mangrove and other coastal marsh vegetation types (including coastal saltmarsh) along the Victorian coastal fringe. They estimated the total loss of coastal marsh in the vicinity of Breamlea to be of the order of 10%. Losses occurred due to the construction of a wastewater treatment at the eastern end of the marsh, conversion of an area fringing the Karaaf at the south-western end to landfill, and destruction of a lagoon once located between Salt Swamp to the east and Breamlea.

DELWP (2021b) evaluated the Thompsons Creek estuary as part of State-wide assessments of estuaries using the Index of Estuarine Condition. Overall they evaluated this estuary as being of moderate condition, with flora being assessed as being in good condition, but assessed the hydrology as relatively modified (4/10). DELWP (*op. cit*.) provided a regional summary of relevant estuaries, but took a larger view of the Thompson Creek estuary (as 5.5. km in length) and lacked additional detail relevant to the Karaaf. The complex metrics used to derive these scores were outlined in DELWP (2021a).

An investigation by Water Technology Pty. Ltd. (2021) indicated that, due to the increase in impervious area as a consequence of urbanization, significantly more freshwater was entering the Karaaf than would have occurred prior to the development on the western side. This was particularly the case during the summer months, when water levels and freshwater inputs within the Karaaf would have been at their lowest under pre-development conditions. Water Technology Pty. Ltd. (*op. cit*.) commented that the wetlands receive water from tidal or overland flows from Thompson Creek and from the catchment to the west (totalling an estimated 1,200 ha), which incorporated the Torquay North urban areas, some rural residential areas and farming land. Drainage from the Torquay Sands development into the Karaaf was noted to occur via a concrete spillway on the eastern boundary of the Estate. Water Technology Pty. Ltd. also noted that the Torquay North urban residential area comprised approximately 40% of the contributing catchment to the Karaaf wetlands. They further commented that treatment wetlands did not currently meet the best practice for stormwater treatment targets, particularly for sediment and nitrogen, and that filamentous algae growth was observed in a number of the amenity lakes of the development.

Boon *et al*. (2014) discussed the impacts of inputs of stormwater from urban areas into coastal wetlands. They cited a range of reports of displacement of more salt-tolerant taxa from saltmarshes due to inputs of stormwater, with resultant dominance by species including *Typha domingensis* [Narrow-leaf Cumbungi], *Typha orientalis* [Broad-leaf Cumbungi], *Schoenoplectus tabernaemontani* [River Club-sedge], *Phragmites australis* [Common Reed] and *Bolboschoenus caldwellii* [Salt Club-sedge]. The relevant reports included observations from the Bellarine Peninsula and Geelong district. Water Technology Pty. Ltd. (2021) commented that the incursion [in the west of the Karaaf] of plants that tolerate or prefer freshwater but can tolerate hyposaline saline conditions (<10,000 mg/litre) was an indication that the soils are not drying out and becoming hypersaline for sufficient time to kill off these species. They reported that both Cumbungi and Common Reed had apparently only entered the Karaaf wetlands within the preceding two years, despite the potential for arrival of airborne seed from wetlands in the vicinity within The Sands and Dunes developments.

Boon *et al*. (2014) also commented on weed invasions in saltmarsh, indicating that Tall Wheat-grass (*Lophopyrum ponticum*) is unquestionably the most serious invader of upper saltmarsh because of its broad ecological amplitude and robust life-form. [Tall Wheat Grass was noted along the verge of the Point Impossible Road north of Mullet Creek during field work for the current assessment, but was not yet observed to have invaded further into the saltmarsh].

Sinclair and Kohout (2017) discussed threats to the fringing vegetation of estuaries and the evaluation of their ecological condition. They noted threatening processes to include habitat loss, fragmentation or modification (e.g. through urbanization and direct destruction), eutrophication from anthropogenic

nutrient loading, toxic pollutants, altered hydrology (including dams, culverts, and stormwater impacts), introduced plants, grazing, recreation, climate change and sea-level rise, and that threats may arise from land-use in the catchment, direct changes to the estuary and modification of flows from the downstream end. They also noted that threats may interact.

Carr (2001) prepared a weed management plan for the Torquay Sands Residential Lakes and Golf Course. While the weed management plan was primarily applicable to terrestrial areas, native species mentioned by Carr as potentially invasive in the wetlands were Common Reed (*Phragmites australis*) and Cumbungi (*Typha domingensis* and *Typha orientalis*), as well as the introduced Lesser Reed-mace (*Typha latifolia*) and a few other non-native aquatic species not yet locally recorded. He also noted that a range of annual herbs and introduced grasses were already established in the Karaaf wetlands.

Sinclair *et al*. (2020) conducted a State-wide assessment of fringing vegetation for the Index of Estuary Condition. They described estuarine fringing vegetation as 'the vegetation that occupies the zone above the permanently inundated portion of the estuary, but which experiences some hydrological influence from the salty waters of the estuary'. They further noted that estuarine vegetation may be inundated or waterlogged periodically by tides and/or flows from the catchment. Sinclair *et al*. (*op. cit*.) also commented that the introduction of freshwater flows into the estuarine fringe from stormwater outlets may cause this fringe to be 'overtaken by freshwater wetlands', noting that this had occurred to a small extent in the Karaaf wetland. Ecology and Heritage Partners (2020) noted an influx of freshwater into the Karaaf wetlands from two points, these being a pipeline and a floodway, with large expanses of freshwater covering previously exposed areas of Beaded Glasswort and the encroachment of freshwater species also apparent. They also reported that in areas where freshwater had previously retreated, saltmarsh groundcover species were experiencing dieback, with very little regeneration observed. Water Technology Pty. Ltd. (2021) noted that every relevant report since 2001 had identified the presence of dieback and freshwater species at the western end of the Karaaf wetlands.

DELWP (2021b) commented on the factors influencing estuary closure: The entrances of many estuaries close naturally, usually when freshwater inflow becomes too small to counter the effects of bar formation by oceanic currents. When estuaries close, estuarine water levels rise and can inundate low-lying shore and flats. Reduced freshwater inflows occur during periods of low rainfall and also as a consequence of interception of water in the catchment. They also noted that climate change is predicted to reduce stream flows across much of Victoria, potentially resulting in fewer flushing flows that open estuary entrances and consequently longer periods of estuary closure. DELWP (2021b) also cited a range of potential environmental impacts associated with artificially opening estuary under certain conditions: These included changes to natural patterns of variation in water quality, adverse effects on plants and animals (e.g. fish deaths) and disruption of animal migration and reproduction cycles.

Arundel (2006), cited by Sinclair *et al.* (2020), noted that the decision as to whether and when to artificially open estuaries to relieve flooding must be informed by the relative risks and benefits to a range of assets, including roads, buildings, agricultural land, fish, birds, water quality and fringing vegetation.

Tolerance levels of coastal saltmarsh vegetation to inundation through estuary closure, based on expert opinion, were proposed by a technical advisory group as part of the development of the Estuary Management Decision Framework (Deakin, 2005). The information assembled during this process is available in McGrath (2018), which presents the background report and user manual for the Estuary Entrance Management Support System (EEMSS): In this documentation it is suggested that more than 12 weeks inundation (at any level above the surface) of Coastal Saltmarsh presents a major hazard level (vegetation largely killed, long-term recovery in excess of twelve months), with inundation of 1-4 weeks being of moderate hazard level (vegetation damaged, some species killed, slow to medium-term recovery > 6 months). Estuarine Wetland, 2-8 weeks of any level of inundation was proposed as being of moderate hazard level and >24 weeks as comprising an extreme hazard level for non-tidal inundation. McGrath (2018) commented that these time periods and effects are indicative rather than validated, and that it is assumed that the water is fresh to brackish.

Other information relevant to the vegetation of saline coastal sites provided in Deakin (2005) included the following: Saline Aquatic Meadow is noted as having extreme salt and environmental tolerance, but with reproduction requiring a period of low salinity, and salinities of <16 ppt. could impact Seagrass Meadow, and it would not tolerate exposure for more than one day. It should be acknowledged that risk levels to plants from sustained inundation can vary according to the extent of submersion of the plant and the seasonal condition during which it occurs (e.g. Vivian *et al*., 2020). Descriptions of the vegetation communities Coastal Saltmarsh Aggregate, Estuarine Wetland, Saline Aquatic Meadow and Seagrass Meadow are provided in section 3.3 of the following report.

SCS provided information on the history of interventions to open the Thompson Creek mouth, as well as 'Estuary Watch' data, covering the period from 30/10/07 until 6/05/21, which includes regular observations of whether the Thompson Creek estuary was closed or open at its entrance. More detail is provided in section 5.2 of the following report.

3. FLORA

3.1 SPECIES

Based on field observations and existing documentation, 88 locally indigenous plant taxa and 91 introduced taxa were recorded from the Karaaf Wetlands. Of the native species, at least 37 are associated with the saltmarsh communities and surrounding brackish grasslands. The greater majority of the introduced species are restricted to the drier areas, fringing the saltmarsh system. Most of the saltmarsh which has not been affected by stormwater inputs is relatively weed-free, especially in the areas subject to tidal inundation. The plant list comprises vascular taxa with the exception of a Charophyte (Stonewort) recorded from previously inundated saline habitat. The desiccated remnants of this aquatic plant were not identified to genus level. A species list is provided as Appendix 2.

3.2 SIGNIFICANT SPECIES

Native populations of two taxa included in the previous list (DEPI, 2014) of plants that were considered rare or threatened at the State level (VROTs) were observed: Both of these, Coast Wirilda (*Acacia uncifolia*) and Creeping Rush (*Juncus revolutus*), were considered to be 'rare' in Victoria. These two taxa are now included in the January 2021 'Threatened List of the Victorian Flora and Fauna Guarantee Act 1988' (DELWP, 2021c), where they are allocated the status of 'endangered' in Victoria.

Bellarine Yellow-gum (*Eucalyptus leucoxylon* subsp. *bellarinensis*) has been included in plantings along the north-western boundary of the Karaaf. It was considered 'endangered' in Victoria in the VROTs list of DEPI (2014), and is currently listed by DELWP (2021c) as 'critically endangered'.

The Bellarine Glasswort *Tecticornia* sp. (Connewarre) is only known from hypersaline saltmarsh vegetation of western Port Phillip Bay and the Bellarine Peninsula. This relatively recently recognised species was informally noted as vulnerable in Victoria by RBG (2014), but does not yet have a formal conservation status. It would meet the requirements for listing under the Flora and Fauna Guarantee as at least 'endangered'. The Karaaf is a stronghold for this taxon, where it is the dominant species of low hypersaline saltmarsh.

The natural Victorian range of Giant Honey-myrtle (*Melaleuca armillaris* subsp. *armillaris*) is eastwards from near Marlo in East Gippsland (RBG, 2022). Native populations of this taxon were considered 'rare' at the State level in the 2014 DEPI list, and allocated the status of 'endangered' in Victoria by DELWP (2021c). However, the occurrence at the Karaaf of this widely cultivated plant represents an introduction outside of the species' natural range and consequently is not regarded as significant.

Species Profiles

Acacia uncifolia (Coast Wirilda): The online Flora of Victoria (RBG, 2022) notes that this bushy shrub to small tree 'occurs from near Geelong to Wilsons Promontory, mainly on coastal dunes or near saltmarsh, chiefly on calcareous sand and sandy loam soils'. Small populations of this plant occur in the remnant Coastal Alkaline Scrub fringing parts of the south and east of the Karaaf (see EVC description in sections 3.3.3). It has also been included in the fenced revegetation planting in the south-east of the Karaaf.

Eucalyptus leucoxylon subsp*. bellarinensis* (Bellarine Yellow-gum): The online Flora of Victoria (RBG, 2022) notes that this tree to 12 metres tall is 'apparently restricted to the Bellarine Peninsula near Ocean Grove and Torquay and inland to near Wallington and Connewarre, mostly on clay and clay-loam soils'. The majority of its habitat has been cleared for agriculture and in part, subsequent residential development. Remnant populations of this taxon occur along roadsides of more elevated sites in the general locality, and its inclusion in plantings on non-saline habitat along the north-western periphery of the reserve can reasonably be regarded as probable reintroductions.

Juncus revolutus (Creeping Rush): The online Flora of Victoria (RBG, 2022) notes that this long-rhizomatous perennial, with erect flowering shoots 1.5–28 cm high, is 'restricted to damp saline or subsaline communities near the coast, with a small number of outlying populations around saline lakes

on the Volcanic Plain'. There is a record from near the southern boundary of the Karaaf (DELWP, 2022a), and Carr *et al*. (2001) recorded it from an isolated subsaline wetland in the vicinity of the Karaaf prior to the development of the Torquay Sands and Golf Course Development. It was not observed during the current assessment, however localised patches dominated by Sea Rush (*Juncus kraussii* subsp. *australiensis*), notably near the central part of the southern boundary, are likely to include suitable habitat.

Tecticornia sp. [Connewarre] (Bellarine Glasswort): The online Flora of Victoria (RBG, 2022) notes that this erect to spreading shrub to one metre high is 'locally common in saltmarsh on the western side of Port Phillip Bay and halophytic shrublands around saline lakes south of Geelong'. It should be noted that the total extent of suitable habitat is nevertheless restricted. This species is locally dominant in areas of low shrubland fringing parts of the Karaaf wetlands, notably along the outer zones of the north-eastern and south-eastern sections of the saltmarsh. It also occurs in association with shallow seasonally hypersaline depressions within the broader area of the saltmarsh, but has experienced very high mortality in these parts of its habitat due to the impacts of excessively prolonged inundation.

Bellarine Glasswort Tecticornia *sp. (Connewarre).*

Other significant flora

Carr *et al*. (2001) surveyed an area including parts of the Karaaf as well as what is now occupied by the Torquay Sands and Golf Course Development. They considered a number of additional species to be of regional significance. Those recorded from within the Karaaf include the following (taxonomy updated):

Agrostis billardierei var. *billardierei* (Coast Blown-grass)

Allocasuarina verticillata (Drooping She−oak)
Althenia cylindrocarpa (Long−fruit Water−mat)
Frankenia pauciflora var*. gunnii* (Southern Sea−heath)
Gahnia filum (Chaffy Saw−sedge)
Hemichroa pentandra (Trailing Hemichroa)
Lepidosperma laeve (Clustered Sword−sedge)
Melaleuca lanceolata (Moonah)
Olearia axillaris (Coast Daisy−bush)
Puccinellia perlaxa (Plains Saltmarsh−grass)
Puccinellia stricta s.s. (Australian Saltmarsh−grass)
Samolus repens (Creeping Brookweed)
Sarcocornia blackiana (Thick−head Glasswort)
Swainsona lessertiifolia (Coast Swainson−pea)
Thyridia repens (Creeping Monkey−flower)
Triglochin striatum s.l. (dwarf saltmarsh form) (Streaked Arrowgrass)
Veronica gracilis (Slender Speedwell)
Wilsonia rotundifolia (Round−leaf Wilsonia)

Other species recorded in the current survey which would also appear to warrant high local to regional significance, include the following:
Althenia bilocularis (Short−fruit Water−mat)
Lilaeopsis polyantha (Australian Lilaeopsis)
Ruppia polycarpa (Water Tassel)
Sonchus hydrophilus (Native Sow-thistle)

3.3 INTRODUCED SPECIES

Introduced plant species are absent from areas subject to regular tidal inundation. The most widespread and abundant species in the saltmarsh communities which are only infrequently if at all tidally inundated include Hastate Orache (*Atriplex prostrata*) and Water Buttons (*Cotula coronopifolia*), with a range of salt-tolerant introduced grasses at higher levels in the elevational profile.

A small and currently localised population of Tall Wheat-grass (*Lophopyrum ponticum*) was observed along the Point Impossible Road north of Mullet Creek. Elimination in the near future of this salt-tolerant invasive plant would be highly desirable. Similarly elimination of any plants of Spiny Rush (*Juncus acutus*) which are identified around the margins of the Karaaf wetland system is warranted – in this case it is important that operators have the required skills to distinguish Spiny Rush from native species, in particular Sea Rush (*Juncus kraussii* subsp. *australiensis*). Otherwise, there is generally no realistic way of broad-scale control of the majority of the introduced plant species established within the saltmarsh communities: These are almost all intractable annuals with large and dispersed populations: Any potential control measures would involve counter-productive and destructive non-target impacts of far greater concern than any impacts these species may be having as environmental weeds.

Water Buttons is particularly prevalent where the vegetation is subject to freshwater inputs and associated shallow inundation. A range of additional invasive, less salt-tolerant species, both native and introduced, occur in the areas directly subject to stormwater inputs. If the stormwater inputs can be

removed and salinity levels still have the potential to recover, then these opportunistic species should be very much reduced if not eliminated. Again, control based on herbicide application is not warranted and would be highly counter-productive. Cumbungi (*Typha* spp.) will not tolerate sustained dry conditions over summer, and will die out if the prior hydrology is restored. The displacement of Salt Club-rush (*Bolboschoenus caldwellii*) is likely to be a slower process, but presumably will occur if salinity levels increase sufficiently – this species should be regarded as an indicator of site conditions rather than as an invasive problem in itself.

It is important to recognise that the extent of the potential for recovery of the vegetation of the western end of the Karaaf and relevant timeframes are unclear - at this stage it is not known whether environmental conditions have passed a tipping point and consequently whether the most impacted areas will continue to support species indicative of brackish wetland into the indefinite future, even if future stormwater inputs are prevented. Elimination of stormwater discharge will however contain the expansion of the impacted zone and optimise the chances of local recovery of the saltmarsh vegetation.

It is noted that a much wider range of introduced species are recorded from the fringing terrestrial vegetation. It is outside of the scope of this project to evaluate these and suggest control actions. It is noted that many of these are ground layer species, where attempted control measures are unlikely to be effective and usually would be accompanies by unacceptable non-target damage to native flora.

It is vital that any weed control is restricted to personnel who are experienced in ecological rehabilitation and have the requisite skills to recognise native species and avoid counter-productive impacts such as poorly targeted herbicide spraying. In cases of the identification of new or emerging weeds which are still localised, careful hand-weeding as was undertaken for Red Stem Goosefoot (*Chenopodium macrospermum*) would be appropriate if labour and suitable resources are available to support this approach. Cut and paint or herbicide dabbing techniques may also be appropriate in some instances.

3.4 PLANT COMMUNITIES AND EVC DESCRIPTIONS

Victoria's Framework for Native Vegetation Management (DNRE, 2002) utilises the notion of Ecological Vegetation Classes (EVCs). This framework defines an EVC as follows: 'An EVC is a type of native vegetation classification that is described through a combination of its floristic, life form, and ecological characteristics, and through an inferred fidelity to particular environmental attributes. Each EVC includes a collection of floristic communities (i.e. a lower level in the classification that is based solely on groups of the same species) that occur across a biogeographic range, and although differing in species, have similar habitat and ecological processes operating'.

The descriptions of the wetland EVCs in the following text have been adapted from DELWP (2020). An asterisk preceding the scientific name of a taxon indicates that it is considered to be introduced. The Bioregional Conservation Status (BCS) is a measure of the current extent and quality of that EVC in a bioregion compared to its original (pre-1750) extent and condition, in this case the Otway Plain bioregion. The BCS ratings for the relevant wetland/saltmarsh EVCs are from Frood and Papas (2016). These authors include definitions of the BCS ratings.

The Karaaf includes remnant flora of two additional terrestrial EVCs: EVC 858 Coastal Alkaline Scrub (to the south and east of the wetland system) and EVC 175 Grassy Woodland (along the north-western boundary of the Karaaf) – brief description of these is also provided. The BCS ratings for these two are from DSE (undated). Areas of fringing vegetation have been altered by prior land-use to the extent that the current vegetation comprises introduced species – these have been mapped in previous studies as EVC 999 ('Unknown/unclassified'), a default unit to indicate modified vegetation which cannot be referred to an identifiable EVC.

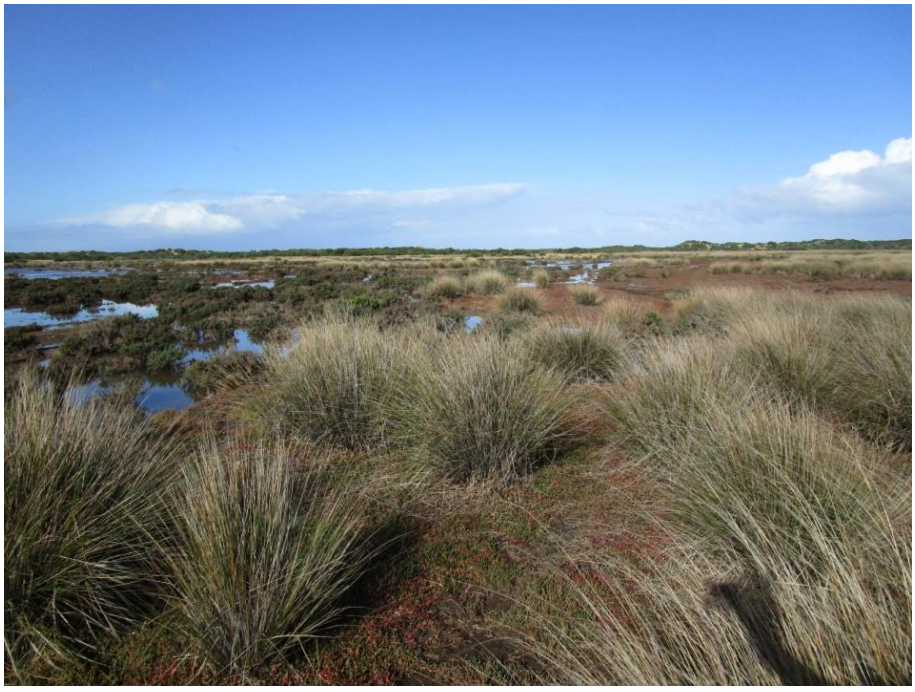
3.4.1 SALTMARSH AND ALLIED VEGETATION COMMUNITIES

Coastal Saltmarsh Aggregate (EVC 9)

This Aggregate EVC comprises variously low shrubby or herbaceous (to grassy or sedgy) vegetation of salinised coastal soils, in or adjacent to tidally influenced wetland. Coastal Saltmarsh Aggregate can include a number of component EVCs. These occur as zones of varying structure and floristics which reflect the regimes of tidal inundation and substrate character. Coastal Saltmarsh is of scattered distribution in sheltered embayments and estuaries along the Victorian coast, but most extensive around the shorelines of Western Port Bay and Corner Inlet, with a BCS of 'Vulnerable'. 'Subtropical and Temperate Coastal Saltmarsh' is a listed Ecological Community under the EPBC Act, with a status of 'Vulnerable' (Australian Government, 2022).

The wetland EVCs A107 to A113 provide resolution of the potential components of Coastal Saltmarsh Aggregate. Six of these seven potential components were recorded from the Karaaf: Coastal Dry Saltmarsh, Coastal Hypersaline Saltmarsh, Coastal Saline Grassland, Coastal Tussock Grassland, Wet Saltmarsh Herbland and Wet Saltmarsh Shrubland. Descriptions of these follow.

Indicator species for Coastal Saltmarsh Aggregate locally include Shrubby Glasswort (*Tecticornia arbuscula*), Bellarine Glasswort (*Tecticornia* sp. [Connewarre]), Beaded Glasswort (*Salicornia quinqueflora* subsp*. quinqueflora*), Austral Seablite (*Suaeda australis*) and Southern Sea-heath (*Frankenia pauciflora* var*. gunnii*), with Chaffy Saw-sedge (*Gahnia filum*), Prickly Spear-grass (*Austrostipa stipoides*), Rounded Noon-flower (*Disphyma crassifolium* subsp*. clavellatum*) and Australian Salt-grass (*Distichlis distichophylla*) conspicuous in the more elevated zones.



Structural variation within the Coastal Saltmarsh Aggregate, with image including herbland, low shrubland and sedgeland components.

Coastal Dry Saltmarsh (EVC A110)

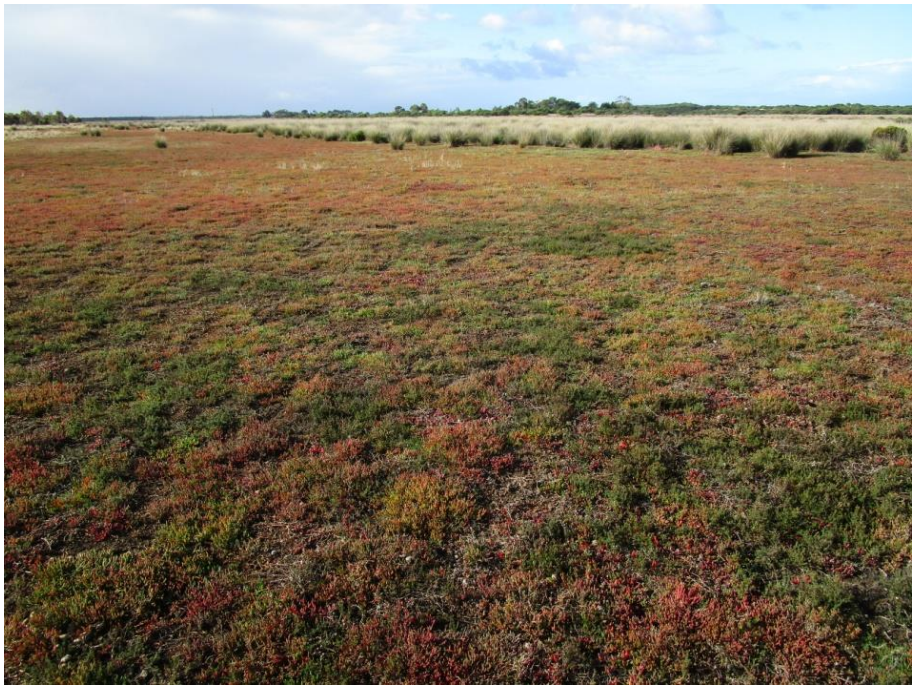
This EVC comprises herbland to low shrubland of the upper coastal saltmarsh in lower rainfall areas. It is subject to relatively infrequent tidal inundation, or sometimes occurs in remnant near coastal lacustrine sites which no longer have direct access to tidal inundation events. In Victoria it is of scattered distribution between the Bellarine Peninsula and Lake Reeve in Gippsland, with a BCS of 'Vulnerable'.

Coastal Dry Saltmarsh occurs as a fringing band around parts of the Karaaf wetlands, particularly along the north-western side, with a few localised patches also present on higher ground within the main body of the wetland. The major species in this EVC at the Karaaf include Beaded Glasswort (*Salicornia quinqueflora* subsp*. quinqueflora*), Rounded Noon-flower (*Disphyma crassifolium* subsp*. clavellatum*) and Southern Sea-heath (*Frankenia pauciflora* var*. gunnii*), with less frequent taxa including Native Sea-spurrey (*Spergularia tasmanica*) and Australian Saltmarsh-grass (*Puccinellia stricta* s.s.). Australian Salt-grass (*Distichlis distichophylla*) and incidental Coast Tussock-grass (*Poa poiformis* var. *poiformis*) can also be present in more peripheral habitat. The cover contribution of introduced species is variable, at the time of the assessment ranging from less than one percent in core areas abutting wetter saltmarsh communities (with recently germinated annuals), to up to 40% of the cover provided by introduced species in more elevated peripheral areas.

The main introduced species observed included Water Buttons (**Cotula coronopifolia*) seedlings and Sea Barley-grass (**Hordeum marinum*), with Wimmera Rye-grass (**Lolium rigidum*) and

Buck's-horn Plantain (**Plantago coronopus*) in the peripheral areas. It is probable that a wider range of introduced salt-tolerant annual grasses, e.g. Barb Grass (**Parapholis* spp.) and Annual Beard-grass (**Polypogon monspeliensis*) and other small herbs would be identifiable during spring.

Trengrove (1998) described the relevant vegetation as 'Sea Heath (*Frankenia pauciflora*)/Rounded Noon-flower (*Disphyma crassifolium* subsp. *clavellatum*) dominated Saline Herbland'. Carr *et al.* (2001) included it within a more broadly circumscribed descriptor of 'Beaded Glasswort (*Sarcocornia quinqueflora*) Herbfield (species-poor, but with *Frankenia pauciflora* and **Polypogon monspeliensis*), with representative quadrats sampled from upper saltmarsh habitat. Victorian taxa previously regarded as representatives of the genus *Sarcocornia* have since been transferred to the genus *Salicornia*.



Broad zone of Coastal Dry Saltmarsh to rear of Coastal Tussock Saltmarsh, along north-western margin of the Karaaf, with Southern Sea-heath and Rounded Noon-flower locally codominant with Beaded Glasswort.

Coastal Dry Saltmarsh occupying zone between Coastal Hypersaline Saltmarsh (to left) and Estuarine Flats Grassland (to right)

Coastal Hypersaline Saltmarsh (EVC A111)

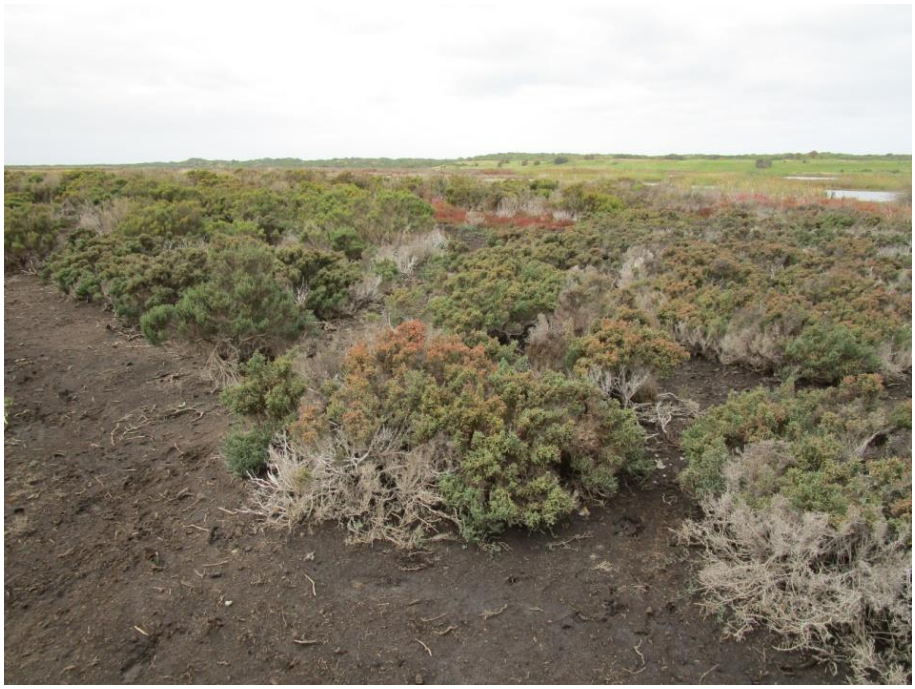
This EVC comprises low shrubland dominated by succulent chenopods (or rarely Salt Lawrencia, *Lawrencia squamata*), typically occurring in at least seasonally hypersaline coastal saltmarsh habitat above the zone of regular tidal inundation. It is extremely localised in Victoria, occurring in Western Port Phillip Bay, on the Bellarine Peninsula and at Lake Reeve in Gippsland, with a BCS of 'Vulnerable'.

At the Karaaf wetlands, Bellarine Glasswort (*Tecticornia* sp. [Connewarre]) is characteristically present in this EVC, sometimes in monospecific stands or variously with Beaded Glasswort (*Salicornia quinqueflora* subsp*. quinqueflora*), Shrubby Glasswort (*Tecticornia arbuscula*) and Austral Seablite (*Suaeda australis*). Round-leaf Wilsonia (*Wilsonia rotundifolia*) is occasionally also present as a minor component. The interpretation of the circumscription of this EVC is difficult at the Karaaf wetlands. Bellarine Glasswort occurs around the outer periphery of the zones dominated by succulent chenopods, as well as in low-lying patches prone to shallow seasonal inundation where hypersaline conditions develop as these dry out during warmer months. These low-lying patches are frequently fringed by Shrubby Glasswort dominated vegetation which is usually referred to Wet Coastal Saltmarsh. However it appears that much of the Shrubby Glasswort dominated vegetation is above the reach of normal tidal inundation, although it may be subject to superficial seasonal inundation from rain events, and can apparently be to some extent seasonally prone to hypersaline conditions. Consequently the application of the most suitable EVC for the dryer Shrubby Glasswort dominated vegetation is

difficult to interpret. For the purposes of this report, Shrubby Glasswort dominated vegetation in sites lacking Bellarine Glasswort, but less prone to tidal inundation, is interpreted as a dryer version of Wet Saltmarsh Shrubland.

At the time of assessment, introduced species were mostly a relatively minor component (up to 5% cover) if present in areas supporting Bellarine Glasswort. These comprised annual species, mainly Water Buttons (**Cotula coronopifolia*) seedlings, with Hastate Orache (**Atriplex prostrata*) also widespread, usually at low covers, and germinants of Sweet Melilot (**Melilotus indicus*) also observed in a localised area on the southern side of the wetlands. Other annuals may become locally more conspicuous during spring.

Trengrove (1998) described the relevant vegetation as Grey Glasswort (*Halosarcia* sp.) dominated Dry Saltmarsh. Carr *et al.* (2001) referred to it as Blackseed Glasswort (*Halosarcia pergranulata*) Shrubland. *Halosarcia* species have since been transferred to the genus *Tecticornia*. Both of these vegetation descriptions predated the recognition of Bellarine Glasswort as a distinct species; hence the inconsistency in previous taxonomic interpretation.



Coastal Hypersaline Saltmarsh dominated by Bellarine Glasswort towards the outer verge of chenopod dominated saltmarsh.

Coastal Hypersaline Saltmarsh codominated by Bellarine Glasswort and Shrubby Glasswort in a low-lying area within the broader saltmarsh vegetation. Note the dieback of glasswort shrubs to the right of the image, due to excessively prolonged inundation.

Coastal Saline Grassland (EVC A109)

This EVC comprises grassland dominated by rhizomatous grasses (at best development forming mounds), and occurs towards the outer zones of coastal saltmarsh, often at the boundary between Coastal Saltmarsh Aggregate and Estuarine Flats Grassland (EVC 914). Coastal Saline Grassland is frequently very species poor, especially at maximum development, and is typically dominated by either *Distichlis distichophylla* or the vegetatively very similar *Sporobolus virginicus*. It is of restricted extent with a scattered distribution along the Victorian coastline, with a BCS of 'Rare'.

Coastal Saline Grassland is of restricted extent at the Karaaf, occurring as localised patches on the outer margins of the saltmarsh vegetation, predominantly along the north-western edge of the wetlands. The relevant vegetation is dominated by Australian Salt-grass (*Distichlis distichophylla*), variously with Rounded Noon-flower (*Disphyma crassifolium* subsp. *clavellatum*) and incidental plants of species including Beaded Glasswort (*Salicornia quinqueflora* subsp. *quinqueflora*), Knobby Club-sedge (*Ficinia nodosa*) and Coast Tussock-grass (*Poa poiformis* var. *poiformis*). Introduced species are mostly at relatively low covers, with the most common species being Hastate Orache (**Atriplex prostrata*) and Buck's-horn Plantain (**Plantago coronopus*). Other introduced species observed in this EVC included Soft Brome (**Bromus hordeaceus*), Wimmera Rye-grass (**Lolium rigidum*) and Ox-tongue (**Helminthotheca echioides*).

Coastal Saline Grassland dominated by Australian Salt-grass: Localised patch along the north-western boundary of the wetlands.

Coastal Tussock Saltmarsh (EVC A112)

This EVC is dominated by robust, tussock-forming, salt tolerant grasses or sedges. It occurs in more elevated parts of Coastal Saltmarsh zones above regular tidal inundation. Coastal Tussock Saltmarsh is dominated by either *Gahnia filum* or *Austrostipa stipoides*, with a range of halophytic species occurring at lower covers. It is of scattered distribution along the Victorian coast, with a BCS of 'Rare'.

Chaffy Saw-sedge (*Gahnia filum*) is the main structural dominant in this EVC at the Karaaf, with Prickly Spear-grass (*Austrostipa stipoides*) much less abundant and with the largest populations to the near south-west of the junction of Mullet Creek with Thompson Creek. Associated species variously included Rounded Noon-flower (*Disphyma crassifolium* subsp*. clavellatum*), Australian Salt-grass (*Distichlis distichophylla*), Austral Seablite (*Suaeda australis*) and Trailing Hemichroa (*Hemichroa pentandra*), with Bellarine Glasswort (*Tecticornia* sp. [Connewarre]) and Beaded Glasswort (*Salicornia quinqueflora* subsp*. quinqueflora*) occasionally also present. Introduced species generally provided only very low cover, and were most conspicuous in association with kangaroo trails through the vegetation. Introduced species present at the time of the assessment included Water Buttons (**Cotula coronopifolia*), Wimmera Rye-grass (**Lolium rigidum*), Hastate Orache (**Atriplex prostrata*), Sea Barley-grass (**Hordeum marinum*) and young seedlings of other introduced grasses.

Trengrove (1998) described relevant vegetation as Chaffy Saw-sedge (*Gahnia filum*) dominated Sedgeland.

Coastal Tussock Saltmarsh dominated by Chaffy Saw-sedge

Coastal Tussock Saltmarsh dominated by Prickly Spear-grass.

Wet Saltmarsh Herbland (EVC A107)

This EVC comprises a low herbland dominated by succulent to semi-succulent halophytic herbs or semi-shrubs. Wet Saltmarsh Herbland is often very species-poor and most frequently dominated by *Salicornia quinqueflora* subsp*. quinqueflora*. It occupies low-lying areas of coastal saltmarsh subject to regular inundation, and is widespread in suitable habitat in sheltered parts of the Victorian coast, with a BCS of 'Rare'.

Beaded Glasswort (*Salicornia quinqueflora* subsp*. quinqueflora*) is the dominant species in this vegetation at the Karaaf wetlands, variously with Trailing Hemichroa (*Hemichroa pentandra*), and sometimes Austral Seablite (*Suaeda australis*) or incidental Round-leaf Wilsonia (*Wilsonia rotundifolia*). This EVC mostly lacked introduced species, however species such as Water Buttons (**Cotula coronopifolia*) and Hastate Orache (**Atriplex prostrata*) were present in locations where the vegetation was subject to freshwater run-off from adjacent areas.

Trengrove (1998) described the relevant vegetation as Beaded Glasswort (*Sarcocornia quinqueflora*) dominated Wet Saltmarsh. Carr *et al.* (2001) broadly described *Salicornia quinqueflora* dominated vegetation as Beaded Glasswort (*Sarcocornia quinqueflora*) Herbfield (species-poor, but with *Frankenia pauciflora* and **Polypogon monspeliensis*). While their quadrats were sampled in the upper saltmarsh (in Coastal Dry Saltmarsh), Carr *et al.* noted that 'Where conditions favour its development, it [Beaded Glasswort] forms almost monospecific herbfields in upper saltmarshes as described here, as well as in lower saltmarshes'.

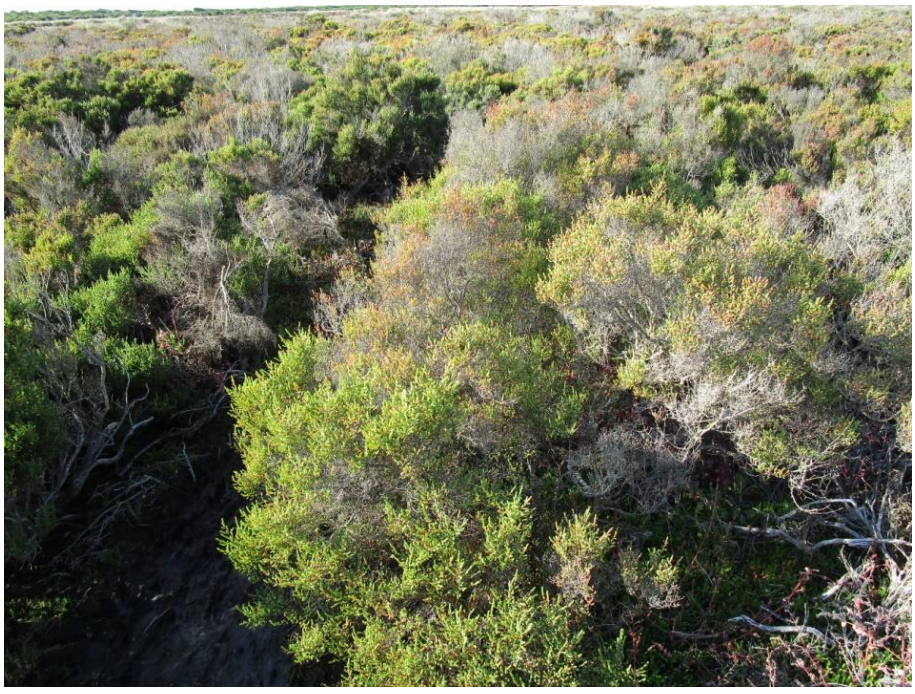
Wet Saltmarsh Herbland dominated by Beaded Glasswort

Wet Saltmarsh Shrubland (EVC A108)

This EVC comprises shrubland dominated by halophytic species and is generally subject to regular tidal inundation. This EVC is often very species-poor, and usually dominated by the succulent shrub *Tecticornia arbuscula*. It is of scattered distribution along the Victorian coast, but largely confined to between Breamlea and Corner Inlet, with a BCS of 'Depleted'.

Shrubby Glasswort (*Tecticornia arbuscula*) is the dominant species in the relevant vegetation at the Karaaf wetlands, frequently occurring in monospecific stands. Where present, associated species variously included Rounded Noon-flower (*Disphyma crassifolium* subsp*. crassifolium*), Beaded Glasswort (*Salicornia quinqueflora* subsp*. quinqueflora*) and Southern Sea-heath (*Frankenia pauciflora* var*. gunnii*). The vegetation is often lacking introduced species, but can occasionally include scattered Hastate Orache (**Atriplex prostrata*) or Water Buttons (**Cotula coronopifolia*). Carr *et al*. (2001) recorded Annual Beard-grass (**Polypogon monspeliensis*) from drier habitat in this vegetation.

Trengrove (1998) described the relevant vegetation as Shrubby Glasswort (*Sclerostegia arbuscula*) dominated Wet Saltmarsh. Carr *et al.* (2001) referred to it as Shrubby Glasswort (*Sclerostegia arbuscula*) Shrubland. The latter authors also recorded Coast Tussock-grass (*Poa poiformis* var*. poiformis*) as an associated species – this is presumed to be a reflection of colonisation into the saltmarsh by this species during the drier conditions prevailing prior to the restoration of tidal flows into the wetlands. *Sclerostegia arbuscula* is a prior synonym of *Tecticornia arbuscula*.



Wet Saltmarsh Shrubland dominated by Shrubby Glasswort

Estuarine Flats Grassland (EVC 914)

This EVC represents tussock grassland to sedgeland of low-lying coastal sites, beyond the zone of normal tidal inundation but sometimes subject to seasonal waterlogging or rarely brief intermittent freshwater inundation. It is of scattered distribution in low-lying coastal sites, with a BCS of 'Endangered'.

At the Karaaf, the relevant vegetation is dominated by Common Tussock-grass (*Poa poiformis* var. *poiformis*), variously with or without Knobby Club-sedge (*Ficinia nodosa*) present as a codominant. The associated species include halophytic plants shared with coastal saltmarsh, e.g. Australian Salt-grass (*Distichlis distichophylla*), Southern Sea-heath (*Frankenia pauciflora* var. *gunnii*), Thick-head Glasswort (*Salicornia blackiana*) and Beaded Glasswort (*Salicornia quinqueflora* subsp. *quinqueflora*). In more peripheral sites, the vegetation is transitional to the prior fringing community of calcareous dune soils Coastal Alkaline Scrub (EVC 858), and includes species more representative of non-saline grassy vegetation types, e.g. Australian Hound's Tongue (*Cynoglossum australe*), Slender Wallaby-grass (*Rytidosperma racemosum* var. *racemosum*), Annual Fireweed (*Senecio glomeratus* subsp. *glomeratus*) and a range of introduced grasses and forbs (dicot herbs).

Introduced species range from providing only very low cover where the EVC is occurring in a more saline context, to prevalent in the relatively elevated areas which have been more modified by prior land-use. Introduced species recorded by Carr *et al.* (2001) from this EVC included Spear Thistle (**Cirsium vulgare*), Common Sow-thistle (**Sonchus oleraceus*), Buck's-horn Plantain (**Plantago coronopus*), Ox-tongue (**Helminthotheca echioides*), Soft Brome (**Bromus hordeaceus*), Hare's-tail Grass (**Lagurus ovatus*), Great Brome (**Bromus diandrus*) and Yorkshire Fog (**Holcus lanatus*).

Carr *et al.* (2001) described relevant vegetation under two community descriptions:

- Blue Tussock-grass (*Poa poiformis*) - Sea Rush (*Juncus kraussii*) Grassland/Sedgeland [as part of the Saltmarsh Complex]. This was dominated by *Poa poiformis* var. *poiformis* and *Ficinia nodosa* (plus one site also with *Juncus kraussii*); with associated species including *Distichlis distichophylla*, *Frankenia pauciflora*, *Salicornia quinqueflora*, *Disphyma crassifolium*, *Hemichroa pentandra* and *Samolus repens*.
- Blue Tussock-grass (*Poa poiformis*) - Knobby Club-sedge (*Isolepis nodosa*) Grassland/Sedgeland [as part of the Dune Complex – occurring on calcareous sand of old dunes]. *Carr et al*. considered this vegetation to have been derived from Moonah – Coast Wirilda Shrubland. Species present included *Poa poiformis* var. *poiformis*, *Ficinia nodosa*, *Cynoglossum australe*, *Rytidosperma racemosa* var. *racemosa*, **Lagurus ovatus*, **Bromus diandrus* and **Holcus lanatus*.

Trengrove (1998) described relevant vegetation as Coast Tussock-grass (*Poa poiformis*) dominated Grassland.

Estuarine Flats Grassland codominated by Coast Tussock-grass and Knobby Club-sedge.

Estuarine Flats Grassland dominated by Coast Tussock-grass.

Estuarine Wetland (EVC10)

This EVC mostly comprises rushland vegetation dominated by *Juncus kraussii* subsp. *australiensis*, variously with a component of halophytic herbs. Estuarine Wetland is of scattered distribution along the coast, with a BCS of 'Endangered'. It occurs in estuarine situations and also at rear of saltmarshes where there is seepage, but is most extensive in association with larger estuarine floodplains.

Estuarine Wetland is of restricted distribution at the Karaaf, where it is confined to a few localised patches along the southern boundary of the saltmarsh vegetation. Species associated with the dominant Sea Rush (*Juncus kraussii* subsp*. australiensis*) include Australian Salt-grass (*Distichlis distichophylla*) and Austral Seablite (*Suaeda australis*). Introduced species provided a relatively low cover (<5%), with the most conspicuous species including Spear Thistle (**Cirsium vulgare*) and Hastate Orache (**Atriplex prostrata*).

Carr *et al.* (2001) described Sea Rush (*Juncus kraussii*) – Streaked Arrow-grass (*Triglochin striatum*) Herbfield as a 'highly unusual saltmarsh vegetation occupying a more-or less circular area c. 100 m wide in pasture away from and upslope of the main saltmarsh'. This included a range of species not recorded from within the adjacent Karaaf wetlands, e.g. **Spergularia rubra* s.l., *Lobelia irrigua* (as *Pratia irrigua*) and *Sporobolus virginicus*. See also the notes under Estuarine Flats Grassland.

Estuarine Wetland dominated by Sea Rush.

Saline Aquatic Meadow (EVC 842)

This EVC comprises submerged herblands of thin grass-like plants, occurring within brackish to hypersaline waterbodies (shallow lakes and swamps and intermittent wetland ponds). The vascular vegetation is characteristically extremely species-poor, comprising one or more species of *Althenia* or *Ruppia*. Non-vascular stoneworts can also be conspicuous and are ecologically important. Saline Aquatic Meadow is widespread within restricted habitat in Victoria's lowlands, principally in the Wimmera, on the western volcanics and in coastal areas, with a BCS of 'Rare'.

Shallow, historically seasonally inundated clay pans (inundated in winter-spring and dry in summer) are mainly concentrated towards the western edge of the Karaaf wetlands, with the largest of these being over a hectare in extent. Relatively intact examples of these supported submerged swards of Water Mat (*Althenia* spp.) when inundated. Plants of Water Tassel (*Ruppia polycarpa*) were noted in sparse aquatic vegetation in what, due to freshwater inputs, is apparently now a continuously inundated shallow lagoon near the western boundary. This species was not noted elsewhere in the Karaaf and it is possible that, due to the changed hydrology, it has been able to colonise from avian introduction. The vegetation of this water body also included Small-fruit Water-mat (*Althenia bilocularis*), Water Starwort (*Callitriche* sp.), Swamp Crassula (*Crassula helmsii*) and mats of filamentous green algae, in what can be interpreted as an ecological shift towards Brackish Aquatic Herbland (EVC 537).

No introduced species were recorded in this EVC, other than Water Buttons (**Cotula coronopifolia*) where the habitat was modified by freshwater inflows of stormwater discharged from adjacent development at the western end of the Karaaf wetlands.

Carr *et al.* (2001) described Long-fruit Water-mat (*Lepilaena cylindrocarpa*) Submerged Herbfield from the wetlands. They sampled a single quadrat comprising a high cover of *Althenia cylindrocarpa* (as its prior name *Lepilaena cylindrocarpa*) with a low cover of *Salicornia quinqueflora* (as *Sarcocornia quinqueflora*). Plants of *Althenia* spp. observed at the time of the current assessment were generally insufficiently mature to enable identification to species level for taxa where fertile material is required.

Saline Aquatic Meadow dominated by Water Mat.

Habitat of Saline Aquatic Meadow (shallow seasonally inundated clay pans), fringed by Wet Saltmarsh Herbland dominated by Beaded Glasswort and Austral Seablite.

Sea-grass Meadow (EVC 845)

This EVC describes sward-forming aquatic herblands of sheltered marine shallows, intertidal flats and lower estuarine habitats. Sea-grass Meadow is often monospecific in relation to vascular plants, and sometimes occurs in close proximity to stands of Grey Mangrove (*Avicennia marina*). It is of scattered distribution along the Victorian coast, with the most extensive development within Corner Inlet and Western Port Bay, with a BCS of 'Vulnerable'.

Billows (2006) observed the appearance of Dwarf Grass-wrack (*Zostera muelleri*) patches within Mullet Creek after tidal flows were restored, but also noted the potential impact of high nutrient conditions to lead to the displacement of this species through the expansion of the red alga *Gracillaria* sp. and heavy accumulation of epiphytes on the leaves of the sea-grass. Dwarf Grass-wrack was not readily apparent within the main channel of Mullet Creek during the current assessment, and was only noted in an extremely localised stretch of a side tributary of this tidal creek. No introduced species were recorded in the potential habitat of Dwarf Grass-wrack along the Mullet Creek system. In Deakin (2005), Seagrass Meadow is regarded as a feature of permanently open estuaries (rather than intermittently closed ones), noting that salinities of <16 ppt. could impact this EVC, and that it would not tolerate exposure to air for more than one day.

Habitat of the localised population of Dwarf Grass-wrack (plant evident as submerged dark patches) on a side arm of Mullet Creek at the Karaaf wetlands.

*Sea-grass Meadow dominated by Tasman Grass-wrack (*Heterozostera tasmanica*) in a tidal creek at a different location (Corner Inlet, Gippsland): Grey Mangrove (as in this photo) reaches its western limit in Victoria at Lake Connewarre, and does not occur in the Karaaf wetlands.*

Seasonally Inundated Sub-saline Herbland (EVC 196)

This EVC comprises a species-poor low herbland of seasonal saline wetland within relicts of former tidal lagoons, dominated by *Wilsonia* spp. (*Wilsonia humilis* and/or *W. backhousei* and *W. rotundifolia*). The habitat is not inundated tidally, but by overland flows. Seasonally Inundated Sub-saline Herbland is extremely localised in Victoria (mostly the Bellarine Peninsula, with small areas in the Gippsland Lakes), with a BCS of 'Rare'.

Carr *et al.* (2001) described Round-leaf Wilsonia (*Wilsonia rotundifolia*) Herbfield from the western margins of the wetlands. These authors noted that a cross fence comparison of this community indicated that it was an artefact of grazing, and that the saline site subject to seasonal inundation formerly carried 'Blackseed Glasswort (*Halosarcia pergranulata*) which had been eliminated by grazing, whereas the soil hugging *W. rotundifolia* apparently evades grazing'. The relevant area has since been substantially modified by the impacts of stormwater inputs from the adjacent development, and Round-leaf Wilsonia is currently only a very minor component of the vegetation in the vicinity of the western edge of the wetlands.

Round-leaf Wilsonia in the Karaaf wetlands.

3.4.2 ADVENTIVE VEGETATION

BCS ratings are not supplied for the examples of these EVCs at the Karaaf as they are atypical artefacts derived from ecological disturbance to pre-existing saltmarsh and allied EVCs.

Brackish Wetland Aggregate (EVC 656)

This EVC provides a collective label for the various zones of sedgy-herbaceous vegetation associated with sub-saline wetlands. Components variously include wetter versions of Brackish Sedgeland (EVC 13), Brackish Herbland (EVC 538) and Saline Aquatic Meadow (EVC 842). Its mainly occurs in western and northern parts of the State (but not the further north-west), but also has natural occurrences in scattered sites on coastal plains.

The main identifiable component in the modified vegetation referable to this EVC at the Karaaf was a version of Brackish Sedgeland dominated by Salt Club-sedge (*Bolboschoenus caldwellii*). This varied from providing a dense sward, e.g. in patches around lagoon verges, to providing a sparse cover in association with a range of herbs, notably introduced dicot species. Native species associated with this vegetation variously included Streaked Arrow-grass (*Triglochin striata*), Creeping Monkey-flower (*Thyridia repens*), Common Spike-sedge (*Eleocharis acuta*), Lance-leaf Groundsel (*Senecio pinnatifolius* var. *lanceolatus*) and occasionally Round-leaf Wilsonia (*Wilsonia rotundifolia*). Introduced species can provide a high cover where Salt club-rush is less dominant, and include Water Buttons (**Cotula coronopifolia*), Hastate Orache (**Atriplex prostrata*), Aster-weed (**Symphyotrichum subulatum*) and Annual Beard-grass (**Polypogon monspeliensis*).

Adventive Brackish Wetland Aggregate with sparser culms of Salt Club-sedge near the western edge of the Karaaf wetlands.

Brackish Sedgeland component of the Brackish Wetland Aggregate, dominated by Salt Club-sedge, developed on the margins of a shallow lagoon near the western margins of the Karaaf wetlands.

Tall Marsh (EVC 821)

This EVC comprises wetland vegetation dominated by tall emergent graminoids, typically in thick, species-poor swards. The structure is variously rushland, sedgeland or reedbed, locally closed or in association or fine-scale mosaic with Aquatic Herbland (EVC 653), e.g. along floodway lagoons. Tall Marsh is naturally of scattered distribution across lowland Victoria. Some of the structurally dominant species of this EVC can be vigorous colonisers into sites with an altered hydrology, notably where this results in shallow warm and unnaturally wet conditions in summer.

The discharge of stormwater into the western section of the Karaaf has allowed species indicative of this EVC to colonise. This colonisation is indicative of a further shift towards sustained freshwater conditions beyond those which have facilitated the development of the brackish wetland flora. The most locally prevalent of these opportunistic invaders is Cumbungi or Bulrush (*Typha* spp.), but Common Reed (*Phragmites australis*) and River Club-sedge (*Schoenoplectus tabernaemontani*) also have localised occurrences. In addition to species indicative of the opportunistic brackish wetland vegetation, associated species include Common Spike-sedge (*Eleocharis acuta*) and Streaked Arrow-grass (*Triglochin striata*). Introduced species can be locally prevalent and include Water Buttons (**Cotula coronopifolia*) and Curled Dock (**Rumex crispus*).

Opportunistic colonisation of Cumbungi around the verges of a shallow lagoon in the western portion of the Karaaf wetlands. The smaller mat-forming plant in the foreground is Water Buttons.

3.4.3 FRINGING NON-SALINE TERRESTRIAL VEGETATION

Coastal Alkaline Scrub (EVC 858)

This EVC (also known as Calcarenite Dune Woodland) comprises a low woodland, tall shrubland or scrub to eight metres tall of near-coastal, deep calcareous (alkaline) and largely stable sand dunes and swales (DELWP, 2022b). Coastal Alkaline Scrub is allocated a BCS of 'Endangered'. It is commonly dominated by Moonah (*Melaleuca lanceolata*), typically with a medium shrub layer, small shrub layer and sedges, grasses and herbs in the ground layer.

Moxham *et al*. (2010) provide a review of Coastal Moonah Woodland in Victoria, noting that it comprises a community within the EVC Coastal Alkaline Scrub, and that it is listed as threatened under the Victorian Flora and Fauna Guarantee Act 1998, with less than 10% of its original distribution remaining. It occurs on the Mornington and Bellarine Peninsulas, also west from Portland to the South Australian Border and in the vicinity of Warrnambool.

Species occurring in this vegetation at the Karaaf include Moonah, Coast Wirilda (*Acacia uncifolia*), Coast Beard-heath (*Leucopogon parviflorus*), Common Boobialla (*Myoporum insulare*), Coast Tea-tree (*Leptospermum laevigatum*), Seaberry Saltbush (*Rhagodia candolleana* subsp. *candolleana*), Bower Spinach (*Tetragonia implexicoma*), Slender Clematis (*Clematis decipiens*), Small-flower Flax-lily (*Dianella brevicaulis*), Australian Hound's-tongue (*Cynoglossum australe*), Coast Tussock-grass (*Poa poiformis* var*. poiformis*), Coast Sword-sedge (*Lepidosperma gladiatum*), Coast Spear-grass (*Austrostipa flavescens*), Knobby Club-sedge (*Ficinia nodosa*) and Slender Wallaby-grass (*Rytidosperma racemosa* var*. racemosa*).

A wide range of introduced species from a variety of life-forms, but notably grasses and forbs, occur in remnants of this vegetation at the Karaaf. Buffalo Grass (**Stenotaphrum secundatum*) is particularly conspicuous in the ground layer of remnant vegetation near the eastern boundary south of Mullet Creek.

Carr *et al.* (2001) described the relevant vegetation as Moonah Woodland – Coast Wirilda Shrubland. Trengrove (1998) referred to it as Moonah Coastal Woodland with two sub-communities, these being Open and Closed variants.

Coastal Alkaline Scrub (to the rear of the image) on the dunes abutting the Karaaf.

Grassy Woodland (EVC 175)

This EVC is described as a variable open eucalypt woodland to fifteen metres tall or occasionally Sheoak woodland to ten metres tall over a diverse ground layer of grasses and herbs, usually with the shrub layer sparse. It occurs on sites with moderate fertility on gentle slopes or undulating hills on a range of geologies (DELWP, 2022b). Grassy Woodland was previously widespread on relatively fertile soils across broad areas of lowland Victoria, but has been extensively cleared for agriculture, and is now mostly reduced to small isolated fragments, with a BCS of 'Endangered'.

This EVC previously abutted the northern and western sides of the Karaaf. It is currently evident only as small populations of remnant species along the boundary including Hedge Wattle (*Acacia paradoxa*), Golden Wattle (*Acacia pycnantha*) and Weeping Grass (*Microlaena stipoides* var. *stipoides*) at the northern tip and Clustered Sword Sedge (*Lepidosperma laeve*) along part of the north-west boundary fenceline. Previous mapping of the extant vegetation of the Karaaf has referred the relevant prior habitat of Grassy Woodland and other more elevated highly disturbed areas to EVC 999 ('Unknown/unclassified') due to the extent of modification and current occupation by introduced species. Two fenced patches along the north-western side of the Karaaf have been revegetated, with additional planted species including Bellarine Yellow-gum (*Eucalyptus leucoxylon* subsp*. bellarinensis*) and Drooping Sheoak (*Allocasuarina verticillata*).

Clustered Sword-sedge along the fenceline on the north-western boundary of the Karaaf.

4. VEGETATION MAPPING

4.1 EVALUATION OF EXISTING EVC MAPPING

Two versions of EVC mapping from 2010 (Osler *et al*., 2010) and 2017 (Sinclair *et al*., 2020) respectively were provided by the SCS. The 2017 mapping allocates values for perennial native cover to the respective EVCs.

Without intense ground-truthing, it is generally unlikely that any vegetation map of more than a very small or highly uniform area will be nearly perfect. Overall, the available vegetation mapping of the Karaaf wetlands is mostly remarkably accurate, especially for Coastal Tussock Saltmarsh, Saline Aquatic Meadow, Wet Saltmarsh Herbland and the combined area of Coastal Hypersaline Saltmarsh and Wet Saltmarsh Shrubland. In the case of the last two saltmarsh EVCs, the two available maps differ in interpretation of the distribution of each – considering the unusual context of the vegetation dominated by *Tecticornia* species at the Karaaf and the challenge of interpreting their respective distributions from aerial photography, this ambiguity is hardly surprising. While there are some inconsistencies between the two versions of the mapping in interpretation of the vegetation adjacent to the western boundary, the vegetation of this area has since been transformed by the expansion of the adventive Brackish Wetland community, as a consequence of stormwater inputs from adjacent development.

The figures provided for perennial native cover in the 2017 mapping by Sinclair *et al*. (2020) are no longer accurate for the Coastal Hypersaline Saltmarsh and Wet Saltmarsh Shrubland EVCs, suggesting that major dieback of glasswort shrubs has occurred within the past five years. This observation was confirmed by discussion with Steve Sinclair, who recalled dieback near the western boundary to be substantially less extensive than what has been mapped in the current assessment. The 2017 mapping indicates a perennial native cover of 0% for the Saline Aquatic Meadow, as the *Althenia* species which characterize this EVC have annual growth which is evident only during the winter-spring period.

4.2 MAPPING OF VEGETATION COMMUNITIES MODIFIED BY STORMWATER INPUTS

The project brief acknowledges that modification of the vegetation at the western end of the Karaaf wetlands has occurred due to inputs of stormwater from adjacent development, with one of the required outputs being to assess and map these impacts. Observable effects include the expansion of species indicative of less saline habitats, both native and introduced, into what was previously saltmarsh vegetation. The adventive Brackish Wetland and Tall Marsh communities are described in the preceding vegetation descriptions.

The Brackish Wetland is largely defined by the presence of Salt Club-sedge, which varies in density from forming a low closed sedgeland, to consisting of scattered tufts dispersed through herb-dominated vegetation. Introduced herbs such as Water Buttons, Aster-weed and Hastate Orache can be locally dominant in this modified vegetation. In places, Common Spike-sedge or Swamp Crassula are prevalent, indicating a further shift towards wetland vegetation indicative of reduced salinity. Patches of taller wetland macrophytes, primarily Bulrush or Cumbungi, but on a few occasions comprising Common Reed, have established in the less saline conditions. These are primarily distributed around the

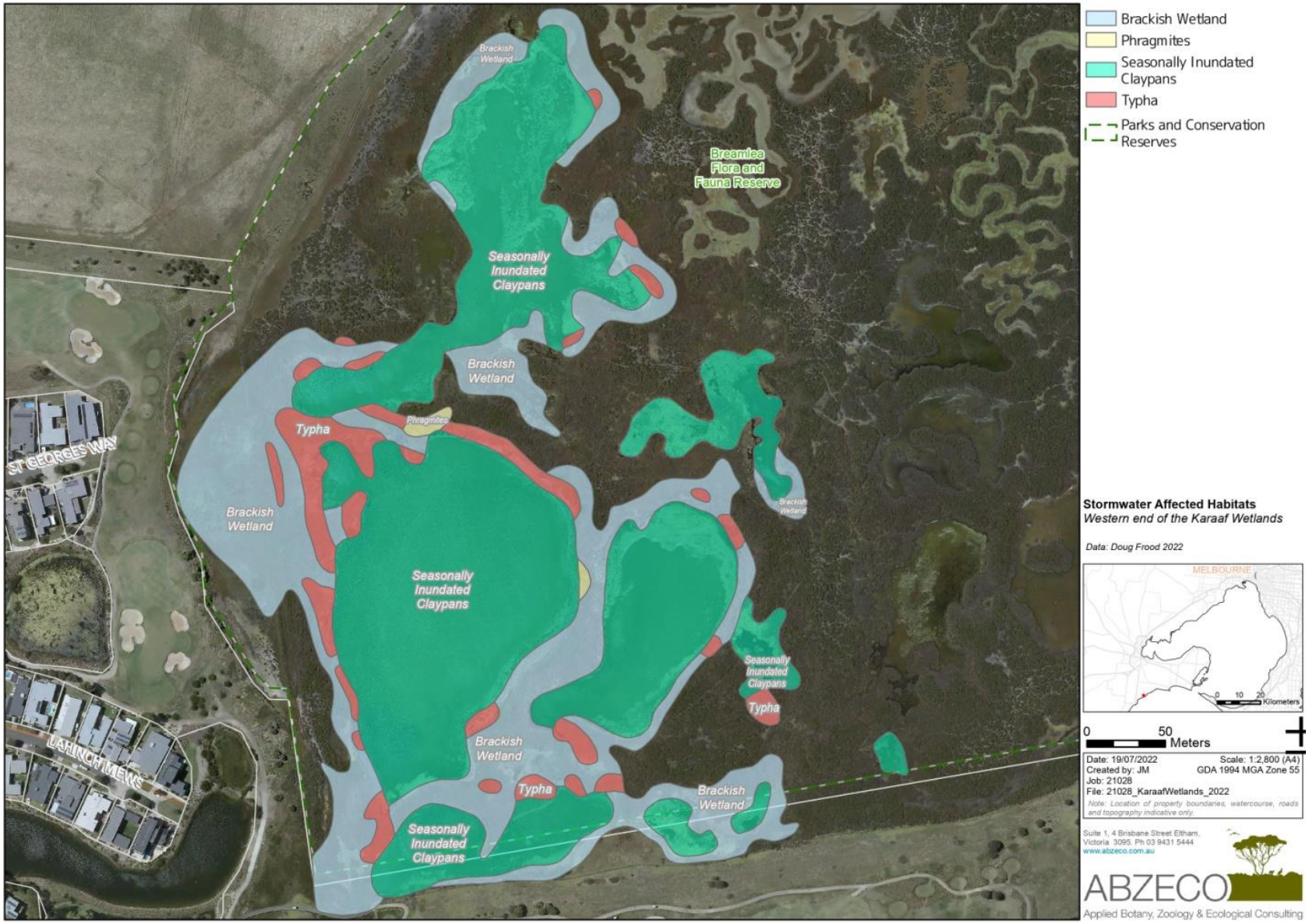
periphery of previously seasonally inundated shallow waterbodies, which now appear to be effectively permanent due to stormwater inputs at the south-western corner of the Karaaf. Patches of smaller plants of Bulrush are also evident within the brackish wetland – these can represent either recent colonisation or conditions where their growth is restricted by residual salinity. Both Bulrush and Common Reed are rhizomatous, allowing further vegetative expansion of clumps into suitable habitat once established from seed.

The effectively shallow lakes in the western section of the reserve have undergone a transition towards sparser aquatic vegetation indicative of reduced salinity, to the apparent detriment of the prior occupation of the indicator species of Saline Aquatic Meadow [recorded by Carr et al. (2001), as Long-fruit Water-mat]. Clumps of filamentous green algae are present in these waterbodies, presumably indicative of elevated nutrient levels associated with the stormwater inputs. The relevant wetlands are indicated on the below mapping as Seasonally Inundated Claypans, even if this is no longer the water regime in operation. A smaller waterbody (the eastern most feature included on the attached map) to the east of the current extent of colonisation by Salt Club-sedge has some characteristics indicative of an ecological shift – these include algal clumps in the water, and on the verges, a high cover of Water Buttons, a relatively low cover of Beaded Glasswort, and the establishment of Common Spike-sedge. While not yet having completed a transition to Brackish Wetland, these indications suggest that this waterbody is on an active front of expansion of the stormwater induced ecological modification.

Mortality rates of glasswort shrubs were particularly high in the western section of the Karaaf, with broad areas of virtually total stand death evident. While it appears highly likely that there is a local contribution to this phenomenon due to stormwater inputs, varying levels of shrub mortality are evident across the wetland system and this impact on the vegetation is presented in separate mapping, as described in subsequent text. Further discussion on the factors behind shrub die-off is also provided later in this report.

The vegetation was inspected in detail from ground-based searches, using a GPS to navigate and record the extent of patches of modified vegetation (as discussed above) onto laminated copies of aerial photography. This aerial imagery was marked with the GPS grid and existing EVC mapping boundaries included as an additional helpful guide.

MAP 2: VEGETATION COMMUNITIES MODIFIED BY STORMWATER INPUTS



Number of patches and extent of modified vegetation communities

Map Unit	FREQUENCY	Hectare
Brackish Wetland	13	3.84
Phragmites	2	0.05
Seasonally Inundated Claypans	9	6.62
Typha	27	0.86
TOTAL		**11.36**

4.3 MAPPING OF MORTALITY OF SALTMARSH SHRUBS

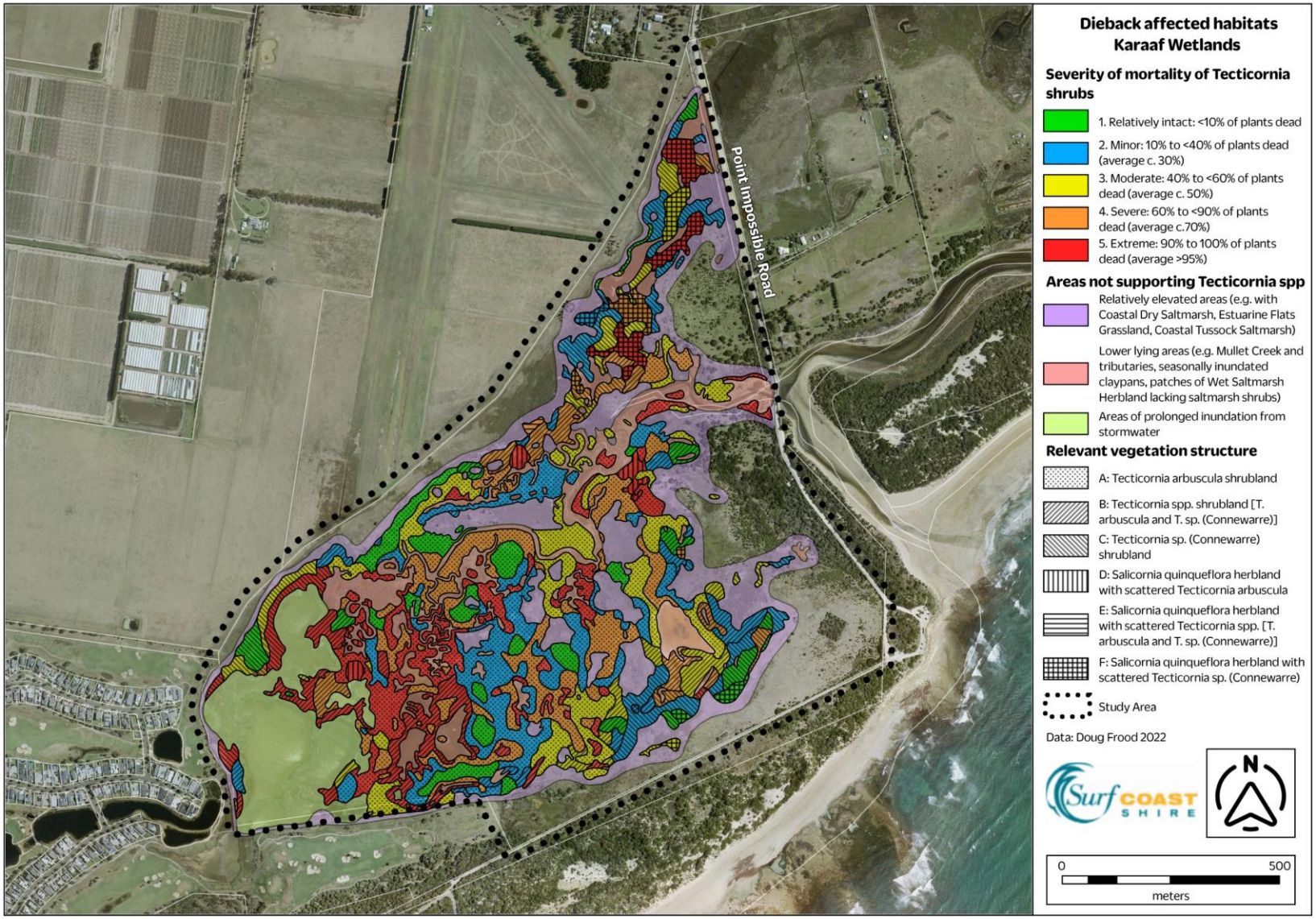
Varying degrees of mortality of plants of the two species of glasswort shrubs (Shrubby Glasswort and Bellarine Glasswort) were apparent across the extent of the Karaaf. This ranged from low frequencies presumed to reflect the natural lifespan of plants, to death of entire stands.

Where mortality rates were higher, the stems often had attached remnants of algal mats well above the level reached by maximum tidal inundation, leading to the conclusion that the shrubs had been subject to sustained inundation outside of their tolerance range. The potential factors responsible for shrub mortalities are discussed further in subsequent sections of this report. Mortality rates were particularly high in the western section of the Karaaf, with broad areas of virtually total stand death evident. Given the relatively intact nature of the finer structure of the branches on many of the dead shrubs, it is apparent that a considerable amount of this mortality is relatively recent (i.e. within the last few years). It is also noted that parts of the area now supporting the adventive brackish wetland would once have also supported glasswort shrubs. Given the extent of ecological change in these locations, no attempt was made to include them on the map of shrub mortality.

The vegetation was inspected in detail from ground-based searches using a GPS and laminated copies of aerial photography, as described above for the mapping of vegetation modified by stormwater discharge into the wetlands. In general terms, mortality rates appeared to match a range of classes, with relative overall consistency when averaged across patches of vegetation. It is suspected that this is a reflection of fine-scale topographic levels and drainage patterns across the Karaaf. These classes provided a functional basis for recording, and are indicated on the mapping by a number code as in the following key. The structural dominants of each patch were also recorded, and are indicated on the mapping by a letter code as below. Gaps within the mapping indicate areas of other vegetation types – these can be either more elevated or lower in the elevation profile than the potential habitat of these shrub species.

It should be noted that the mapping is based on visual estimates rather than prohibitively complex population counts. Interpretation can be challenging during conditions of poor light and where plants have lost most of their foliage but still retain a small proportion of living canopy. However given the detailed level of field inspection and the starkness of major stand mortality, it is considered that the mapping provides an accurate overview of the condition of the structural dominants of the shrubby saltmarsh communities and the patterns of impact across the Karaaf.

MAP 3: MAP OF MORTALITY OF SALTMARSH SHRUBS



5. DISCUSSION OF FACTORS IMPACTING VEGETATION CONDITION IN THE KARAAF WETLANDS

5.1 HISTORICAL PERSPECTIVES

A sequence of post-colonisation events is relevant to the ecological condition of the Karaaf. Notes from information supplied by SCS follow: The Karaaf was sold off as private land in 1865. The site had a history of grazing by domestic stock up to the early to mid 1970s, as well as apparently some localised cropping. This land-use has left residual impacts, noticeably through the establishment of introduced ground-layer species and displacement of native flora from parts of the fringing terrestrial areas. The Karaaf underwent a series of landholder arrangements prior to being established as a reserve. Construction of The Sands residential development and golf course commenced in the early 2000s. As part of this process, the title to the Karaaf wetlands allotment was surrendered to the Crown. The Karaaf has been under the management of Parks Victoria since ca. 2001.

With only a single pipe of ca. 750 mm diameter under the road, the construction during the 1950s of the Point Impossible Road across Mullet Creek, adjacent to its confluence with Thompson Creek, resulted in substantially reduced tidal flows into the Karaaf. Tidal flows into the saltmarsh were restored with the installation of a set of larger inlets in 2004. A prior internal causeway across Mullet Creek to the west of this road was also removed to assist the return of a close to natural tidal regime to the system when the entrance of Thompson Creek is open to the ocean.

Information provided by SCS includes a communication from Breamlea Foreshore and Reserve Ground Committee. This file note reports that a dam was constructed on Thompson Creek in the early 1950s, 2 km north of the Blackgate Road Bridge [measured along the path of the watercourse rather than as a direct distance], and has since been increased in height. It is further commented that flow from upstream rarely passes this point except in winter after exceptionally heavy rains, and that significant irrigation occurs from this dam. Elsewhere in the file notes supplied by SCS, it is mentioned that there are multiple farm dams constructed on freehold land in the Thompson Creek catchment, changing the quantity and timing of freshwater flows from the broader catchment, citing Eric Bird as a source.

Stream flows along Thompson Creek have been reduced through upstream extraction of water for agricultural use and impacts related to climate change. The entrance of the estuary has historically been subject to periodic closure events. However, it is considered likely that overall reduced stream flows may be leading to more prolonged periods of estuary closure, with increased potential for prolonged inundation of areas of the Karaaf due to potential backflow of water into the Mullet Creek system and accumulation of stormwater within the wetlands behind the barrier of the closed estuary.

Development to the west of and abutting the reserve has resulted in a substantial increase in stormwater runoff into the Karaaf, due to the large area of hard surface present within the urbanized areas. The stormwater system passes through a series of ponds within the development which eventually overflow into the south-western corner of the Karaaf. This additional water has resulted in changing the hydrology of the adjacent claypan depressions from seasonally inundated into permanent shallow waterbodies, as well as importing elevated levels of nutrients. The stormwater inputs have led

to substantial modifications to the floristics and structure of the vegetation of a substantial area of the western part of the Karaaf.

5.2 WATER SOURCES FOR VEGETATION AT THE KARAAF

Mean annual rainfall at Torquay is approximately 620 mm per annum (https://weather-and-climate.com/average-monthly-precipitation-Rainfall,torquay-victoria-au,Australia).

A range of water sources additional to direct rainfall are relevant to the wetland vegetation of the Karaaf. These are:

- Tidal inflows via Mullet Creek on the eastern side of the Karaaf.
- Back flooding from Mullet Creek when the entrance is closed.
- Local runoff of rainfall (overland).
- Stormwater outlets from adjacent development on the western side.
- Groundwater: Data from bores within 'The Sands' development to the near west of the Karaaf indicate brackish groundwater (12.8 to 19.0 ms, equivalent to 6.4 to 9.5 ppt.) close to the original soil surface beneath overlayed fill (A.S. Miner Geotechnical, 2008).

Water quality and inundation regime are a critical influence on the condition of the vegetation of The Karaaf. Key aspects of water quality are salinity and nutrient levels. Interactions between the components of the above range of water sources determine the local water regime. Salt in the system originates from several sources. These include tidal inputs and to a lesser extent from drift of spray from the ocean, as well as residual salt from previous geological events, such as when the Karaaf was a coastal embayment. The groundwater on adjacent areas is also noted as brackish. Areas of the saltmarsh outside of the reach of normal tidal inundation can be subject to shallow inundation due to accumulation of winter rainfall. Concentration of salt through evaporation can then lead to hypersaline conditions in the soil during warmer months.

Inflows from stormwater will dramatically alter the environmental conditions, particularly where they lead to unnaturally wet conditions over summer. Every 100 megalitres of stormwater (i.e. a volume of 100,000 cubic metres) generated from the adjacent development is equivalent to 10 cm of water spread across the entire c. 100 hectares of saltmarsh. While this is somewhat unrealistic ratio of inundation due to seepage and evaporation, nevertheless a lot of extra water is entering the Karaaf. This additional water could also be impacting fringing vegetation through seepage outwards into the abutting sandy soils, including as a source of nutrient enrichment and potentially promoting introduced plant species.

Rainfall during the course of the fieldwork for the current project led to increased levels of inundation from stormwater inputs at the western end of the Karaaf. Notes on rainfall and inflows of stormwater were supplied by local resident Andy McAuley of the Sands Owners Corporation: These indicate stormwater inflows into the wetlands on nineteen days during June 2022, from rainfall on ten days totalling 74.5 mm, a little more than the monthly average of 69.4 mm. Observations during the assessment suggested that there is potential for drainage from the western end of the Karaaf into the upper extensions of the Mullet Creek system, indicating the potential for an interaction between

stormwater inputs and ponding within the saltmarsh due to closure of the estuary – i.e. with the stormwater contributing to the extent of ponding within the saltmarsh. Consequently as well as developing a lens of fresh to hyposaline water under the relevant part of the saltmarsh and allied vegetation, the stormwater inputs may be flushing salt out of the system, compounding ecological change.

Information supplied by SCS indicates that, prior to the Water Act of 1989, landowners undertook annual or 'as required' openings of the Thompson Creek mouth. The mouth of the creek was closed for about 12 months from mid 1994 until mid June 1995, when SCS obtained a permit from Southern Water to open it. Prior to this opening there had been concerns about inundation leading to vegetation dying off. Subsequent organized openings are reported for August 1996, June 2008, and September 2016. A coordinated multi-organisation opening of the creek mouth occurred in late October 2021 after inundation concerns were expressed from August onwards. 'Estuary Watch' data was supplied by SCS covering the period from 30/10/07 until 6/05/21. This information comprises approximately monthly observations of whether the Thompson Creek Estuary was closed or open at its entrance. Observations over this period include consecutive observations of closure across intervals of five months (10/9/14 to 28/4/15), about sixteen months (31/5/15 to 6/9/16) and seven months (28/10/18 to 26/5/19). Extended closure is also understood to have occurred in 2021, but the data to indicate the extent of inundation beyond the first couple of months was not available.

5.3 HYDROLOGICAL IMPACTS ON THE CONDITION OF THE VEGETATION

5.3.1 HYDROLOGICAL IMPACTS ON SALTMARSH SPECIES

Prior to the installation of the larger culverts to restore tidal flows into the Karaaf, Carr *et al.* (2001) noted decline and death of Shrubby Glasswort due to the reduced tidal penetration. These authors also suggested increased freshwater runoff from clearance of native vegetation in the catchment, resulting in a lowering of salinity, was a factor in decline of this species. Trengrove (1998) noted the recent death of mature plants of Shrubby Glasswort along Mullet Creek, where replaced by Austral Seablite. While the reason for this was not known, Trengrove suspected that it was due to 'changes in hydrological patterns and possible nutrient levels within the catchment'.

While much older remnants of dead Shrubby Glasswort bases are evident amongst the relevant vegetation, it would appear that any residual effects of the previously reduced tidal penetration are extremely minor in comparison to more recent dieback events. Floristic changes noted by Billows (2006) after installation of the larger culverts included a decline in Trailing Hemichroa and an increase in Beaded Glasswort, with some decline in cover in the shrubland community (from both Shrubby Glasswort and Beaded Glasswort). Billows also observed extensive mortality of both Coast Tussock-grass and Knobby Club-rush at the grassland–saltmarsh interface after the works to increase tidal flows, suggesting that during the period of greater tidal restriction, some grassland species had advanced into the upper saltmarsh.

While saltmarsh plants of the intertidal zones are adapted to regular inundation to a particular depth, sustained and deeper inundation can exceed their tolerances. Species adapted to highly saline

conditions can be intolerant of sustained conditions of low salinity, further increasing their vulnerability to freshwater inputs. Water Technology (2021) commented that waterlogging forces the saltmarsh plants to respire anaerobically, depleting the plants' energy stores, leading to dieback or death. They further note that the lack of drying and development of hypersaline soil conditions also interrupts the recruitment processes of some saltmarsh species.

In addition to the ecological shift towards wetland species indicative of less saline habitats in the western section of the reserve, there has been substantial mortality of the succulent glasswort shrub species which dominate much of the extent of the Karaaf saltmarsh. Evidence such as the remains of algal growth attached to their stems indicates that these plants have been subject to prolonged inundation well above the depth reached by normal tidal inflows. As evidenced by the frequent retention of finer branch structures on dead plants, much (but not all) of this impact is relatively recent, apparently within the last few years.

While varying extents of shrub dieback are evident across most of the saltmarsh system, it is particularly severe in the western part of the Karaaf, with substantial areas of total or nearly so mortality. Mortality of Shrubby Glasswort is also locally conspicuous west from the Point Impossible Road crossing of Mullet Creek. Where scattered dead shrubs of glasswort occur within Beaded Glasswort herbland, lower down the hydrological profile (e.g. in the northern and north-eastern parts of the Karaaf), these remains of shrubs are often less structurally intact and appear to represent earlier, less-extensive dieback events. Information provided by SCS indicates that there has been public concern about vegetation dieback during previous prolonged inundation events (e.g. in 1995).

Key points:

- Estuary closure may be more sustained as a consequence of reduced flows in Thompson Creek, due to drought conditions and water extraction for agriculture.
- Sustained inundation of the saltmarsh can occur due to ponding during periods of estuary closure. It is noted that mortality of Shrubby Glasswort is also evident in the saltmarsh adjacent to Breamlea, further implicating estuary closure as a cause of shrub dieback in the saltmarsh system. Shrubby Glasswort plants are mostly healthy in more elevated positions, e.g. on the ecotone with Chaffy Saw-sedge sedgeland.
- While there is a history of estuary closures, it appears that the substantially increased stormwater inputs in recent years have compounded the impacts of any resultant ponding within the saltmarsh.
- The habitat of Bellarine Glasswort is mostly above normal high tide levels, but is potentially subject to shallow seasonal inundation due to accumulation of rainfall. However this is not normally sustained through warmer months in the absence of estuary closure. The ecology of Bellarine Glasswort is poorly known. It is a plant of extreme sites and clearly more tolerant of hypersaline conditions than Shrubby Glasswort. It may also have a shorter life-span than for the larger and potentially longer lived Shrubby Glasswort. However high levels of stand death for either species are concerning.

- Stranded desiccated remnants of filamentous green algae or Charophytes are frequently apparent on stems of dead glasswort shrubs (up to ca. 30 cm above normal maximum tide levels). Charophyte remnants on Bellarine Glasswort around a claypan in the south-eastern section of the Karaaf are indicative of at least subsaline conditions maintained during the inundation period (unlike around the claypan wetlands near the western boundary where the vegetation responses indicate greatly reduced salinity).
- There are patterns within the extent and timelines of dieback of the glasswort shrubs: The stems of scattered dead plants in some areas of Beaded Glasswort herbland are often more disintegrated, indicating they have been dead for longer. There has been 30-70% mortality in much of the area which has been subject to sustained inundation due to estuary closure, but mortality is generally much higher in low-lying areas such as shallow depressions and shallow channels through the saltmarsh. There has been extensive very high mortality around the previously seasonally inundated clay pans in the western section of the Karaaf. This area is subject to the twin influences of back-flooding from the upper channel system of Mullet Creek when the estuary is closed, as well as freshwater inputs from stormwater.
- Over much of Karaaf, death of *Tecticornia* plants has not been followed by substantial colonisation of other species, apart from patchy recruitment by Austral Seablite or Beaded Glasswort, and occasional early stages of regeneration of the glasswort shrubs. A different pattern is present towards the western margins of the Karaaf, where a dense carpet of Beaded Glasswort and Water Buttons can be prevalent in association with dead stems of glasswort shrubs, presumably indicative of more sustained wet conditions due to stormwater runoff, part of a progression of effects towards vegetation indicative of hyposaline conditions.

5.3.2 HYDROLOGICAL IMPACTS ON SPECIFIC EVCs

Note that levels of weed invasion are discussed in the descriptions of the EVCs (section 3.3).

- Coastal Dry Saltmarsh (EVC A110): This EVC occurs at the highest levels of the saltmarsh system and does not appear to have been impacted by ponding of water due to estuary closures. There may have been localised losses due to the impacts of stormwater at the western end of the Karaaf; however these would be very minor in relation to the total local extent of this EVC.
- Coastal Hypersaline Saltmarsh (EVC A111): This EVC has been subject to substantial dieback, particularly around shallow depressions within the broader saltmarsh. Even relatively intact areas around the outer drier saltmarsh can have an average of around 30% mortality of Bellarine Glasswort: Given surviving plants in this context appear healthy, it may be that this rate of population turnover is less of concern that it would be within a stand of the larger and possibly longer-lived Shrubby Glasswort. However the substantial mortality in areas which have been subject to deeper and more sustained ponding is clearly indicative of more substantial issues.
- Coastal Saline Grassland (EVC A109): This EVC has localised occurrences along the north-western verges of the saltmarsh system and does not appear to have been impacted by ponding of water

due to estuary closures. Patches of this EVC were mapped along the western edge in the previous EVC mapping; however the relevant areas have been subsumed into the adventive Brackish Wetland.

- Coastal Tussock Saltmarsh (EVC A112): This EVC occurs in elevated parts of the saltmarsh and does not appear to have been impacted by ponding of water due to estuary closures. There has been mortality of small numbers of plants of Chaffy Saw-sedge along the saltmarsh verges to the near north-east of the western edge of the reserve, but this has had a negligible effect on the population of this species as a whole. The vegetation dominated by Chaffy Saw-sedge can include scattered plants of the glasswort shrub species – these are generally healthy, showing no indications of having been impacted by ponding.
- Estuarine Flats Grassland (EVC 914): This EVC is peripheral to the saltmarsh and does not appear to have been impacted by ponding of water due to estuary closures. Previously noted mortality of Coast Tussock-grass plants within the saltmarsh, following the reinstatement of tidal flows, is interpreted as a reversal of some encroachment by this species which had occurred as a response to the prior modification of the saltmarsh hydrology.
- Estuarine Wetland (EVC 10): This EVC has localised occurrences on the southern verges of the Karaaf saltmarsh, presumably indicating some local seepage from adjacent more elevated areas. It does not appear to have been impacted adversely by ponding of water due to estuary closures.
- Saline Aquatic Meadow (EVC 842): This EVC occupies seasonally inundated claypan habitat within the saltmarsh, primarily in the western part of the Karaaf. Stormwater from the adjacent development discharges directly into the most south-westerly of these shallow depressions. It then spreads into the adjacent similar features, resulting in a set of now apparently permanent and fresh to hyposaline (salinity less than ten parts per thousand) shallow wetlands with an altered ecology. The wetlands where impacts were evident are indicated on Map 2.
- Sea-grass Meadow (EVC 845): Billows (2006) noted the expansion of patches of Dwarf Grass-wrack within the lower reaches of Mullet Creek. It appears that the localised occurrences of this species within the tidal creek have since declined markedly. While it is uncertain what events have led to the apparent displacement of this species, lack of tidal variation and potentially reduced salinity during ponding would appear to be factors.
- Seasonally Inundated Sub-saline Herbland (EVC 196): It is unclear whether this EVC previously occurred within the current boundaries of the Karaaf. No occurrences of it were observed during field work. Herbland dominated by Round-leaf Wilsonia was recorded by Carr *et al*. (2001) at the western end of the Karaaf, but was considered to be an artefact of grazing of hypersaline saltmarsh. The area from which this vegetation was reported now supports adventive Brackish Wetland.
- Wet Saltmarsh Herbland (EVC A107): Potential local fluctuations in cover of Beaded Glasswort in response to changes initiated by restoring tidal flows are discussed by Billows (2006). Any such changes appear to have since stabilized. Vegetation in the lower reaches of Mullet Creek is subject to deeper inundation and deposition of detritus of sea-grasses (mostly Sea Nymph, *Amphibolis antarctica*) and marine algae bought in by tides. Beaded Glasswort is visibly stressed

and on the edges of its tolerance in a localised area around the entrance of Mullet Creek; however this species is clearly healthy over broad areas elsewhere in the Karaaf, without evident dieback apart from near the western boundary in areas where displacement of saltmarsh by Brackish Wetland is occurring.

- Wet Saltmarsh Shrubland (EVC A108): The dominant species of this EVC (Shrubby Glasswort) has been subject to high levels of mortality across the Karaaf, particularly in the western section of the saltmarsh. The evidence suggests this is due to sustained ponding of water due to closure of the entrance of Thompson Creek. It is considered likely that impacts have been compounded by an interaction with stormwater inputs into the system during the period of ponding.

6. INTERPRETATION OF INFORMATION AND CONCLUSIONS

6.1 EVALUATION OF INFORMATION AND OBSERVATIONS

Tracking, whether it is about observations of sign such as footprints or evaluations of ecological information, addresses a fundamental two-part question: Firstly, 'what has happened here?', and secondly, 'what does that mean, or what does that 'tell' us?'.

Summary of key observations relevant to the vegetation at the Karaaf

Relevant historical information

- The estuary has a history of periodic closure.
- The hydrology of Thompson Creek is modified, with reduced flows.
- Stormwater runoff from the west is substantially increased.
- Close to natural tidal flows were restored to the Karaaf in 2004.

Relevant current observations include:

- Extensive dieback of shrubby species of glassworts in the saltmarsh vegetation, much of which is recent.
- While some extent of dieback is dispersed across the Karaaf, it is particularly severe in the western section of the Karaaf.
- There is some evidence of prior, less extensive dieback.
- Filamentous algae attached to glasswort stems at heights well above the level of normal tidal inundation.
- Some regeneration of saltmarsh species occurring in the outer zones of dieback, but not in the most affected areas.
- Shallow flooding in the lower lying western area is independent of tidal flows.
- Accumulation of stormwater inputs occurs across the low-lying western parts of the Karaaf.
- Some movement of water from the zone impacted by stormwater can occur into the upper reaches of Mullet Creek, within an area above the apparent normal tidal range.
- The channel of Mullet Creek is quite shallow at low tide levels.

- At least when not blocked by debris, low-tide drainage via Mullet Creek is effective, with continuous inundation restricted to shallow depressions and drainage channels.

Discussion

The outcomes of past geomorphological processes have influenced how and where water variously accumulates or moves through the Karaaf. The western section of the wetland system includes broad low-lying areas, even though these are above the level of normal tidal inundation. The shallow seasonally inundated claypans are presumed to indicate deflation basins within a slightly more elevated area, fringed by shallow accumulation of blown material.

The inference is that water has accumulated across the Karaaf due to closure of the estuary. While some of this water may have come down from the catchment of Thompson Creek, it is suspected that stormwater inputs on the western side of the Karaaf provided a substantial contribution, and possibly the majority.

If the entrance is open, a certain level of inundation of low-lying areas in the western section of the Karaaf can be maintained: However above this level water will flow into the upper reaches of Mullet Creek. The evidence of a prior sustained inundation event in the west of the Karaaf indicates that it was maintained at a substantially higher level than that at which potential for drainage into Mullet Creek occurs when the estuary is open. Hence it is assumed that an impoundment has formed behind the closure of the estuary (referred to as backfilling in this report). While the estuary has a history of periodic closures, it is apparent that recent events have had a substantially higher impact, due to a combination of depth, duration and presumably lowered salinity.

No evidence to suggest that the increased tidal flows since 2004 are a factor in any recent dieback was observed. It is considered that the vegetation has had sixteen years to recalibrate and that relevant adjustments have already occurred. In addition much of the dieback is outside of the normal tidal reach and the depth of inundation as marked by attached residues of filamentous green algae clearly implicate ponding as an overriding influence. Similarly sized plants of Shrubby Glasswort in more elevated locations remain healthy, suggesting that dieback is not due to stand age alone.

It is quite possible that Shrubby Glasswort at lower levels of the elevational profile may have been killed following the return of more natural tidal flows in 2004: However it seems unlikely that this species had substantially extended its local range at higher levels within the saltmarsh during the period of reduced tidal flows prior to 2004, and that as a consequence it would have been more vulnerable to dieback in the zones within and above the higher levels of tidal inundation. The current author has not observed instances of apparent senescence of even-aged stands of Shrubby Glasswort elsewhere along the Victorian Coast.

While maintaining an open estuary alone may not eliminate the potential for further expansion of adventive vegetation indicative of fresh to brackish conditions, it will prevent more extreme events of deep ponding and hence provide some limitation to the potential impacts of stormwater.

There are a range of considerations In relation to deciding whether or not it is appropriate to maintain any stormwater inflow into the Karaaf. Key components of these are volume, seasonality and water quality, particularly nutrient loads. One question is if without stormwater, there would be sufficient overland flow and/or seepage to seasonally inundate the shallow claypans. Ideally there would be no stormwater inputs unless it was of extremely high quality, with delivery restricted to the cooler months and based on evidence of an ecological need. It is presumed that in the absence of stormwater, Saline Aquatic Herbland would still be the potential vegetation in the shallow depressions during wet phases even if conditions are drier and they are filled less frequently. It could be a worthwhile exercise to model the potential hydrological regime of these features in the absence of stormwater inputs, allowing for the impacts of urbanization to the west of the Karaaf.

Stormwater treatment ponds tend to support species shared with some variants of Tall Marsh and Aquatic Herbland. The current situation is that the western part of the Karaaf is turning into a system of stormwater treatment ponds. As it currently stands, the point of entry and directed flow into the wetland in the south-western corner does not mimic natural hydrology, there is no indication that the water quality is consistently controllable to a high level, and any options for future delivery could be open to misuse. The simple answer is probably that there are only hazards and no environment benefits from any stormwater entering the Karaaf from the adjacent development. In the current situation, the best option is allowing the wetlands to dry and hoping that a return to more saline conditions is possible – there is no need for anymore freshwater inputs. The best chances for the future of the vegetation of the Karaaf will come from maximising ecological separation from the adjacent development

6.2 CONCLUSIONS

Dieback occurs when the saltmarsh experiences prolonged flooding due to closure of the entrance of the Thompson Creek estuary. Impoundment and harvesting of water for agricultural use, in conjunction with climate change, may be influencing the natural cycles of stream opening and closure. It is suspected that there is an interaction between the impacts of non-saline stormwater inputs and the ponding of water within the saltmarsh during events of estuary closure.

If stormwater inputs into the wetlands can ideally be prevented, or at least minimised, the development of thresholds for subsequent decision-making around artificially opening the Thompson Creek entrance could be a useful tool for minimizing the extent of future dieback events. In the interim it is recommended that the estuary be maintained in open condition to limit the extent of further impacts of the stormwater and to assist recovery of the saltmarsh vegetation previously impacted by ponding. It is noted that no organisation currently has responsibility for opening of the Thompson Creek estuary and that this situation will require resolution.

The negative impacts of stormwater inputs on saltmarsh and allied vegetation are considered to far outweigh any potential perceived benefits of maintaining the potential for delivery of additional water into the wetland system at the Karaaf: The more the Karaaf can be insulated from the impacts of adjacent development, the better the chances of maintenance of the existing ecological values and the greater the potential for recovery of currently impacted vegetation.

6.3 COMMENTS IN RELATION TO FUTURE ENVIRONMENTAL MONITORING AND MANAGEMENT

From the current author's perspective, future monitoring can initially be very simple, particularly since more complex monitoring programmes are both expensive and rarely maintained for sufficient duration, unless perhaps a university takes it up as an ongoing study. A set of strategically placed ten by ten metre monitoring quadrats sampled for species and cover estimates, accompanied by suitable photo points, would be suitable to evaluate the return of saltmarsh species – while there is substantial uncertainty associated with cover assessments, the intention is to detect any coarse changes in the vegetation, which will be largely based on recruitment events. In the case of monitoring fixed quadrats or transects, it is advisable to be wary of and avoid the potential for trampling of the saltmarsh plants: Detailed measuring or frequent sampling can increase the risks of this occurring.

It may also be informative to measure salinity levels in the upper soil layers (e.g. including as percentage dry weight, as water column readings while relevant may to be too variable to be particularly informative). This would be particularly relevant within areas currently supporting adventive Brackish Wetland. Obviously, it needs to be appreciated that monitoring alone does not assist any recovery process.

The priority of any future management to maintain and enhance ecological values of the Karaaf wetlands would be to ideally remove causes of ecological change, primarily inputs of stormwater. Bulrush/Cumbungi species will die out if dry conditions are maintained over summer. Salt Club-rush will eventually be replaced by saltmarsh species if higher salinity levels return: At this stage it is difficult to know to what extent tipping points have been exceeded and return to previous vegetation composition is possible in the most highly affected areas. Other than resolving the current hydrological issues, a pragmatic focus of recovery of the saltmarsh vegetation would be based on natural regeneration rather than interventions (i.e. essentially protection rather than revegetation). It is unclear as to how much if any soil-stored seedbank persists in the most affected areas – colonisation may take a substantial period of time, and possibly involve other saltmarsh species as colonisers (notably Austral Seablite). If the hydrological issues are resolved, the eventual return of *Tecticornia* species within relevant habitat is suspected to be likely unless the relevant sites have passed a tipping point: However, it is uncertain what will happen in the most affected areas, what recovery potential they have and how long this may take. Just because major impacts have occurred in the recent past does not mean that the rate of recovery from these will be rapid.

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APPENDIX 1: OBSERVATIONS AT THE KARAAF WETLANDS (ANNOTATED IMAGES)

Eastern side

Mullet Creek looking west from the culverts along Point Impossible Road under conditions of very high tide. Tidal inundation restored to near natural conditions, with inundation extending deep into the saltmarsh when the entrance of Thompson Creek is open to the sea,

Mullet Creek west from the culverts along Point Impossible Road under conditions at low tide.

Accumulation of fragments of Sea Nymph and marine algae along the lower section of Mullet Creek.

Stressed Beaded Glasswort at limits of tolerance near the Mullet Creek entrance

Dieback of Shrubby Glasswort adjacent to Mullet Creek, with remnants of filamentous algae hanging from stems and finer branches still attached, indicating relatively recent death of the plants.

Western side

Stormwater flowing over the spillway between the stormwater treatment pond system and the Karaaf.

Stormwater overflowing into the wetlands at the south-western corner of the Karaaf.

Filamentous green algae in shallow lake at the western end of the Karaaf, reflecting changed hydrology and elevated nutrients.

Colonization by Cumbungi due to freshwater inputs at the western boundary. Older plants are to the rear, with younger more recent colonization in the foreground.

Extensive displacement of prior saltmarsh vegetation by adventive Brackish Wetland at the western end of the Karaaf.

Progressive dieback of Bellarine Glasswort at the western end of the Karaaf, further from the major point of stormwater discharge (adjacent to the Brackish Wetland). Beaded Glasswort has increased in abundance in the wetter area fringing the lagoon to the rear, where the mortality of Bellarine Glasswort has been comprehensive.

In between

Extent of inundation during at a particularly high tidal event into shallow depression within the saltmarsh in the south-eastern section of the Karaaf.

The vegetation surrounding the tidally influenced pond pictured in the previous image includes a mixture of Shrubby Glasswort and Bellarine Glasswort, indicating hypersaline conditions, and is above the usual range of tidal influence. Dieback of sections of this shrubland vegetation has occurred due to sustained inundation associated with the closure of the entrance of Thompson Creek. The white matting comprises the remains of a Stonewort or Charophyte, which is a salt-tolerant aquatic plant intermediate between algae and vascular plants. Shrub mortality in this area does not appear to be due to the direct impact of freshwater from stormwater inputs at the western end of the saltmarsh.

Vegetation dynamics: Regeneration of Bellarine Glasswort on the outer verges of impacted shrubland vegetation.

Vegetation dynamics: Recolonization of the herb Beaded Glasswort into impacted shrubland vegetation.

Broad-scale death of Shrubby Glasswort towards the western side of the Karaaf. Remnants of algae attached to the stems are indicative of a sustained inundation event.

Shrubland of Shrubby Glasswort with relatively minor level of mortality in the south-central part of the Karaaf, in area less prone to excessive inundation.

APPENDIX 2: PLANT SPECIES LIST, THE KARAAF

Key to codes

Status:

The symbol '*' preceding the scientific name of a species denotes that it is considered introduced in Victoria. The symbol '#' preceding the scientific name of a species denotes that it is considered introduced within the study area, but indigenous within some other part of Victoria.

'P' following the scientific name denotes species that were only observed within the Karaaf as planted specimens.

Source:

F: denotes observations from the current study.

C: denotes additional records from Carr *et al.* (2001).

V: denotes additional records from the Victorian Biodiversity Atlas (DELWP, 2022a).

S: denotes additional records from information supplied by Gabrielle O'Shea of Surf Coast Shire.

T: denotes additional records from Trengrove (1998).

Records identified to genus level only are not included if they are clearly referable to taxa indentified to species level elsewhere. Existing records excluded from the list as considered synonymous were *Lepidosperma congestum* spp. agg. (= *Lepidosperma laeve*) and *Spergularia media* s.l. (= *Spergularia tasmanica*). Plants observed which were previously referable to *Tecticornia pergranulata* [s.l.] conform to the relatively recently distinguished taxon *Tecticornia* sp. (Connewarre). In the absence of local records or field observation of *T. pergranulata* s.s., this taxon is also omitted from the list.

Plant taxonomy (scientific names) follows RBG (2022) and nomenclature from previous records is updated accordingly where appropriate (e.g. the currently recognised name for *Sclerostegia arbuscula* is *Tecticornia arbuscula*, plants previously known as *Sarcocornia quinqueflora* are currently referred to *Salicornia quinqueflora* and *Puccinellia stricta* var. *perlaxa*, recorded from the western margins of the site by Carr *et al*. (2001), is now attributed species status as *Puccinellia perlaxa*). The scientific names follow RBG (2022) and the common names follow DELWP (2022a).

The column heading 'Adv.List' indicates where a taxon was allocated a status in the advisory list of Victorian Rare or Threatened Plant Species (DEPI, 2014). The code 'r' in this column denotes that the relevant taxon was considered 'rare' in Victoria, and the code 'e' denotes that it was considered 'endangered' in Victoria on this list.

The heading 'FFG' indicates where a taxon is now included in the January 2021 'Threatened List of the Victorian Flora and Fauna Guarantee Act 1988' (DELWP 2021c). The code 'e' in this column denotes that the relevant taxon is currently regarded as 'endangered' in Victoria, and the code 'ce' denotes that it is considered to be 'critically endangered' in Victoria.

SCIENTIFIC NAME	COMMON NAME	SOURCE	Adv.List	FFG
Native				
Acacia longifolia subsp*. sophorae*	Coast Wattle	F		
Acacia paradoxa	Hedge Wattle	F		
Acacia pycnantha	Golden Wattle	F		
Acacia uncifolia	Coast Wirilda	F	r	En
Acaena novae-zelandiae	Bidgee-widgee	F		
Agrostis s.l. spp*.*	Bent/Blown Grass	V		
Allocasuarina verticillata (P)	Drooping Sheoak	F		
Althenia bilocularis	Small-fruit Water-mat	F		
Althenia cylindrocarpa	Long-fruit Water-mat	C		
Althenia spp.	Water Mat	F		
Apium sp.	Celery	T		
Austrostipa flavescens	Coast Spear-grass	V		
Austrostipa mollis	Supple Spear-grass	V		
Austrostipa stipoides	Prickly Spear-grass	F		
Bolboschoenus caldwellii	Salt Club-sedge	F		
Callitriche sp.	Water Starwort	F		
Carpobrotus rossii	Karkalla	F		
Characeae spp.	Stonewort	F		
Chenopodium glaucum	Glaucous Goosefoot	V		
Clematis decipiens	Slender Clematis	F		
Crassula helmsii	Swamp Crassula	F		
Cynoglossum australe	Australian Hound's-tongue	F		
Dianella brevicaulis	Small-flower Flax-lily	F		
Dichondra repens	Kidney-weed	V		
Disphyma crassifolium subsp*. clavellatum*	Rounded Noon-flower	F		
Distichlis distichophylla	Australian Salt-grass	F		
Eleocharis acuta	Common Spike-sedge	F		

SCIENTIFIC NAME	COMMON NAME	SOURCE	Adv.List	FFG
Epilobium billardiereanum subsp*. cinereum*	Grey Willow-herb	V		
Eucalyptus leucoxylon subsp*. bellarinensis* (P)	Bellarine Yellow-gum	F	e	ce
Ficinia nodosa	Knobby Club-sedge	F		
Frankenia pauciflora var*. gunnii*	Southern Sea-heath	F		
Gahnia filum	Chaffy Saw-sedge	F		
Geranium sp.	Crane's Bill	T		
Geranium sp. 5	Naked Crane's-bill	F		
Hemichroa pentandra	Trailing Hemichroa	F		
Hydrocotyle spp.	Pennywort	V		
Isolepis cernua s.l.	Nodding Club-sedge	V		
Juncus flavidus	Gold Rush	F		
Juncus kraussii subsp*. australiensis*	Sea Rush	F		
Juncus revolutus	Creeping Rush	V	r	en
Lachnagrostis filiformis s.s.	Common Blown-grass	F		
Lepidosperma gladiatum	Coast Sword-sedge	F		
Lepidosperma laeve	Clustered Sword-sedge	F		
Leptospermum laevigatum	Coast Tea-tree	F		
Leucopogon parviflorus	Coast Beard-heath	F		
Lilaeopsis polyantha	Australian Lilaeopsis	V		
Lobelia anceps	Angled Lobelia	V		
Lythrum hyssopifolia	Small Loosestrife	F		
Melaleuca lanceolata	Moonah	F		
Microlaena stipoides var. *stipoides*	Weeping Grass	F		
Microtis ?unifolia	(?Common) Onion-orchid	T		
Myoporum insulare	Common Boobialla	F		
Olearia axillaris	Coast Daisy-bush	F		
Oxalis perennans	Grassland Wood-sorrel	V		
Oxalis sp.	Wood Sorrel	T		
Phragmites australis	Common Reed	F		

SCIENTIFIC NAME	COMMON NAME	SOURCE	Adv.List	FFG
Plantago varia	Variable Plantain	V		
Poa poiformis var. *poiformis*	Coast Tussock-grass	F		
Puccinellia perlaxa	Plains Saltmarsh-grass	C		
Puccinellia stricta s.s.	Australian Saltmarsh-grass	F		
Rhagodia candolleana subsp. *candolleana*	Seaberry Saltbush	F		
Rubus parvifolius	Small-leaf Bramble	V		
Ruppia polycarpa	Water Tassel	F		
Rytidosperma racemosum var. *racemosum*	Slender Wallaby-grass	F		
Rytidosperma spp.	Wallaby Grass	V		
Salicornia blackiana	Thick-head Glasswort	F		
Salicornia quinqueflora subsp. *quinqueflora*	Beaded Glasswort	F		
Samolus repens	Creeping Brookweed	V		
Schoenoplectus tabernaemontani	River Club-sedge	F		
Schoenus nitens	Shiny Bog-sedge	V		
Senecio biserratus	Jagged Fireweed	T		
Senecio glomeratus subsp. *glomeratus*	Annual Fireweed	F		
Senecio pinnatifolius var. *lanceolatus*	Lance-leaf Groundsel	F		
Sonchus hydrophilus	Native Sow-thistle	F		
Spergularia tasmanica	Native Sea-spurrey	F		
Spinifex sericeus	Hairy Spinifex	V		
Suaeda australis	Austral Seablite	F		
Swainsona lessertiifolia	Coast Swainson-pea	V		
Tecticornia arbuscula	Shrubby Glasswort	F		
Tecticornia sp. (Connewarre)	Bellarine Glasswort	F		
Tetragonia implexicoma	Bower Spinach	F		
Thyridia repens	Creeping Monkey-flower	F		
Triglochin striata	Streaked Arrow-grass	F		
Typha domingensis	Narrow-leaf Cumbungi	F		
Typha spp.	Bulrush	F		

SCIENTIFIC NAME	COMMON NAME	SOURCE	Adv.List	FFG
Veronica gracilis	Slender Speedwell	F		
Wilsonia rotundifolia	Round-leaf Wilsonia	F		
Zostera muelleri	Dwarf Grass-wrack	F		
Introduced				
* *Aira caryophyllea* subsp. *caryophyllea*	Silvery Hair-grass	V		
* *Aizoon pubescens*	Galenia	V		
* *Allium triquetrum*	Angled Onion	F		
* *Arctotheca calendula*	Cape Weed	F		
* *Asphodelus fistulosus*	Onion Weed	F		
* *Atriplex prostrata*	Hastate Orache	F		
* *Avena fatua*	Wild Oat	V		
* *Avena* spp.	Oat	V		
* *Brassica fruticulosa*	Twiggy Turnip	F		
* *Briza maxima*	Large Quaking-grass	F		
* *Bromus catharticus*	Prairie Grass	V		
* *Bromus diandrus*	Great Brome	C		
* *Bromus hordeaceus*	Soft Brome	F		
* *Cakile maritima* subsp. *maritima*	Sea Rocket	F		
* *Catapodium rigidum*	Fern Grass	F		
* *Cenchrus clandestinus*	Kikuyu	F		
* *Cerastium* spp.	Mouse-ear Chickweed	V		
* *Chenopodium macrospermum*	Red-stem Goosefoot	S		
* *Chrysanthemoides monilifera* subsp. *monilifera*	Boneseed	V		
* *Cirsium vulgare*	Spear Thistle	F		
* *Clematis vitalba* var. *vitalba*	Traveller's Joy	V		
* *Coprosma repens*	Mirror bush	V		
* *Cortaderia selloana* subsp. *selloana*	Pampas Grass	V		

SCIENTIFIC NAME	COMMON NAME	SOURCE	Adv.List	FFG
* *Cotoneaster glaucophyllus*	Large-leaf Cotoneaster	V		
* *Cotoneaster pannosus*	Velvet Cotoneaster	V		
* *Cotula coronopifolia*	Water Buttons	F		
* *Cynodon dactylon* var. *dactylon*	Couch	F		
* *Dactylis glomerata*	Cocksfoot	F		
* *Delairea odorata*	Cape Ivy	V		
* *Diplotaxis tenuifolia*	Sand Rocket	V		
* *Dittrichia graveolens*	Stinkwort	F		
* *Ehrharta erecta*	Panic Veldt-grass	V		
* *Erigeron sumatrensis*	Tall Fleabane	F		
* *Erigeron* spp.	Fleabane	V		
* *Euphorbia peplus*	Petty Spurge	F		
* *Euphorbia terracina*	Terracina Spurge	V		
* *Foeniculum vulgare*	Fennel	V		
* *Helminthotheca echioides*	Ox-tongue	F		
* *Holcus lanatus*	Yorkshire Fog	F		
* *Hordeum glaucum*	Northern Barley-grass	V		
* *Hordeum marinum*	Sea Barley-grass	F		
* *Hypochaeris radicata*	Flatweed	F		
* *Juncus acutus* subsp. *acutus*	Spiny Rush	F		
* *Juncus articulatus* subsp. *articulatus*	Jointed Rush	V		
* *Kickxia spuria* subsp. *integrifolia*	Round-leaf Toadflax	V		
* *Lactuca serriola*	Prickly Lettuce	V		
* *Lagurus ovatus*	Hare's-tail Grass	F		
* *Leontodon saxatilis* subsp. *saxatilis*	Hairy Hawkbit	F		
* *Lolium rigidum*	Wimmera Rye-grass	F		
* *Lolium perenne*	Perennial Rye-grass	V		
* *Lophopyrum ponticum*	Tall Wheat-grass	F		
* *Lycium ferocissimum*	African Box-thorn	F		

SCIENTIFIC NAME	COMMON NAME	SOURCE	Adv.List	FFG
* *Lysimachia arvensis*	Pimpernel	F		
* *Malus pumila*	Apple	V		
* *Malva parviflora*	Small-flower Mallow	V		
* *Malva* sp.	Mallow	T		
* *Medicago polymorpha*	Burr Medic	F		
# *Melaleuca armillaris* subsp. *armillaris*	Giant Honey-myrtle	F	r	en
* *Melilotus indicus*	Sweet Melilot	F		
* *Nassella trichotoma*	Serrated Tussock	F		
* *Onopordum acanthium*	Stemless Thistle	T		
* *Oxalis pes-caprae*	Soursob	F		
* *Parapholis incurva*	Coast Barb-grass	V		
* *Parapholis strigosa*	Slender Barb-grass	V		
* *Paraserianthes lophantha* subsp. *lophantha*	Cape Wattle	V		
* *Paspalum dilatatum*	Paspalum	F		
* *Phalaris aquatica*	Toowoomba Canary-grass	F		
* *Piptatherum miliaceum*	Rice Millet	V		
* *Plantago coronopus*	Buck's-horn Plantain	F		
* *Plantago lanceolata*	Ribwort	F		
* *Polygonum aviculare* s.s.	Hogweed	V		
* *Polypogon monspeliensis*	Annual Beard-grass	F		
* *Rapistrum rugosum*	Giant Mustard	F		
* *Romulea rosea*	Onion Grass	F		
* *Rumex crispus*	Curled Dock	F		
* *Rumex pulcher* subsp. *pulcher*	Fiddle Dock	F		
* *Salvia verbenaca*	Wild Sage	T		
* *Senecio elegans*	Purple Groundsel	V		
* *Silene* spp.	Catchfly	V		
* *Silybum marianum*	Variegated Thistle	V		
* *Sonchus asper* s.l.	Rough Sow-thistle	F		

SCIENTIFIC NAME	COMMON NAME	SOURCE	Adv.List	FFG
* *Sonchus oleraceus*	Common Sow-thistle	F		
* *Sporobolus africanus*	Rat-tail Grass	F		
* *Stenotaphrum secundatum*	Buffalo Grass	F		
* *Symphyotrichum subulatum*	Aster-weed	F		
* *Tragopogon porrifolius* subsp. *porrifolius*	Salsify	V		
* *Tribolium acutiflorum* s.l.	Desmazeria	V		
* *Trifolium* spp.	Clover	V		
* *Trifolium tomentosum* var. *tomentosum*	Woolly Clover	V		
* *Ulex europaeus*	Gorse	F		
* *Vulpia* spp.	Fescue	F		

APPENDIX 3: FAUNA LIST (BIRDS AND MAMMALS), THE KARAAF

Key to codes

- The symbol '*' preceding the common name of a species denotes that it is considered introduced in Australia.
- The heading FFG denotes species listed under the Victorian Flora and Fauna Guarantee Act (DELWP, 2021c). The threat level codes are as follows: v – vulnerable; e – endangered; ce – critically endangered.
- The heading 'Status' denotes the Conservation Status as listed in the Victorian Biodiversity Atlas (DELWP, 2022a). These are based on DSE (2013), apparently including some updates (e.g. Marsh Sandpiper listed as 'endangered'). The threat level codes are as follows:
- CR – Critically endangered at the National level; cr - critically endangered in Victoria.
- en – endangered in Victoria.
- VU – Vulnerable at the National level; vu – vulnerable in Victoria.

Records are from the Victorian Biodiversity Atlas (DELWP, 2022a), with the exception of the Brolga, which is based on field observation of a group of five birds within the western margins of the Karaaf during field work and also reported by local naturalist Glenda Shomaly.

	Common Name	Scientific Name	FFG	Status	Last Record
		Phalacrocoracidae spp.			9/09/2018
	Australasian Gannet	*Morus serrator*			26/07/2014
	Australasian Shoveler	*Spatula rhynchotis*	v	vu	1/09/2019
	Australasian Swamphen	*Porphyrio melanotus*			10/09/2016
	Australian Hobby	*Falco longipennis*			28/06/2019
	Australian Magpie	*Gymnorhina tibicen*			9/07/2021
	Australian Pelican	*Pelecanus conspicillatus*			16/05/2015
	Australian Pipit	*Anthus australis*			20/08/2017
	Australian Shelduck	*Tadorna tadornoides*			1/09/2019
	Australian Spotted Crake	*Porzana fluminea*			9/07/2021
	Australian White Ibis	*Threskiornis molucca*			9/07/2021
	Australian Wood Duck	*Chenonetta jubata*			26/07/2014
	Banded Stilt	*Cladorhynchus leucocephalus*			1/01/2015
	Black Swan	*Cygnus atratus*			1/09/2019
	Black-browed Albatross	*Thalassarche melanophris*		VU	26/07/2014
	Black-fronted Dotterel	*Elseyornis melanops*			13/09/2014
	Black-shouldered Kite	*Elanus axillaris*			13/09/2014
	Black-tailed Native-hen	*Tribonyx ventralis*			14/09/2013
	Blue-winged Parrot	*Neophema chrysostoma*			25/07/2015
	Brolga	*Antigone rubicunda*	e	vu	19/6/2022
	Brown Falcon	*Falco berigora*			15/04/2021
	Brown Goshawk	*Accipiter fasciatus*			22/06/2013
	Brown Thornbill	*Acanthiza pusilla*			9/07/2021
	Buff-banded Rail	*Hypotaenidia philippensis*			9/07/2021
	Caspian Tern	*Hydroprogne caspia*	v	vu	1/09/2019
	Chestnut Teal	*Anas castanea*			28/06/2019
*	Common Blackbird	*Turdus merula*			28/06/2019
	Common Greenshank	*Tringa nebularia*	e	en	30/01/2016
*	Common Myna	*Acridotheres tristis*			16/05/2015
	Common Sandpiper	*Actitis hypoleucos*	v	vu	30/01/2016
*	Common Starling	*Sturnus vulgaris*			28/06/2019
	Crested Pigeon	*Ocyphaps lophotes*			16/05/2015
	Crimson Rosella	*Platycercus elegans*			28/06/2019
	Curlew Sandpiper	*Calidris ferruginea*	ce	CR cr	9/09/2018
*	Domestic Cat (feral)	*Felis catus*			24/07/1983
	Dusky Moorhen	*Gallinula tenebrosa*			27/07/2013
	Eastern Grey Kangaroo	*Macropus giganteus*			25/08/2018
	Eastern Osprey	*Pandion cristatus*			26/06/2013

	Common Name	Scientific Name	FFG	Status	Last Record
	Eastern Spinebill	*Acanthorhynchus tenuirostris*			15/03/2013
	Eastern Yellow Robin	*Eopsaltria australis*			23/07/2015
	Eurasian Coot	*Fulica atra*			27/07/2013
*	Eurasian Skylark	*Alauda arvensis*			9/07/2021
*	European Goldfinch	*Carduelis carduelis*			26/04/2016
*	European Greenfinch	*Chloris chloris*			25/08/2014
	Fan-tailed Cuckoo	*Cacomantis flabelliformis*			9/07/2021
	Flame Robin	*Petroica phoenicea*			24/04/2016
	Galah	*Eolophus roseicapilla*			25/07/2015
	Golden Whistler	*Pachycephala pectoralis*			13/09/2014
	Golden-headed Cisticola	*Cisticola exilis*			9/07/2021
	Great Cormorant	*Phalacrocorax carbo*			23/07/2015
	Great Egret	*Ardea alba*			1/09/2019
	Grey Butcherbird	*Cracticus torquatus*			23/07/2015
	Grey Fantail	*Rhipidura albiscapa*			15/04/2021
	Grey Shrike-thrush	*Colluricincla harmonica*			25/04/2016
	Grey Teal	*Anas gracilis*			20/05/2014
	Hardhead	*Aythya australis*	v	vu	18/05/2019
	Hoary-headed Grebe	*Poliocephalus poliocephalus*			10/09/2016
	Hooded Plover	*Thinornis cucullatus*	v	VU vu	18/05/2019
	Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*			20/08/2017
*	House Sparrow	*Passer domesticus*			25/07/2015
	Latham's Snipe	*Gallinago hardwickii*			9/09/2018
	Little Black Cormorant	*Phalacrocorax sulcirostris*			15/04/2021
	Little Corella	*Cacatua sanguinea*			25/08/2014
	Little Eagle	*Hieraaetus morphnoides*	v	vu	26/04/2016
	Little Grassbird	*Poodytes gramineus*			9/07/2021
	Little Pied Cormorant	*Microcarbo melanoleucos*			9/07/2021
	Little Raven	*Corvus mellori*			9/07/2021
	Magpie-lark	*Grallina cyanoleuca*			16/05/2015
	Marsh Sandpiper	*Tringa stagnatilis*	e	en	16/05/2015
	Masked Lapwing	*Vanellus miles*			9/07/2021
	Nankeen Kestrel	*Falco cenchroides*			9/09/2018
	New Holland Honeyeater	*Phylidonyris novaehollandiae*			9/07/2021
	Orange-bellied Parrot	*Neophema chrysogaster*	ce	CR cr	4/09/1973
	Pacific Black Duck	*Anas superciliosa*			9/07/2021
	Pacific Gull	*Larus pacificus*			15/04/2021
	Peregrine Falcon	*Falco peregrinus*			13/09/2014
	Pied Stilt	*Himantopus leucocephalus*			7/11/2015
*	Red Fox	*Vulpes vulpes*			7/11/2015

	Common Name	Scientific Name	FFG	Status	Last Record
	Red Wattlebird	*Anthochaera carunculata*			25/04/2016
	Red-browed Finch	*Neochmia temporalis*			16/05/2015
	Red-capped Plover	*Charadrius ruficapillus*			23/07/2015
	Red-kneed Dotterel	*Erythrogonys cinctus*			25/08/2014
	Red-necked Avocet	*Recurvirostra novaehollandiae*			2/12/2015
	Royal Spoonbill	*Platalea regia*			7/11/2015
	Sharp-tailed Sandpiper	*Calidris acuminata*			1/01/2015
	Short-beaked Echidna	*Tachyglossus aculeatus*			11/05/2017
	Silvereye	*Zosterops lateralis*			15/04/2021
	Singing Honeyeater	*Gavicalis virescens*			15/04/2021
	Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*			15/04/2021
*	Spotted Dove	*Spilopelia chinensis*			13/09/2014
	Straw-necked Ibis	*Threskiornis spinicollis*			16/05/2015
	Striated Fieldwren	*Calamanthus fuliginosus*			9/07/2021
	Stubble Quail	*Coturnix pectoralis*			13/09/2014
	Superb Fairy-wren	*Malurus cyaneus*			9/07/2021
	Swamp Harrier	*Circus approximans*			28/06/2019
	Tree Martin	*Petrochelidon nigricans*			26/08/2016
	Wedge-tailed Eagle	*Aquila audax*			23/07/2015
	Welcome Swallow	*Hirundo neoxena*			9/07/2021
	Whiskered Tern	*Chlidonias hybrida*			23/12/2018
	Whistling Kite	*Haliastur sphenurus*			28/06/2019
	White-browed Scrubwren	*Sericornis frontalis*			15/04/2021
	White-faced Heron	*Egretta novaehollandiae*			9/07/2021
	White-fronted Chat	*Epthianura albifrons*			9/07/2021
	White-necked Heron	*Ardea pacifica*			1/09/2019
	Willie Wagtail	*Rhipidura leucophrys*			16/05/2015
	Yellow-billed Spoonbill	*Platalea flavipes*			7/11/2015
	Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*			27/07/2013
	Zebra Finch	*Taeniopygia guttata*			20/10/2015