Australian Government
Department of Agriculture, Water and the Environment

The Threatened Species Scientific Committee provided their advice to the Minister on 31 July 2020.
The Minister approved this Conservation Advice on 3 December 2020 and agreed that no recovery plan is required at this time.

Conservation Advice[1] for the Karst springs and associated alkaline fens of the Naracoorte Coastal Plain Bioregion

This document combines the approved conservation advice and listing assessment for the threatened ecological community. It provides a foundation for conservation action and further planning.

Karst springs and alkaline fens, Ewen Ponds © Copyright, Anthony Hoffman

Conservation Status

The Karst springs and associated alkaline fens of the Naracoorte Coastal Bioregion is listed in the Endangered category of the threatened ecological communities list under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The ecological community was assessed by the Threatened Species Scientific Committee, who found it to be eligible for listing as Endangered and recommended that a recovery plan is not required at this time. The Committee's assessment and recommendations are at Section 6.

The Committee's assessment of the eligibility against each of the listing criteria is:
Criterion 1: Vulnerable
Criterion 2: Endangered
Criterion 3: Insufficient data
Criterion 4: Endangered
Criterion 5: Insufficient data
Criterion 6: Insufficient data

The main factors that make the threatened ecological community eligible for listing in the Endangered category are its historic losses to drainage, clearing and resulting fragmentation, and ongoing threats to its integrity and function, particularly from hydrological changes.

The Karst springs and associated alkaline fens of the Naracoorte Coastal Plain Bioregion occurs within country (the traditional lands) of the Boandik and the Gunditjmara peoples.

[1] The Conservation Advice is a statutory document as per section 266B of the *Environment Protection and Biodiversity Conservation Act 1999*.

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1 CONSERVATION OBJECTIVE

To mitigate the risk of extinction of the Karst Springs and associated alkaline fens of the Naracoorte Coastal Plain Bioregion ecological community, and help recover its biodiversity and function, through protecting it from significant impacts as a Matter of National Environmental Significance under national environmental law, and by guiding implementation of management and recovery, consistent with the recommended priority conservation and research actions set out in this advice.

This Conservation Advice contains information relevant to the objective by:

- describing the ecological community and where it can be found (section 2);
- identifying the key threats to the ecological community (section 3);
- summarising the existing protections for the ecological community (section 4);
- outlining information to guide its identification and conservation, including the key diagnostic features, condition thresholds and classes, and additional information to identify the ecological community, and the priority conservation and research actions to stop its decline, support its recovery and recognise the importance of involving current landholders and Indigenous people in its maintenance (section 5); and
- presenting evidence to explain why the ecological community merits listing as nationally threatened under national environment law (section 6).

2 DESCRIPTION OF THE ECOLOGICAL COMMUNITY AND THE AREA IT INHABITS

2.1 Description

The ecological community described in this conservation advice includes plants, animals and other organisms associated with a type of groundwater dependant ecosystem that occurs in association with the Tertiary limestone Gambier Karst Province of the Otway Basin on low lying areas near the coast in eastern South Australia and western Victoria. Its primary defining features are the underlying limestone geology, predominantly karst fed (alkaline) springs, soaks, pools or streams and associated fringing fens which include herblands, peatlands, sedgelands and/or shrubland vegetation.

This section describes the natural and largely undisturbed state of the ecological community, with more information to assist in identifying occurrences of the ecological community in Section 5.1. However, as a result of past disturbance, not all occurrences of the ecological community still exist in their natural and undisturbed state (further outlined in Section 2.1.7.5). Section 5.2. provides information to identify patches that retain sufficient conservation values to be considered a matter of national environmental significance.

2.1.1 Name

The name of the ecological community is the '**Karst[2] Springs and Associated Alkaline Fens of the Naracoorte Coastal Plain Bioregion**', hereafter referred to as 'Karst springs and alkaline fens', or 'the ecological community'. The ecological community was originally placed on the 2015 Finalised Priority Assessment List as the 'Karst rising springs of south east South Australia'.

[2] Karst is a type of landscape with distinctive landforms that primarily result from highly soluble bedrock. Karst features include, caves, dolines, cenotes, solution pipes and tufa. Limestone is the most widespread karst rock (Jennings 1971).

2.1.2 Location and physical environment

The Karst springs and alkaline fens are located in the Gambier Karst Province of the Otway Basin in south east South Australia and south west Victoria. Known occurrences of the ecological community are scattered across the near-coastal areas from near Beachport in South Australia to west of Portland Victoria.

The coastal region of south east South Australia and south west Victoria is characterised by broad plains of Tertiary and Quaternary limestone and sediments. Calcareous[3] sand ridges parallel to the coast are separated by inter dune swales, closed limestone depressions and bordered inland by geologically recent volcanoes such as *Berrin*[4]/Mount Gambier and *Budj Bim*[5]/Mount Eccles.

Due to the low relief landscape and the porous and highly transmissive geology, there are few major natural river systems in this region. The exception is the Glenelg River and a small number of perennial streams originating from coastal springs which flow to the coast. The majority of surface water expressed in the south east of the Bridgewater subregion results from groundwater sources.

Otway Basin groundwater discharge occurs at locations close to the coast and inland through natural springs, swamps and terminal wetlands as well as submarine discharge off the coast (Webb et al. 2010; Wood 2011). Recharge of the upper unconfined tertiary limestone aquifer occurs via the infiltration of local and regional rainfall within the Lower South East and East Glenelg groundwater catchments of the Gambier Karst Province. The lower confined aquifer is recharged from the Dundas Highlands of Victoria and may contribute to hydrological inputs into deep karst systems.

This groundwater dependant ecological community is limited to the Gambier Limestone formation (Gambier Karst Province) within the Bridgewater (NCP01) subregion of the Naracoorte Coastal Plain IBRA[6] bioregion.

At May 2020, known occurrences of the ecological community occurred within the Glenelg Hopkins Catchment Management Authority region in Victoria and the Limestone Coast Landscape Board region in SA. Local government areas known to contain the ecological community (at May 2020) include: District Council of Grant (SA), Wattle Range Council (SA) and Glenelg Shire Council (Vic).

2.1.3 Climate

The climate throughout the Bridgewater subregion where the ecological community occurs is currently described as Mediterranean, with cool wet winters and mild to hot dry summers.

The ecological community occurs in the E1 agro-climatic classification and the eastern extent (Victoria) of the ecological community primarily in the D5 agro-climatic classification of Hutchinson et al. (2005) (Table 1).

[3] Calcarious soils/sediments are composed of at least 15% calcium carbonate.
[4] Boandik language
[5] Gunditjmara language
[6] IBRA refers to the Interim Biogeographical Regionalisation of Australia. IBRA regions are large geographically distinct areas of similar climate, geology and landform with corresponding similarities in their vegetation and animal communities. The version current at the time of this advice is IBRA v7 (DoE, 2013), which divides Australia into 89 bioregions and 419 subregions, including offshore islands.

Table 1. Agro-climatic classes associated with the Karst springs and alkaline fens

Agro-climate class	Agro-climate	Location and main land uses
E1	Classic "Mediterranean" climate with peaks of growth in winter and spring and moderate growth in winter	Southern South Australia: Forestry, horticulture, winter cropping, improved pastures
D5	Moisture availability high in winter-spring, moderate in summer, most plant growth in spring	Southern Victoria: Forestry, cropping, horticulture, improved and native pastures

Source: Hutchinson et al. (2005).

The coastal plains have a median annual rainfall of 714mm near Mt Gambier SA and 835mm at Portland in Victoria. Rainfall for this region is strongly seasonal, occurring predominantly in winter (Table 2). The seasonal climate predisposes these regions to summer fires but fire regimes are likely to have changed substantially since non-Indigenous settlement.

Areal (potential) evapotranspiration[7] rates for these regions are >1000mm/year with evaporation exceeding rainfall in the non-winter months and with much higher evaporation rates in cleared areas (Paydar 2009; Sinclair Knight Merz 2009; BOM 2019). The Tertiary unconfined aquifer which supplies groundwater to the ecological community is recharged when winter precipitation exceeds evapotranspiration, which is typically between May and September (Mustafa et al. 2012).

Table 2. Evapotranspiration, mean rainfall and mean temperature across the range of the ecological community

Weather station	Period	Evapotranspiration (mm)	Rainfall (mm)	Temperature (°C)
Mount Gambier Aero SA				
	January	≥70mm	27.0	25.4
	July	≥30mm	100.6	13.2
	Annual	>1000mm	713.7	19.0
Portland Vic				
	January	≥70mm	35.6	21.8
	July	≥30mm	108.3	13.6
	Annual	>1000mm	835.1	17.8

Source: BOM (2019).

2.1.4 Geology and elevation

The ecological community occurs over the tertiary limestone of the Otway Basin which underlays the near coastal region of south east South Australia and south west Victoria. The Otway Basin formed during the Antarctic–Australian continental separation about 65 million years ago (Paleogene) and contains the Gambier Limestone formation and minor Bridgewater formation[8] (Grimes et al. 1999; Birch 2003). These Tertiary marine limestones were deposited approximately 15-35 million years ago (during the Oligocene and early Miocene) (Scholz 1987;

[7] Evapotranspiration is sometimes used interchangeably with evaporation. However, evaporation refers to open water surfaces and bare soil, and evapotranspiration refers to land surfaces with vegetation (BOM).

[8] The Bridgewater Formation is a series of Quaternary formed calcareous dune ridges that run parallel to the coast and that rise up to 30 m above the adjoining plains.

Grimes et al. 1999; Wood 2011; Bourman et al. 2016). Gambier Limestone thickness ranges from several metres in the north to over 300 m at the coast (Harris 1983).

Dissolution of the underlying Gambier limestone[9] bedrock in combination with fluctuating sea levels and water tables from ≈ 2.6 million years ago (during the Quaternary) and extensive faulting has led to the formation of the karstic landscape (Grimes et al. 1999; Butcher et al. 2011a; Mustafa et al. 2012). Approximately one million years ago (during the Pleistocene epoch) altered sea levels and tectonic uplift contributed to the Bridgewater Formation of calcareous sands and calcarenite, which occur as a series of dunes sub-parallel to the coast over the Gambier Limestone. Basalt lava deposited during the Pliocene-Holocene (and as recently as 5000 years ago) overlay the onshore sediments of the Otway Basin in the newer Volcanic Province that extends through the adjacent areas of western Victoria. The present eroded upper surface of the domed Gambier Limestone is elevated approximately 80 m above sea level near Mount Gambier and extends 75 m below sea-level about 5 km offshore.

The low lying flat porous shallow surface soils, that extend inland of the coast, range from calcareous sand, fine textured saline soils and loam to localised areas of alkaline peats overlaying the Tertiary and Quaternary limestone (Payder et al. 2009; White 2010; Wood 2011). Elevation of the south east South Australian and south west Victorian coastal region where the ecological community occurs is generally <25 metres above sea level with a gradual relief and gradient toward the sea (some examples in Table 3).

Table 3. Elevation near selected occurrences of the ecological community within the coastal regions of south east South Australia and south west Victoria.

Location	Elevation (above sea-level)
Nelson Vic	20 m
Lake Mombeong/Momboeng/Moniboeng Vic	6-8 m
Cress Creek, Jerusalem Creek, Port MacDonnell Swamp SA	0-5 m
Clarke Park SA	0-2 m
Ewens Ponds and Eight Mile Creek SA	0-6 m
Piccaninnie Ponds and Pick Swamp SA	0-4 m

Source: BOM (2019).

2.1.5 Hydrology

Groundwater[10] moves from regions of higher hydraulic head[11] to regions of lower hydraulic head where discharge typically occurs through sedimentary aquifers. The highly transmissive, porous and permeable nature of the underlying sedimentary Gambier limestone of the south east South Australian and south west Victorian coastal region results in substantial groundwater flow rather than surface flow (Grimes 1994; Butcher et al. 2011a; Lewis pers comm 2018; White pers comm 2018). These regions typically have few natural surface drainage channels in the form of rivers or streams. The exception is the Glenelg River and a small number of short perennial

[9] Limestones in this region fall into two groups, both relatively young: Tertiary (mainly Miocene) limestones of the Gambier Limestone and its equivalent Port Campbell Limestone (Victoria), and the younger Quaternary calcareous dune limestones of the Bridgewater Formation and associated calcareous marine and coastal sediments of the inter-dune flats.

[10] Groundwater is subsurface water that occurs beneath the watertable in soils and geologic formations that are fully saturated.

[11] Hydraulic head is a measurement of the height of a static water column above an arbitrary point.

streams originating from springs (Wood 2011). The water table is typically high near the coast and discharged at a number of locations through natural terrestrial springs that support the ecological community, as well as submarine discharge off the coast (White 2010; Wood 2011). Much of the coastal region, given the shallow depth to groundwater and relatively high winter rainfall, was historically inundated by groundwater and seasonally by surface water to form permanent and semi-permanent wetlands particularly when drainage was impeded by the coastal dunes (Grimes et al. 1999; Butcher et al. 2011a; Geoscience Australia 2018).

Groundwater flow within this region of south east South Australia and south west Victoria occurs in two main regional aquifer systems: an upper unconfined Tertiary limestone aquifer (TLA), and a deeper Tertiary confined sand aquifer (TCSA). The two aquifer systems are separated by a low permeability aquitard in the south east and generally consisting of the Narrawaturk Marl formation and the upper carbonaceous clay of the TCSA (Mustafa pers comm 2018). The Gambier Limestone and younger overlying limestones of the Otway Basin form the main unconfined aquifer system (Grimes 1994; DEWNR 2014). Recharge of the unconfined aquifer occurs from the infiltration of regional rainfall generally between May and September when winter precipitation exceeds evapotranspiration. Direct drainage of surface water via natural sink-holes and other solution tubes also occurs in some areas and by lateral groundwater flows from northeast to southwest toward the coast (Wood 2011; Mustafa et al. 2012). A proportion of groundwater within the TLA originates from the laterised Dundas Tablelands (Table 3) which occurs east of the Kanawinka fault-line in south west Victoria and is dissected by the Glenelg and Wannon Rivers and their tributaries (Costar et al. 2017; DEWNR 2014).

The Karst springs and alkaline fens ecological community is intrinsically connected with the broader regional hydrology and geology. Wood (2011) and Mustafa et al. (2012) noted that the source of ground water discharge for the ecological community can vary from shallow and seasonal to deep and perennial. Shallow systems have a strong dependence on seasonal groundwater discharge from the upper regional Tertiary Limestone Aquifer and can fluctuate in volume. Deep perennial systems, while having a strong dependence on the upper parts of the Tertiary Limestone Aquifer, may also be partially fed by discharge from deeper parts of the same aquifer. Many examples of flow for the ecological community would have historically discharged into the surrounding soil or formed lakes, such as at Pick Swamp, with a few occurrences having small natural outlet streams to the sea. Constant groundwater discharge from the Karst springs and alkaline fens inundated the surrounding landscape (Butcher et al. 2011a) prior to the landscape and hydrological changes that have occurred since non-Indigenous settlement.

Groundwater in the region which supplies the ecological community is typically low in salinity but may fluctuate due to the season and proximity to the saltwater/freshwater interface near the coast. The interface occurs where fresh groundwater flowing toward the coast is diverted upwards by a wedge of dense marine saltwater at the bottom of the aquifer, contributing to aquifer discharge from the springs. Discharge volumes from the springs typically range from 20 m^3/day in the less permeable parts of the aquifer to more than 25 000 m^3/day. Water age discharged from springs near the coast can vary from at least 23 years, to more than 37 years (Wood 2011; Rigosi et al. 2015; Shanafield et al. 2020). A study published in 1990 showed that water temperature regardless of depth typically ranged from 15-17°C depending on season (Scholz 1990).

2.1.6 Vegetation

The Karst springs and alkaline fens exhibit a range of biological components that can occur in broad interconnected habitats: An open water or aquatic zone; a transition zone which, depending on pool depth, contains an inner submergent zone and/or outer emergent zone; and a fringing zone. Due to the consistent delivery of groundwater inputs to the ecological

community, these zones tend to be permanent unless hydrological flows and quality are disrupted. The adjacent hydrological influence of the springs extends into the surrounding soils of the fringing zone and results in the occurrence of rare terrestrial vegetation assemblages.

2.1.7 Flora

2.1.7.1 OPEN WATER ZONE

When present, the central permanent open freshwater / aquatic zone of the ecological community is restricted to aquatic species due to spring water depth such as in a drowned sinkhole (fissures in the limestone bedrock) or deep lake. Although typically representing a small surface area, the presence of flooded karst systems can be a key feature of the ecological community (Butcher et al. 2011a). The submerged assemblage of aquatic vegetation within spring pools is considered unique to this ecological community (Bonifacio and Pisanu 2012; Bonifacio and Pisanu in Keith et al. 2013; Bachmann et al. 2015). Free-floating macrophytes[12] such as duckweeds, e.g. *Lemna disperna* (Common Duckweed), *Lemna trisulca* (Floating Ivy Leaf Duckweed), can also be evident on the surface and extend into the emergent zone on pool fringes. However, the pools are generally dominated by Phytoplankton (algae) at depth. Algae in the aquatic zone include species such as *Batrachospermum boryanum* and *Enteromorpha intestinalis* and from the genera *Anabaena*, *Cladophora*, *Enteromorpha*, *Lyngbya*, *Oscillatoria*, and *Spirogyra*.

2.1.7.2 SUBMERGENT ZONE

Vascular plant species are variable according to water depth, the degree of the pool floor slope and substrate type i.e. peat or silt. With increasing depths beyond three metres, where species transition from the peripheral emergent zone to the submergent zone, true aquatic plant species become evident. Macrophytic species can occur down to six metres and include helophytes[13] such as *Cycnogeton procerum* and *Triglochin striata* (Water Ribbons), Sea Tassel (*Ruppia polycarpa*), *Hydrocotyle* spp. such as Pennywort (*Hydrocotyle verticillata*) and *Ranunculus inundatus* (River Buttercup). Other macrophytic species include *Eleocharis acuta* (Common Spike Rush) and *Althenia cyllindrocarpa* (Water Mat). In some locations where water depth is generally less than six metres and the pool floor quite broad, extensive beds of macrophytes can occur. However, some species may extend to greater depth due to water clarity and sediment substratum, for example, the submerged perennial macrophytes *Myriophyllum crispatum*, *M. simulans* and *M. variifolium* (Water-Milfoil) can be present to seven metres and *Stuckenia pectinata* (Fennel Pondweed) to 15 metres in deep caverns sometimes covered by *Cladophora* sp. (Scholz 1990; Thurgate 1995; Butcher et al. 2011a).

Vascular (aquatic) plants generally become increasingly sparse as water depth increases beyond five metres (Butcher et al. 2011a). Below approximately six metres algae, such as *Batrachospermum boryanum* (a red algae), *Chaetomorpha linum*, *Chara globularis*, *Cladophora aegagropila*, *Enteromorpha intestinalis, E. prolifera* and the genera *Anabaena*, *Lyngbya, Nitella, Oscillatoria*, *Porphysiphon* and *Vaucheria* transition as the dominant growth form and often in dense mats (Scholz 1990; Thurgate 1995; Butcher et al. 2011a; Frood and Papas 2016). Mosses, such as *Cratoneuropsis relaxa*, *Distichophyllum microcarpum* and *Fissidens rigidens*, may be present on limestone outcrops and floors of submerged caverns to depths exceeding 15 metres (Scholz 1990; Thurgate 1995; Butcher et al. 2011a; Bachmann et al. 2015). Epiphytic algal growth can also occur on genera such as Ranunculus, particularly when reduced water flow occurs.

[12] Macrophytes are plants that have adapted to living in aquatic environments.
[13] Helophytes are aquatic plants that are rooted in submerged substrate, but with leaves above the waterline.

2.1.7.3 EMERGENT AND FRINGING ZONE (FENS)

The central open water and/or submergent zones transition with decreasing depth into waterlogged soils in the emergent zone fringing the karst springs. The saturated alkaline soils can support a continuum of dense fen vegetation that ranges from reedbeds, sedgelands and herblands to shrublands (Jones 1978; Bachmann 2002; Ecological Associates 2009; Bonifacio and Pisanu in Keith et al. 2013; Bachmann et al. 2015; Frood and Papas 2016). The inundated emergent zone occurs as a dense herbaceous verge of reeds, sedges and rushes which include emergent macrophytic species, such as twig-rushes (*Baumea articulata*, *B. arthrophylla*, *B. juncea*, *B. rubiginosa*), *Cladium procerum* (Leafy Twig-rush), *Cyperus laevigatus* (Boredrain Sedge), *Eleocharis gracilis* (Slender Spike Sedge), *Phragmites australis* (Common Reed), *Selliera radicans* (Swamp Weed), *Schoenoplectus pungens* (Three-square), *Schoenus nitens* (Shiny Bog-sedge) and *Typha domingensis* (Bull-rush).

As sedgeland transitions to shrubland, the overstorey is typically dense, particularly in wetter older stands. *Leptospermum lanigerum* (Silky Tea-tree/Woolly Tea-tree/Punung/Wiriyu) is commonly the dominant canopy species (typically 3-6 m but up to 10 m) due to its preference for moist to wet conditions. Other species that are tolerant of waterlogging which may co-occur in the canopy include *Melaleuca squarrosa* (Scented Paperbark), *M. ericifolia* (Swamp Paperbark) and *Ozothamnus ferrugineus* (Tree Everlasting). Large tree species such as *Eucalyptus ovata* (Swamp Gum) can occur sporadically.

Dominant understorey species include tall tussock sedges such as *Gahnia trifida* (Cutting Grass) and *Gahnia clarkei* (Tall Saw-sedge) e.g. on the less waterlogged edges of the fringing zone. The fringing zone also provides habitat for other herbaceous species including *Acaena novae-zelandiae* (Bidgee-widgee), *Brachyscome graminea* (Grass Daisy), *Centella cordifolia*, *Epilobium billardiereanum* subsp. *billardiereanum* (Variable Willow-herb), *Lobelia anceps* (Angled Lobelia), *Samolus repens* (Creeping Brookweed), *Senecio biserratus* (Fireweed), *Viola hederacea* (Australian Native Violet) and genera such as *Cotula*, *Hydrocotyle* and *Cycnogeton* (Bachmann 2002; Ecological Associates 2009; Butcher et al. 2011a; Butcher et al. 2011b; Bonifacio and Pisanu in Keith et al. 2013; Bachmann et al. 2015; Frood and Papas 2016). The ecological community also provides habitat for orchids such as the vulnerable *Pterostylis tenuissima* (Swamp Greenhood) which grows exclusively under the dense canopy of Silky Tea-tree/Woolly Tea-tree. Other orchid species include *Corybas* sp. aff. *diemenica* (Swamp Helmet Orchid), *Prasophyllum frenchii* (Maroon Leek-orchid) and *Pterostylis* sp. aff. *Falcata* (Small Sickle Greenhood). As the shrub canopy density increases, the groundlayer can become sparse due to shading and competition.

Some complexes have small natural connecting channels between spring pools, for example Ewens Ponds and Piccaninnie Ponds (Horne 1993). In addition, many occurrences of the ecological community now have artificial outflow streams that drain into the marine environment. These streams are typically fast flowing and can support submergent aquatic vegetation such as *Chara* and *Ruppia* species and emergent plants such as *Hydrocotyle, Ranunculus, Schoenoplectus, Triglochin, Typha* and *Vallisneria* species. The riparian areas of the streams support similar species to the fringing zones of the spring pools i.e. sedges (*Isolepis*), rushes (*Juncus*) and reeds (*Phragmites*) and *Leptospermum* shrublands. As the outflow streams pass through coastal dunes toward the marine environment, flora species will transition to more salt tolerant species that make up different ecological communities, including the nationally listed Subtropical and Temperate Coastal Saltmarsh.

A list of characteristic plants of the ecological community is at Appendix A – Species lists.

2.1.7.4 NATURAL VARIABILITY AND DISTURBANCE

The preceding description of the vegetation generally relates to the less disturbed, or ‘reference’ occurrences of the Karst springs and alkaline fens. In many locations there has been substantial

and long term disturbance to the ecological community, which is also reflected in its current state: drainage, clearance, hydrological management history, and land management history (including for grazing) having had a strong influence on the current structural and floristic composition of the ecological community (Foulkes and Heard 2003; Taylor 2006; Bachmann et al. 2015; Butcher and Brookes 2018; SENRMB 2019; SENRMB and SEWCDB 2019).

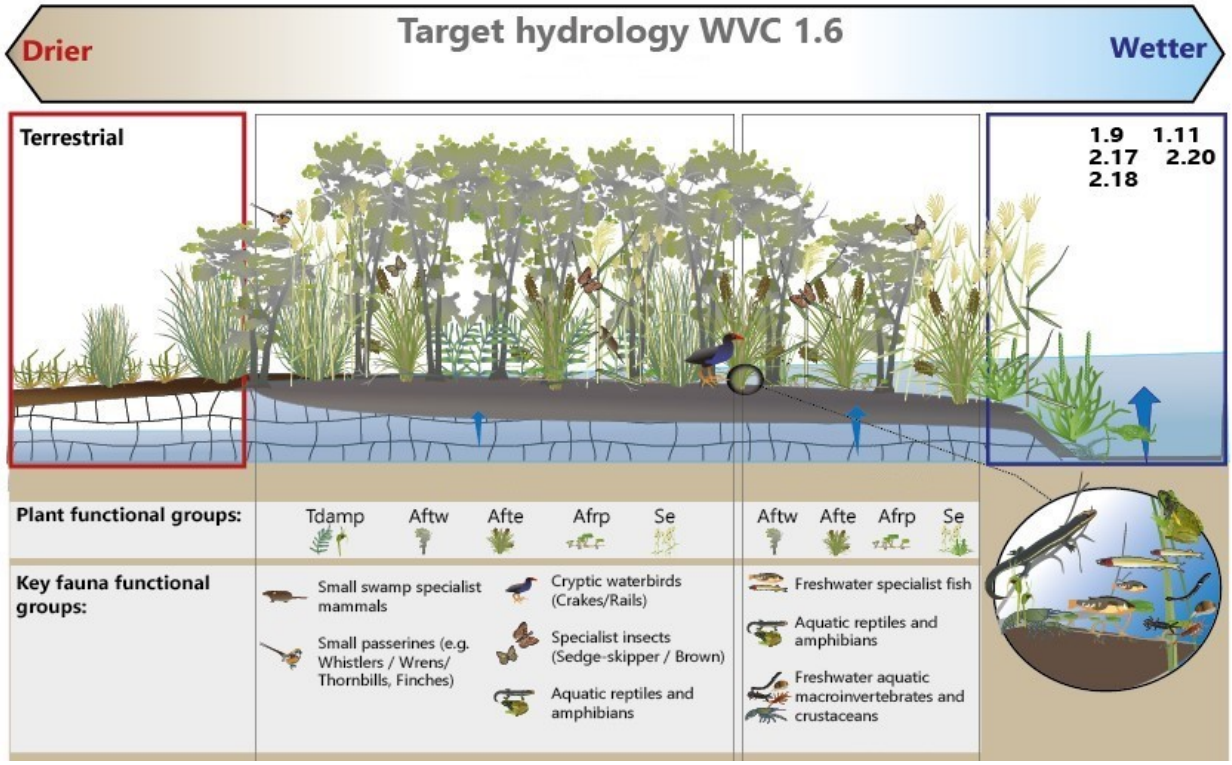
Australia typically has a low annual rainfall, high evaporation and high rainfall variability. As a result, many freshwater wetlands are ephemeral with few having relatively stable water levels and permanence such as the Karst spring and alkaline fens (Briggs 1981). Wetland dependant plants within the ecological community range from aquatic, emergent to fringing terrestrial species. Obligate aquatic species such as free floating and submergent flora require permanent inundation while emergent to fringing species such as shrubs experience intermittent inundation. Figure 1 provides an example of flora and fauna components, interconnected habitats and hydrology for the ecological community. Only fringing native vegetation that is hydrologically connected (at least intermittently) or dependant on the Tertiary limestone aquifer is part of the Karst springs and alkaline fens. This is shown in Figure 1, where drier terrestrial vegetation is not considered part of the Karst springs and alkaline fens.

The fringing vegetation structure of the Karst springs and alkaline fens varies from closed shrubland to sedgeland and aquatic herbland. The local expression of the ecological community is influenced by the quality and quantity of permanent groundwater and surface water, salinity and pH, history of inundation, disturbance regimes and both local and regional land management. Many remnant occurrences of the ecological community contain regrowth from past clearance, hydrological disruptions or other disturbances. Some occurrences, for example where natural hydrological regimes have been re-established e.g. where drainage has been impeded, may initially be expressed primarily as sedgeland with very sparse shrub canopy (<10% crown cover). Other areas may occur as dense shrublands of predominantly *Leptospermum lanigerum* (Silky Tea-tree/Woolly Tea-tree) with sparse understorey.

Not all zones described in Section 2.1.7 will necessarily be present within the same location due to variations in local hydrology, elevation, substrate and landscape position. In low relief, low altitude areas where karst pools may be present, for example Piccaninnie Ponds, the biological associations can include all zones. However, in elevated areas with higher relief, large aquatic pools are not necessarily present, and the ecological community may only contain an emergent and/or fringing zone in and/or adjacent to a seep. With the continual discharge of groundwater from the ecological community into fringing zones, other adjacent wetland types and riparian vegetation near watercourses can be contiguous due to their proximity and hydrological connection.

The structure and composition of the ecological community varies in response to groundwater or disturbance. High water tables stimulate emergence of native wetland species that leads to development of a sedgeland and/or dense shrubland layers. Increased and prolonged water levels may also temporarily remove or reduce a Tea-tree canopy but can also stimulate their regeneration in areas fringing the new emergent zone. The diversity in the shrubland can decrease over time, as species with short to medium generation lengths and high light requirements progressively decline as overstorey density increases. Eventually a lower diversity mature form establishes.

Figure 1. Indicative flora and fauna components, vegetation types and hydrological requirements that may be present in some examples of the ecological community. (SA Wetland Vegetation Component (WVC): 1.6 – *Leptospermum lanigerum* tall wet shrubland; 1.9 – *Gahnia trifida* tussock sedgeland; 1.11 – Freshwater emergent sedgeland; 2.17 – Typha/Phragmites tall aquatic grassland; 2.18 – Karst rising spring – open water component; 2.20 – Freshwater open aquatic herbland. Plant functional groups: Tdamp – Terrestrial damp; Aftw – Amphibious fluctuation tolerators-woody; Afte – Amphibious fluctuation tolerators-emergent; Afrp – Amphibious fluctuation responders-plastic; Se – Submerged-emergent).



Source: Harding (2019 in draft)

Other disturbances such as hydrological variability, in combination with grazing, also lead to shifts in vegetation structure and composition. These often lead to changes in plant species composition within and around the ecological community; for instance, through the conversion of fens into native and/or exotic pasture (Butcher et al. 2011a).

2.1.8 Fauna

The Karst springs and alkaline fens occurs near the boundary between two major Australian biogeographic regions: the temperate southern and eastern Australia Bassian region and the semi-arid inland Eyrean region. This area, which occurs across the South Australian south-east and Victoria's south-west border, is recognised as a national biodiversity hotspot. The Karst springs and alkaline fens provides diverse habitats for a range of aquatic, terrestrial and volant vertebrates and invertebrates that rely on permanent or near permanent wetlands. The Karst springs and alkaline fens provide food, shelter, breeding, nesting habitats and other resources for fauna over all or part of their life cycles. Some characteristic species such as *Chelodina longicollis* (Eastern Long-Necked Turtle), *Egretta novaehollandiae* (White-faced Heron) and *Notechis scutatus* (Tiger Snake) are widely distributed, while others, such as *Antechinus minimus maritimus* (Swamp Antechinus) and *Euastacus bispinosus* (Glenelg Spiny Freshwater

Crayfish), have specialised habitat niches and more restricted ranges. Most fauna species that are a part of the ecological community also use adjacent or nearby habitats, such as other kinds of wetlands, sedgelands, shrublands and woodlands.

Mammals

The closed shrub canopy and sedge layers of the ecological community support a diversity of mammal species. Volant species such as microbats typically forage for insects over a variety of habitats including shrubland canopy and edge zones, over pools, outflow creeks and fens. The south east region has the highest bat species richness for South Australia (Foulkes and Heard 2003). Microbat species include the critically endangered *Miniopterus orianae bassanii* (Southern Bent-wing Bat) which prefers wetland foraging habitat, *Nyctophilus geoffroyi* (Lesser Long-eared Bat), *Ozimopos planiceps* (South-eastern Free-tailed Bat) and *Chalinolobus gouldii* (Gould's Wattled Bat). The Karst springs and alkaline fens is also known to provide habitat for *Myotis macropus* (Large-footed Myotis) which forages for small fish, prawns and aquatic insects by trawling water surfaces with its feet.

Mammals, dependant on damp or wet habitats such as the Karst springs and alkaline fens, include the carnivorous *Antechinus minimus maritimus* (Swamp Antechinus) and the predominantly carnivorous and amphibious *Hydromys chrysogaster* (Rakali/Water Rat). Other mammal species likely to occur in the ecological community are the herbivorous *Rattus lutreolus* (Swamp Rat) and the omnivorous *Rattus fuscipes* (Bush Rat). These mammals utilise the clumping and dense aquatic and terrestrial ground cover of the ecological community for foraging and shelter. The nocturnal Bush Rat is likely to also pollinate flowers while feeding on nectar. The Swamp Antechinus is particularly reliant on *Leptospermum lanigerum* (Silky Tea-tree), a key dominant in the fringing component of wetlands such as the Karst springs and alkaline fens.

Birds

The continual discharge of fresh groundwater from the Karst springs into the associated alkaline fens supports habitat for roosting, foraging and breeding for at least 140 bird species. The ecological community occurs across diverse habitats ranging from deep expanses of freshwater, floating vegetation in lakes, flowing water in outlet channels, shallow water sedgeland, herblands and grasslands to dense shrublands. The ecological community includes numerous bird groups from coastal shrublands, open woodlands and grasslands, sedgelands and wet shrublands, migratory waders and waterbirds (Foulkes and Heard 2003, Butcher et al. 2011a, DELWP 2017a).

The Karst springs and alkaline fens provides habitat for at least 79 waterbird species including at least 19 migratory species listed under international agreements with China - CAMBA (9), Japan - JAMBA (9), the Republic of Korea - ROKAMBA (10) and the Bonn Convention - BONN (9) (Butcher et al. 2011a, DELWP 2017a).

Various waterbird feeding and dietary guilds are present within the ecological community and include brolga, coots, ducks, egrets, grebes, herons, ibis, rails, spoonbills and waterfowl. The fresh water and dense cover of *Gahnia trifida* (Cutting Grass) also attracts cryptic waterbirds such as *Porzana fluminea* (Australian Spotted Crake), *Botaurus poiciloptilus* (Australasian Bittern) and *Gallinago hardwickii* (Latham's Snipe) (Butcher et al. 2011a; Butcher et al. 2011b). The Karst springs and alkaline fens also acts as an important refuge for birds from more arid regions, during drought in other parts of south east Australia as well as a stopover for migratory waders such as sandpipers (Foulkes and Heard 2003).

Waterbird breeding patterns are closely tied to seasonal patterns for water availability, food resources and nesting habitat. The consistent flooding patterns of the aquatic component of the Karst springs and alkaline fens provide resources to support breeding for at least ten waterbird

species including: *Antigone rubicunda* (Brolga), *Anseranas semipalmata* (Magpie Goose), *Biziura lobata* (Musk Duck), *Cygnus atratus* (Black Swan) and *Vanellus miles* (Masked Lapwing). Black Swans and Brolgas build their nests from grass and reedy material on small islands or directly on shallow waters (Brolgas), or deeper water (Black Swans). Brolgas are listed as threatened in South Australia and Victoria with populations in Victoria estimated at between 600 – 700 individuals (DELWP 2017b).

The high invertebrate abundance and diversity within the ecological community supports insectivore species such as *Acanthiza* spp. (thornbills), *Malurus cyaneus* (Superb Fairywren), *Stagonopleura bella* (Beautiful Firetail) and *Stipiturus malachurus* Southern Emu-wren). Other small passerines that can be characteristic of the fringing zone include *Dasyornis broadbenti* (Rufous Bristlebird) and *Pachycephala olivacea* (Olive Whistler). The terrestrial and aquatic vegetation supplies seeds, fruit and other material for herbaceous waterbirds such as the *Chenonetta jubata* (Australian Wood Duck), *Hypotaenidia philippensis* (Buff-banded Rail), *Lewinia pectoralis* (Lewin's Rail) and *Porphyrio melanotus* (Australasian Swamphen). The aquatic macrophytes within the ecological community provide breeding and shelter for macroinvertebrates, frogs and fish (Harding and de Jong 2007). These support omnivore waterbirds such as *Anas gracilis* (Grey Teal), *Anas superciliosa* (Pacific Black Duck) and *Tadorna tadornoides* (Australian Shelduck). The Karst springs and alkaline fens was also at least previously a winter roosting and feeding habitat for the critically endangered *Neophema chrysogaster* (Orange-bellied Parrot) after migration from breeding sites in Tasmania (Foulkes and Heard 2003, Butcher et al. 2011a).

Amphibians

The Karst springs and alkaline fens provide diverse breeding and foraging habitat for at least nine frog species including the *Crinia signifera* (Common Eastern Froglet), *Geocrinia laevis* (Smooth Frog), *Limnodynastes tasmaniensis* (Spotted Grass Frog) and *Neobatrachus pictus* (Painted Frog). Growling Grass Frog (*Litoria raniformis*), listed as nationally vulnerable, breeds in spring and summer in this part of its range. The species' preference for permanent still or slow flowing freshwater bodies is important for its long tadpole phase while thick vegetation allows the species to overwinter close to these water components. Favoured sites frequently have a large proportion of emergent, submerged and floating vegetation, which is a characteristic of some examples of the ecological community such as Piccaninnie and Ewens Ponds (Clemann and Gillespie 2012). Amphibians provide food for cryptic bird species such as the Australasian Bittern and Lewin's Rail as well as for other birds, reptiles and mammals.

Reptiles

The Karst springs and alkaline fens ecological community includes many snakes, lizards and turtles. Lizards that are a part of the ecological community include *Acritoscincus duperreyi* (Eastern Three-Lined Skink), *Eulamprus tympanum* (Southern Water Skink) and *Liopholis whitii* (White's Skink). Lizards currently listed as threatened at the state level include *Lissolepis coventryi* (Eastern Mourning Skink), *Pseudomoia rawlinsoni* (Glossy Grass Skink) which is at its western extent and favours sedgelands dominated by *Gahnia trifida* (Cutting Grass) tussocks, *Anepischetosia maccoyi* (Salamander Skink) and *Lissolepis coventryi* (Swamp Skink). The common *Chelodina longicollis* (Eastern Long-Necked Turtle) feed on frogs and macroinvertebrates within the various flooded components of the ecological community including the outlet streams. Snakes present in many occurrences of the ecological community include the *Austrelaps superbus* (Lowland Copperhead) and *Notechis scutatus* (Tiger Snake). These species are top predators that feed on frogs, lizards, eggs, small and juvenile birds and other animals present in the ecological community.

Fish

The Karst springs and alkaline fens provide important resources for fish such as food and migration pathways, spawning grounds and nursery areas. When present, the aquatic zones of the ecological community provide habitat for at least 24 fish species (Hammer et al. 2009; Hammer et al. 2011; Veale and Whiterod 2014). Several functional groups are present ranging from obligate freshwater specialists such as *Nannoperca australis* (Southern Pygmy Perch) and *Galaxiella pusilla* (Dwarf Galaxias), estuarine species such as *Afurcagobius tamarensis* (Tamar River goby), *Pseudogobius olorum* (Western Bluespot Goby), to estuarine/marine species such as *Acanthopagrus butcheri* (Black Bream) and *Liza argentea* (Jumping Mullet). Several diadromous species, including *Anguilla australis* (Southern Shortfin Eel), *Geotria australis* (Pouched Lamprey), *Prototroctes maraena* (Australian Grayling) and *Pseudaphritis urvillii* (Congolli) migrate between the freshwater springs and marine systems to complete their lifecycles (Hammer et al. 2009; Butcher et al. 2011a). Four fish species in the ecological community are currently classified as nationally vulnerable: *Galaxiella pusilla* (Dwarf Galaxias), *Nannoperca obscura* (Yarra Pygmy perch), *Nannoperca variegata* (Variegated Pygmy Perch) and *Prototroctes maraena* (Australian Grayling). Veale and Whiterod (2014) described a further eight species as regionally threatened.

The ecological community includes short lived fish species such as *Atherinosoma microstoma* (Small Mouthed Hardyhead) and *Galaxias maculatus* (Dwarf Galaxias/Common Galaxias) which reach maturity within one year. The ecological community also includes longer-lived species such as the Southern Pygmy Perch which can live up to five years and the Southern Short Fin Eel up to 24 years.

Many fish species within the ecological community have particular habitat preferences. For example, Yarra Pygmy Perch has a strong preference for highly vegetated habitats such as the dense zones fringing springs and outlet streams. *Galaxias truttaceus* (Spotted/Trout Galaxias), prefers cool flowing freshwater at lower altitudes and the Australian Grayling, prefers deep clear pools. Both of these fish species are at the western edge of their South Australian range in the ecological community. Areas with shallow water (~0.1 m) provide habitat for small-bodied native fish, notably Dwarf Galaxias.

Invertebrates

The persistence of permanent freshwater in the Karst springs and alkaline fens and the various terrestrial and aquatic zones around that provide habitat for a diverse invertebrate fauna. Typically the aquatic components of the community are dominated by *Austrogammarus* spp.*, Paracalliope* spp.*,* Corophiidae spp. and *Austrochiltonia* spp. (amphipods), *Simulium* spp. (blackflies), *Notalina* spp. and *Triplectides* spp. (caddisflies), *Austroagrion* spp. and *Austrolestes* spp. (damselflies), dragonflies, dytiscid beetles, chironomids, marsh flies, *Atalophlebia* spp., *Centroptilum* spp. and *Nousia* spp. (mayflies)*, Angrobia* spp. and *Glyptophysa* spp. (native snails), *Sphaeriidae* spp. (pea mussels), *Austrocerca* spp. and *Dinotoperla* spp. (stone flies), *Oxus* spp. (water mites) and waterbugs and beetles (Coleoptera) (Foukes and Heard 2003; EPA 2014).

The shallower ponds of the ecological community also provide habitat for crustaceans and macro-invertebrates that use submerged and emergent aquatic macrophytes such as *Cycnogeton* spp., *Myriophyllum* spp., *Triglochin* spp. and *Juncus kraussii*. Crustaceans include *Amarinus* spp. (freshwater crabs), *Engaeus strictifrons* (Portland Burrowing Crayfish), *Geocharax* spp*.* (Swamp Yabby), *Paratya* spp. (freshwater shrimp) and the nationally endangered *Euastacus bispinosus* (Glenelg Spiny Freshwater Crayfish) (Ecological Associates 2009; EPA 2014). The Glenelg Spiny Freshwater Crayfish is at its most western extent and the ecological community provides its main habitat in South Australia (TSSC 2016b).

The Karst springs and alkaline fens provides preferential habitat for butterflies in the family Nymphalidae (brush-footed butterflies). Sedges, especially *Gahnia* species, are an important flora component within the ecological community and are the dominant food plant for *Hesperillini* Skippers and several brown butterflies (Caton et al. 2011; Grund 2019). Other skippers that are dependent on *Gahnia* sedgelands as food plants for their larvae include *Hesperilla chrysotricha* and *Hesperilla idothea* (Bachman 2002). Other butterfly species are: *Hesperilla idothea idothea* (Flame Sedge-skipper), *Heteronympha cordace wilsoni* (Bright-eyed Brown), *Oriexenica kershawi kanunda* (Striped Xenica), *Taractrocera papyria papyria* (White-banded Grass-dart) and *Tisiphone abeona albifascia* (Sword-grass Brown). Some butterfly species are indicators of good wetland health such as *Hesperilla chrysotricha chrysotricha* (Golden-Haired Sedge-Skipper) and *Hesperilla donnysa* (Varied Sedge-Skipper) (Bachman 2002).

A more comprehensive list of fauna species that are part of the ecological community, including threatened fauna, are in Appendix A - Species lists.

2.2 Cultural and community significance

The Boandik and Gunditjmara people have a special connection and affinity with many of the places and species (see Appendix A – Species lists) associated with the Karst springs and alkaline fens. They believe there is an obligation and responsibility to protect and care for Country and all species that make up the unique landscape where the ecological community occurs. The Karst springs and alkaline fens are home to important Totemic species as well as resources that have sustained Indigenous people for thousands of years. It was through careful management, and the ability to adapt to changing conditions, that the land was effectively maintained for millennia.

Aboriginal people depended on native flora and fauna for all of life's necessities, and their survival is evidence of a balance between natural resource use and renewal (Gott 2008). Traditional owners and custodians have an ongoing connection to, and use of, natural resources. A wide variety of plant and animal resources from within the Karst springs and alkaline fens were used for food and materials by the Traditional custodians of the area (see Appendix C - Indigenous people, cultural values and use of the ecological community).

A notable occurrence of the ecological community is the Piccaninnie Ponds Karst Wetlands Ramsar Site near Mount Gambier, South Australia. It contains a series of springs and ponds, with the largest and deepest of the springs reaching a depth of 110 metres. The karst springs here support unique macrophyte and algal associations, with macrophyte growth extending to 15 metres below the surface, as a result of exceptional water clarity. Hence, this site and other sites such as Ewens Ponds are popular for regulated recreational diving.

3 THREATS

The Karst springs and alkaline fens have been primarily impacted by historic drainage and clearing for agriculture and forestry (conversion to monoculture plantation), and the areas that remain continue to be under threat from ongoing degradation from hydrological changes and invasive species.

3.1 Threat table

Table 4 outlines the key threats facing the ecological community. The key threats faced by the ecological community are described to help explain why this ecological community merits listing as threatened and supports the assessment against the criteria at section 6.1. Although presented as a list, in reality these threats often interact, rather than act independently.

Table 4. Summary of threats facing the ecological community

Threat factor	Threat status*	Evidence base
Hydrological changes	Timing: Mostly Past/Some Ongoing	Aproximately 55% of the lower south east of South Australia was covered by seasonal and permanent wetland vegetation including the Karst springs and alkaline fens. These interconnecting wetland complexes were extensively modified by a combination of private and government drainage schemes and water extraction from the 1860s. Between 6-18% of mixed quality seasonal and permanent wetlands remain across the Bridgewater subregion of which the Karst springs and alkaline fens is a subset. Changes in land use and hydrology have significantly altered the ecology of remaining wetlands, resulting in lower aquifer flows and falling water table depths. In the Bridgewater subregion there has been a shift from dryland agriculture to irrigated cropping, pastures for dairy and orchards/vineyards. This increases groundwater usage, lowering the water table and reducing aquifer flow rates. Expansion of plantation forestry can also contribute to reduced aquifer recharge and falling water tables. Current hydrological groundwater impacts to the ecological community are associated with ongoing drainage (including the maintenance and deepening of drains) and irrigation (such as centre irrigation pivots). Continued drainage of remaining wetlands and surrounding land, in addition to the expansion of groundwater extraction for irrigation in the same areas has compounded the impact on the hydrology of the local area. As the underlying peat dries, shrinks and evaporates (releasing carbon dioxide), localised land subsidence can occur and is evident, for example, at Ewens Ponds and the Eight Mile Creek wetland complex. As land subsides, further groundwater drainage may be required to avoid flooding during wet periods and to maintain agricultural and grazing activities. Historical and ongoing groundwater management practices can facilitate detrimental nutrient levels, algal blooms, eutrophication, chemical pollution and salinity levels (Rigosi et al. 2015; Shanafield et al. 2020). For example, higher salinity levels have been noted within some occurrences of the ecological community e.g. Spencer Pond (Mustafa et al. 2012). Pollution of the unconfined aquifer can occur from disseminated areas, through excessive fertiliser use such as agricultural nitrates and phosphates, or from

Threat factor	Threat status*	Evidence base
		point sources such as transport, industry, waste dumping and recycling sites. Toxic chemicals that can impact groundwater include PFAS fire-fighting chemicals, petroleum products and timber treatments such as copper chrome arsenic. Plantation forestry in the south east of South Australia occurs over more than 140 000 ha. Radiata Pine (*Pinus radiata*) has been grown in the region for timber for at least 120 years and Tasmanian Blue Gum (*Eucalyptus globulus*) has been grown on a commercial scale since the late 1990s (Beynon et al. 2006). Taylor (2006) noted plantation forestry expansion can impact on water table levels in the Lower South East and East Glenelg groundwater catchments. Plantations reduce groundwater recharge (Holmes and Waterhouse 1983). In addition, deep rooted plantations also take up groundwater directly leading to a likely decline in water table level in recently planted areas (Leaney et al. 2006; Benyon et al. 2006; Taylor 2006; Sinclair Knight Merz 2009). Modifications to the natural landscape levels by extraction of resources from mining can disrupt hydrological processes by altering aquifer recharge, water quality and flow rates of the unconfined aquifer. Potential impacts from mining, e.g. coal seam gas, can result in subsidence or fractures to subsurface rocks and cracking of aquifers, and leach of chemicals into groundwater impacting wetlands and other remnant vegetation. Such deep geological impacts are difficult/impossible to correct. Tracks through or adjacent to wetlands, particularly raised causeways for vehicles, also impact natural water regimes for the ecological community by altering hydrological flows in and out.
Vegetation clearance, habitat loss, fragmentation and small remnant habitat size	Timing: Mostly Past/Some Ongoing	Further to the hydrological changes covered with the previous threat factor, the vegetation of the ecological community has been progressively cleared, following drainage, since non-Indigenous settlement primarily for agricultural use, typically grazing. Forest plantations have been established from about 1900. The ecological community's location on relatively fertile soils/peat, high rainfall and on flats and lower slopes made it a prime target for clearance. There are also many roads and human-made tracks through and adjacent to the ecological community. Tracks through wetlands typically disconnect and fragment occurrences and provide a vector for the spread of weeds and other invasive species. Although

Threat factor	Threat status*	Evidence base
		tracks may benefit some native species such as edge foraging microbats, they do not favour other cryptic species such as crakes and rails which require continuous dense vegetation for foraging and nesting. Taylor (2006) noted that tracks were a common form of degradation for otherwise intact wetlands, particularly in the lower south east of South Australia where the ecological community occurs. Fragmentation and loss of landscape-level and hydrological connectivity influences the ability of occurrences to function as habitat. Isolation and poor connectivity of many fragments can make the ecological community highly susceptible to small-scale, cumulative threats that impact either directly on flora and fauna species or indirectly through loss of other resources or species they rely on (e.g. seeds, nectar, prey, pollinators, seed dispersers). Hence, smaller occurrences of intact vegetation are less likely to support the range of resources required to maintain diverse flora and fauna species. Isolated smaller occurrences often show lower abundance, critically low genetic diversity and a decline in the number of species detected within and across the ecological community, including for aquatic fauna species (Miller et al. 2014). Fragmentation can result in populations being broken up into many smaller populations which are at greater risk of local extinctions. For example, Whiterod et al. (2015) noted that previously relatively abundant subpopulations of Glenelg Spiny Freshwater Crayfish in the Cress Creek occurrence of the ecological community had substantially reduced. Whiterod and Hammer (2012) found that juvenile crayfish were not detected in three sub-populations at Bones Pond, Jerusalem Creek and Clarke Park occurrences. In addition, much of the habitat for the threatened *Antechinus minimus maritimus* (Swamp Antechinus) has been cleared and drained, and fragmented populations are at higher risk of local extinction (TSSC 2016a). Smaller remnants due to clearance and drainage are more susceptible to ‘edge effects’ such as higher levels of weed and feral animal invasion and encroachment of adjoining land use impacts. Edge effects may arise from activities such as maintenance of access tracks; spray drift (from fertilisers, herbicides and other chemicals); and browsing and trampling from livestock grazing. The cumulative result is reduced diversity and abundance of native species.

Threat factor	Threat status*	Evidence base
Grazing and trampling	Timing: Mostly Past/Some Ongoing	The Karst springs and alkaline fens ecological community occurs on relatively productive soils, much of which has been developed for highly productive and intensive farming industries such as dairy farming. In areas yet to be fully converted to pasture, browsing, preferential grazing, trampling and nutrification by stock can rapidly damage or change the structure, composition and functionality of the ecological community. The loss of, and changes in, native vegetation caused by this affects microclimate, including humidity levels, at ground level. Pugging can alter soil structure, surface drainage and infiltration, impede vegetation regrowth, lead to weed spread and density, and exacerbate the leaching of potassium and nitrogen from the soil. Removal of riparian habitats through unrestricted grazing and trampling can have long-term impacts as it can affect underlying peat layers and bank stability of the ecological community leading to erosion, sedimentation, reduced water quality and increased water temperature. The silting up of outflow streams and drainage beds can have negative consequences for aquatic fauna species. As an example of fauna impacts, livestock have been reported to reduce habitat suitability and population viability for species such as the Swamp Antechinus (TSSC 2016a).
Invasive and other problematic species, genes and diseases	Timing: Ongoing	The ecological community now typically occurs as isolated occurrences adjacent to heavily disturbed and modified land and drainage channels. As a result, invasive weeds often associated with agricultural and pastoral areas have invaded occurrences. Weed dispersal into the aquatic and/or terrestrial components of the ecological community can occur through numerous vectors including livestock and feral animals, machinery, water, wind and native birds and animals. For example, bird dispersed species such as Arum Lilly (*Zantedeschia aethiopica*), Briar Rose (*Rosa rubiginosa*), Italian Buckthorn (*Rhamnus alaternus*) and Mirror Bush (*Coprosma repens*) invade both dry and wet areas of the ecological community. The ecological community is impacted by Weeds of National significance such as African Boxthorn (*Lyceum ferocissimum*), Blackberry (*Rubus fruticosus* spp. agg.), and Bridal Creeper (*Asparagus asparagoides*). In areas where a drying hydrological regime occurs, particularly for long periods, Coastal Wattle (*Acacia*

Threat factor	Threat status*	Evidence base
		longifolia var. *sophorae*) and the introduced native Sallow Wattle (*Acacia longifolia* var. *longifolia*) and their hybrids can colonise sites (Native Vegetation Council 2014). Dense infestations of Coastal Wattle may cause up to 75% of indigenous species to be lost from the terrestrial vegetation layer (Butcher et al. 2011a). The Spiny Rush (*Juncus acutus*) can quickly invade watercourses and other damp areas and forms dense monocultures which exclude other native species and is indicative of changing hydrological and salinity levels. Tall Fescue/Williams Grass (*Festuca arundincea*) is a threatening weed in areas where it has been established as a waterlogging tolerant pasture. This pasture grass species can form dense mats around the highwater mark. Pine wildlings from plantations may establish in the drier fringing areas in and adjacent to the ecological community. Several feral animal species, for example foxes, cats, deer, goats, mice, pigs, rabbits and rats, have been recorded in and adjacent to the Karst springs and alkaline fens. These invasive species subject the ecological community and the broader landscape to individual and compounding impacts such as predation of native animals, competition for resources, habitat disturbance, weed spread and direct transmission of disease and parasites. For example, predation by foxes has been demonstrated for the Swamp Antechinus, and population-level risks assumed to be substantial. Risks may be magnified where grazing has reduced ground cover (TSSC 2016a). Occasional kills of this species by domestic cats have been recorded where human settlements have come into contact with populations (TSSC 2016a). Feral herbivores such as rabbits alter the structure and composition of native vegetation communities by selectively removing the most palatable vegetation and removing large amounts of biomass. They compete with native fauna and stock for grasses, herbs and seeds, affect the regeneration of woody trees and shrubs and spread weed seeds. Goats (*Capra hircus*) and deer (*Cervus dama* and *Cervus elaphus*) occur in the region. These species exert high grazing pressure on native vegetation and can impede woody species regeneration by grazing on seedlings and young saplings. They also disperse weeds through their droppings and can cause considerable soil disturbance. and trample ground layer

Threat factor	Threat status*	Evidence base
		plants, causing changes to the structure of remnant vegetation. Populations of invasive fish species such as Mosquito Fish/Gambusia (*Gambusia holbrooki*), Marron (*Cherax tenuimanus*) and Redfin (*Perca fluviatilis*) are present in the region and have the potential to directly predate on native species, compete for resources and introduce disease and parasites. Predatory fish such as Brown Trout (*Salmo trutta*) have previously been detected and removed from the ecological community (Butcher et al. 2011a).
Climate change and severe weather	Timing: Ongoing	Changes to climate are likely to impact upon the ecological community through seasonal shifts in temperature, evaporation and rainfall (Limestone Coast 2015). This may result in issues such as: • decreased recharge of the unconfined aquifer and lowered groundwater levels; • reduced groundwater discharge into springs and seeps; • rising sea-levels leading to direct inundation, increased storm surge via coastal drains, and/or increasing groundwater salinity levels (seawater intrusion) (Harding et al. 2015); • loss of resilience to degradation and fragmentation; • structural and compositional changes of terrestrial and aquatic species; • predominance of exotic plant species and reduced native forb diversity; • higher incidence of algal blooms; • higher rainfall areas under increased pressure for agricultural intensification and groundwater resource development; • cascading changes in ecological interactions; and • increased intensity and frequency of bushfires. More extreme climate events such as heat waves and drought will have greater impact upon the outer areas of wetlands and those native species with limited dispersal ability. For example, drier conditions would substantially change wetland characteristics for Swamp Antechinus' preferred habitat, exacerbated by the small size of remaining habitat occurrences and the subspecies' limited dispersal ability (DEWNR 2015). Significant population declines have occurred during periods of below average rainfall and drought (TSSC 2016a).

Threat factor	Threat status*	Evidence base
Altered fire regimes	Timing: Ongoing	The ecological community can carry fire, even when there is surface water present with some native species such as *Leptospermum* and *Typha* species providing major fuel components. Wetland remnants with a high woody weed component, or surrounded by land with high woody weed loads, are particularly susceptible to fire. Indigenous Cultural fire practices, such as likely Traditional cool burning of fire prone vegetation near the ecological community, have been disrupted since Non-Indigenous settlement. Fire may contribute to species loss and structural changes to the Karst springs and alkaline fens, exacerbated where sites are fragmented and fire impacts a large proportion of a remnant. For example, a population of Swamp Antechinus within the ecological community at Cress Creek Bubbling Spring, had its habitat substantially burnt in 2013 (Sweeney 2013). Subpopulations of this subspecies have been shown to be eliminated by wildfire, and recolonisation may be slow or absent (TSSC 2016a). The ecological community contains substantial deposits of peat in some areas that can be many metres deep. Drainage has exposed and dried these peat layers in many areas leading to subsidence (Armstrong and Watson 1974). Gill et al. (2014) noted that in south east Australia, peat-substrate fires have also been ignited by prescribed and/or unplanned fires. Peat fires have slow rates of spread but can burn for long time periods (up to months) and can have multiple ignition points due to spread of fire in the above ground vegetation.
Recreational disturbance	Timing: Future	An increase in diver and snorkeler access (e.g. unregulated) to some spring pool sites has the capacity to mobilise sediments and reduce water clarity in ponds, increase introductions of microbiota, disturb and dislodge macrophytes and cause degradation of margin sediments and soil.
Timing – the threat occurs in the **past** (and unlikely to return), is **ongoing** (present/continuing), is likely to occur/return in the **future** or timing is **unknown**		

3.2 Key threatening processes

The national *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and Victorian *Flora and Fauna Guarantee Act 1988* (FFG ACT) provides for the identification and listing of key threatening processes. A process is defined as a key threatening process if it threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.

The following are EPBC and FFG-listed key threatening processes (Table 5), current at the date of writing, that may be relevant to entire areas of the ecological community or specific plants and animals that comprise it:

Table 5. Key threatening processes

VIC FFG Act	EPBC Act
Alteration to the natural flow regimes of rivers and streams	
Alteration to the natural temperature regimes of rivers and streams	
	Land clearance
Degradation of native riparian vegetation along Victorian rivers and streams	
Habitat fragmentation as a threatening process for fauna in Victoria	
Inappropriate fire regimes causing disruption to sustainable ecosystem processes and resultant loss of biodiversity	
Increase in sediment input into Victorian rivers and streams due to human activities	
Infection of amphibians with Chytrid Fungus, resulting in chytridiomycosis	Infection of amphibians with chytrid fungus resulting in chytridiomycosis
Input of toxic substances into Victorian rivers and streams	
Introduction of live fish into waters outside their natural range within a Victorian river catchment after 1770	Novel biota and their impact on biodiversity
Invasion of native vegetation by Blackberry *Rubus fruticosus* L. agg	Novel biota and their impact on biodiversity
Invasion of native vegetation by 'environmental weeds'	Novel biota and their impact on biodiversity
Invasion of native vegetation communities by Tall Wheat-grass *Lophopyrum ponticum*	Novel biota and their impact on biodiversity
	Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants
Loss of biodiversity as a result of the spread of Coast Wattle (*Acacia longifolia* subsp. *sophorae*) and Sallow Wattle (*Acacia longifolia* subsp. *longifolia*) into areas outside its natural range	Novel biota and their impact on biodiversity
Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases	Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases

VIC FFG Act	EPBC Act
Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*)	Predation, habitat degradation, competition and disease transmission by feral pigs
Predation of native wildlife by the cat, *Felis catus*	Predation by feral cats
Predation of native wildlife by the introduced Red Fox *Vulpes vulpes*	Predation by European red fox
Prevention of passage of aquatic biota as a result of the presence of instream structures	
Reduction in biomass and biodiversity of native vegetation through grazing by the Rabbit *Oryctolagus cuniculus*	Competition and land degradation by rabbits
Removal of wood debris from Victorian streams	
Soil degradation and reduction of biodiversity through browsing and competition by feral goats (*Capra hircus*)	Competition and land degradation by unmanaged goats
Threats to native flora and fauna arising from the use by the feral honeybee *Apis mellifera* of nesting hollows and floral resources	Novel biota and their impact on biodiversity
Wetland loss and degradation as a result of change in water regime, dredging, draining, filling and grazing	

Source: DELWP (2019a); DAWE (2020).

The following approved EPBC threat abatement plans[14] are considered relevant to the Karst springs and alkaline fens (at May 2020):

- Threat abatement plan for competition and land degradation by unmanaged goats;
- Threat abatement plan for competition and land degradation by rabbits;
- Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis;
- Threat abatement plan for predation by European red fox;
- Threat abatement plan for predation by feral cats; and
- Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs

Any approved threat abatement plans or advice associated with these items provides information to help landowners manage these threats and reduce their impacts to biodiversity. These can be found at http://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl.

4 EXISTING PROTECTION

4.1 Existing protection in reserves

The majority of the remaining area of the ecological community occurs on freehold tenure (492 ha). About 387 ha of the ecological community is known to be reserved (Butcher et al. 2011b; DELWP 2017a), including approximately 335 ha in South Australia (Clarke Park, Ewens Ponds, Piccaninnie Ponds Ramsar Wetland and Pick Swamp) and 52 ha in Victoria (Lake Mombeong/Momboeng/Moniboeng) representing 42% of the estimated remaining extent and

[14] The threat abatement plan for beak and feather disease affecting endangered psittacine species ceased on 1 October 2015. A non-statutory threat abatement advice is being developed.

less than 17% of the original (pre-1750) extent. Many of the threats identified in Table 4 operate regardless of land tenure.

4.2 Existing protection under national law

Ramsar sites under the Convention on Wetlands of International Importance are protected as a matter of national environmental significance under the *EPBC Act* 1999. Approximately 374 ha (41%) of the known Karst springs and alkaline fens occur within the following Ramsar sites:

Piccaninnie Ponds Karst Wetlands
- Piccaninnie Ponds
- Pick Swamp

Glenelg Estuary and Discovery Bay
- Lake Mombeong/Momboeng/Moniboeng

Australia is party to International and bilateral agreements, initiatives and conventions for the conservation of migratory birds which are administered under the EPBC Act. The agreements and conventions relevant to migratory birds within the Karst springs and alkaline fens are:

- The Bonn Convention on Migratory Species (CMS) - The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For this ecological community, this includes several migratory birds;
- China-Australia Migratory Bird Agreement (CAMBA) - The Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment 1986;
- Japan-Australia Migratory Bird Agreement (JAMBA) – The agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment, 1974; and
- Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) - The Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment, 2006.

4.3 Existing protection under state laws

South Australia

There are no provisions under the South Australia *National Parks and Wildlife Act 1972* or *Native Vegetation Act 1991* to list ecological communities as threatened entities. However, the Karst springs and alkaline fens located at Ewens Ponds and Piccaninnie Ponds Conservation Parks are protected under the south Australian *National Parks and Wildlife Act 1972*.

Threatened vegetation associations identified on the provisional list of threatened ecosystems (section 8.2) and in association with wetlands may be considered for protection on a case by case basis under the *Native Vegetation Act 1991* and the associated *Native Vegetation Regulations 2003*.

Other South Australian legislation that may apply to the management of Karst springs and alkaline fens or its component species include:

- The *Aboriginal Heritage Act 1988* provides for the protection and management of Aboriginal heritage in South Australia;
- The *Coast Protection Act 1972* enables some management of coastal erosion, pollution and development;

- The *Environment Protection Act 1993* enables noise, water and pollution standards to be set;
- The *Groundwater (Border Agreement) Act 1985* sets groundwater allocation and aquifer levels 20 kilometres either side of the South Australian and Victorian border.
- The *Landscape South Australia Act 2019* and *Landscape South Australia (Transitional Provisions) Regulations 2019* manages soil, water, pest plants and animals and biodiversity;
- The *Natural Resources Management Act 2004* provides for the protection and management of catchments and the sustainable use and restoration of water resources; and
- The *South Eastern Water Conservation and Drainage Act 1992* enables the conservation and management of water, the prevention of flooding of rural land, development of natural wetlands, watercourses and the natural environment in the South East of South Australia.

Victoria

Threatened ecological communities are listed under the *Flora and Fauna Guarantee Act 1988* and regulated under the *Fauna Guarantee Regulations 2011*. However, there are no Victorian ecological communities that partially or wholly correspond to the Karst springs and alkaline fens.

At least one occurrence of Karst springs and alkaline fens, Lake Mombeong/Momboeng/Moniboeng, occurs in the Discovery Bay Coastal Park. All National, State and Coastal parks in Victoria are managed under the *National Parks Act 1975*.

Other Victorian legislation that may apply to the management of Victorian occurrences of Karst springs and alkaline fens or its component species include:

- The *Aboriginal Heritage Act 2006* provides for the protection and management of Aboriginal heritage within Victoria;
- The *Catchment and Land Protection Act 1994* provides a framework for the integrated management and protection of catchments. It establishes processes to encourage and support community participation in the management of land and water resources and provides for control of noxious weeds and pest animals;
- The *Crown Land (Reserves) Act 1978* provides a framework for the administration and management of Crown land reserves including nature conservation reserves;
- The *Environment Protection Act 1970* and the *Environment Protection Act 2017* enables noise, water and pollution standards to be set for inland waters;
- The *Fisheries Act 1995* provides for the regulation, management and conservation of Victorian fisheries, declared noxious aquatic species and fisheries reserves;
- The *Water Act 1989* establishes rights and obligations in relation to water resources and provides mechanisms for the allocation of water resources. This includes the consideration of environmental water needs of rivers and wetlands as well as for human uses such as urban water supply and irrigation; and
- The *Wildlife Act 1975* provides for the conservation of any taxa of wildlife and prevention from extinction. Regulations under the Act considers whether the consumptive use or other interactions with flora and fauna in Victoria threatens the sustainability of wild populations, while facilitating cultural and recreational pursuits.

The protection measures referred to here were valid at the time of writing (May 2020). It is advisable to check with relevant government agencies (notably the relevant state and local councils) for any updated information.

4.4 Existing management plans

Management plans relevant to this ecological community at this time (May 2020) exist in the form of recovery plans for some threatened species within the community, threat abatement plans for threats acting upon this community, regional natural resource management plans, conservation plans and plans of management for National Parks estate and Ramsar wetlands that include areas of Karst spring and alkaline fens, as well as local planning documents. These include:

- Bachmann MR (2002) Silky Tea-tree and Cutting Grass Wetland Rehabilitation Project 1999-2002. Nature Conservation Society of South Australia, Adelaide.
- Bachmann MR, Dickson CR and Sweeney O (2015) Karst Rising Springs Wetland Community Regional Action Plan in the South East of South Australia: 2015-2015. Report to the Department of Environment, Water and Natural Resources, Government of South Australia. Nature Glenelg Trust, Mount Gambier, South Australia.
- Butcher R, Hale J and Cottingham P (2011a) Ecological character description for Piccaninnie Ponds Karst Wetlands. Prepared for the Department of Environment, Water and Natural Resources.
- Butcher RJ, Cottingham P, Hale J, Philips B and Muller K (2011b) Ramsar Management Plan for Piccaninnie Ponds Karst Wetlands.
- Caton B, Quinn J, Detmar S, Fotheringham D, Rubbo N, Royal M, Sandercock R and Laurence S (2011) Limestone Coast and Coorong Coastal Action Plan and Conservation Priority Study. South East NRM Board and Department of Environment and Natural Resources, Adelaide.
- Clemann N and Gillespie GR (2012) National Recovery Plan for the Southern Bell Frog *Litoria raniformis*. Department of Sustainability and Environment, Melbourne.
- Coleborn K (2018) The impact of fire on two contrasting caves in New South Wales ACKMA cave and karst management in Australasia XXII. Proceedings of the 22nd Australasian conference on cave and karst management. Margaret River, Western Australia.
- DEWLP (2017a) Ecological Character Description for Glenelg Estuary and Discovery Bay Ramsar Site. Department of Environment, Land, Water and Planning, East Melbourne, Victoria.
- DEWLP (2017c) Glenelg Estuary and Discovery Bay Ramsar Site Management Plan. Department of Environment, Land, Water and Planning, East Melbourne, Victoria.
- DEE (2016) Threat abatement plan for competition and land degradation by rabbits. Department of the Environment and Energy, Canberra.
  Available on the Internet at:
  http://www.environment.gov.au/biodiversity/threatened/publications/tap/competition-and-land-degradation-rabbits-2016
- DEWHA (2008). Threat abatement plan for competition and land degradation by unmanaged goats. Department of the Environment, Water, Heritage and the Arts, Canberra.
  Available on the Internet at:

http://www.environment.gov.au/biodiversity/threatened/publications/tap/competition-and-land-degradation-unmanaged-goats

- DotE (Department of the Environment) (2018) Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* – 2018
  Available on the Internet at:
  http://www.environment.gov.au/biodiversity/threatened/publications/threat-abatement-plan-disease-natural-ecosystems-caused-phytophthora-cinnamomi-2018
- DEE (Department of the Environment and Energy) (2016) Infection of amphibians with chytrid fungus resulting in chytridiomycosis (2016)
  Available on the Internet at:
  http://www.environment.gov.au/biodiversity/threatened/publications/tap/infection-amphibians-chytrid-fungus-resulting-chytridiomycosis-2016
- DEWHA (Department of the Environment, Water, Heritage and the Arts) (2008) Threat Abatement Plan for predation by the European red fox. Canberra.
  Available on the internet at:
  http://www.environment.gov.au/biodiversity/threatened/publications/tap/predation-european-red-fox
- DotE (Department of the Environment) (2015) Threat abatement plan for predation by feral cats. Canberra.
  Available on the Internet at:
  http://www.environment.gov.au/biodiversity/threatened/publications/tap/threat-abatement-plan-feral-cats
- DEE (Department of the Environment and Energy) (2017) Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*). Canberra.
  Available on the Internet at:
  http://www.environment.gov.au/biodiversity/threatened/publications/tap/feral-pig-2017
- Dickson CR, Anderson RA, Murphy A, Pritchard A and Craig A (2012) Recovery Plan for three orchid species in South Australia and Victoria: *Caladenia richardsiorum* (Little Dip Spider-orchid), *Caladenia calcicola* (Limestone Spider-orchid) and *Pterostylis tenuissima* (Swamp Greenhood). Department of Environment, Water and Natural Resources, South Australia, South East Region & Department of Sustainability and Environment, Victoria, South West Victoria Region.
- DSE (2003) Brolga *Grus rubicunda* Action statement 119. Flora and Fauna Guarantee Act 1988. Department of Sustainability and Environment.
- Duncan M (2010) National Recovery Plan for the Maroon Leek Orchid *Prasophyllum frenchii*. Department of Sustainability and Environment, Melbourne.
- Eberhard S and Hamilton-Smith E (1997) Conservation of cave fauna in Australia. Proceedings of the 12th cave and karst management conference. Cave and karst management in Australasia 12. Waitomo, New Zealand.
- Ecological Associates (2009) Estimation of Water Requirements of Wetlands in the South East of South Australia. Department of Water, Land and Biodiversity Conservation, Adelaide, South Australia.
- Hammer M, Wedderburn S and van Weenaen J (2009) Action plan for South Australian freshwater fishes. Native Fish Australia (SA) Inc. Department for the Environment and Heritage, South Australia.

- Parks Victoria (2015) Ngootyoong Gunditj Ngootyoong Mara South West Management Plan. Portland, Victoria.
  Available on the Internet at:
  https://www.parks.vic.gov.au/places-to-see/parks/discovery-bay-coastal-park
- Rigosi A, Liu Y, Shanafield M and Brookes JD (2015) Determining environmental risks to Ewens Ponds in the South East. Goyder Institute for Water Research Technical Report Series No. 15/19. Adelaide, South Australia.
- Saddlier S and Hammer M (2010) National Recovery Plan for the Variegated Pygmy Perch Nannoperca variegata. Department of Sustainability and Environment, Melbourne.
- Saddlier S and Hammer M (2010) National Recovery Plan for the Yarra Pygmy Perch *Nannoperca obscura*. Department of Sustainability and Environment, Melbourne.
- Shanafield M, Rigosi A, Liu Y and Brookes J (2020) The interaction of flow regimes and nutrient fluxes on the water quality and ecosystem health of a clear, freshwater wetland. Ecology and Society 25(2): 6.
- South East Natural Resources Management Board (2019) Water allocation plan for the Lower Limestone Coast prescribed wells area.
  Available on the internet at:
  http://www.naturalresources.sa.gov.au/southeast/water-and-coast/water-allocation-plans/lower-limestone-coast
- South East Natural Resources Management Board and South Eastern Water Conservation and Drainage Board (2019) South East drainage and wetland strategy.
  Available on the internet at:
  https://www.natural resources.sa.gov.au/southeast/water-and-coast/drainage_wetlands_strategy

5 CONSERVATION OF THE ECOLOGICAL COMMUNITY

5.1 Identification of the ecological community

The Karst springs and alkaline fens intergrades with other ecological communities. Key diagnostic characteristics are used to identify an area as being the Karst springs and alkaline fens, and define the features that distinguish it from other communities, noting that additional information to assist with identification is provided in the other sections of this document, particularly the description (section 2.1) and Appendix A - Species lists.

5.1.1 Key diagnostics

The key diagnostic characteristics are designed to allow identification of the ecological community irrespective of the season.

Areas that do not meet the key diagnostics are not the nationally listed ecological community.

The ecological community is defined as areas meeting the description in section 2.1 that also meet the following key diagnostic characteristics:

Location

The ecological community occurs in the Gambier Karst Province within the Bridgewater subregion of the Naracoorte Coastal Plain IBRA Bioregion and is likely to occur at ≤ 25m in elevation.

Hydrology

The ecological community is associated with a range of wetland types that are inundated on a permanent to semi-permanent basis depending on their hydrological connection to the unconfined Tertiary limestone aquifer (TLA). This includes bodies of open water such as spring pools, shallow fens/swamps and outflow channels (excluding the Glenelg River).

The ecological community's hydrological regime is predominantly groundwater fed. Its main groundwater source is from the TLA which includes the Green Point Member, Camelback Member and Greenways Member. Groundwater from limestone aquifers is neutral to alkaline. The permanent freshwater discharge feature (e.g. pool/spring/soak/seep) must be associated with the TLA to be considered part of the ecological community.

Salinity

Water salinity is typically fresh[15], less than 1000 µS/cm but may range up to 3000 µS/cm due to seasonal influences and may periodically rise to 5000 µS/cm in some occurrences e.g. during drought or as a result of tidal influences. Any occurrences consistently ≥ 5000 µS/cm is considered too saline to be part of the ecological community.

Soil/substrate

Typically silt/loam/peat with some sites containing calcareous rock, sand or shell overlying permeable Tertiary limestone bedrock.

The alkaline hydrological inputs support the formation and retention of peat. Typically peat[16] depth is a function of the persistence of the overlying vegetation and permanent alkaline freshwater inputs.

Biological assemblages

Generally contains species associated with neutral to alkaline freshwater, including species that require freshwater at some stage to complete their life cycle. The assemblages of species present may vary with the landscape position, season, hydrological regime and water quality. A complex of vegetation types may occur that varies with degree of inundation, including one or more of the following:

- Floating aquatic vegetation on open water (e.g. Azolla);
- Submergent aquatic vegetation (e.g. milfoil and ribbon weed);
- Emergent vegetation and peat fens (e.g. rushes, reeds, sedges, shrubs) which typically include one or more of the following vegetation types:
    - Aquatic grassland, herbland, sedgeland, reedland, notably
        - Calcareous Wet Herbland
        - Freshwater open aquatic herbland
        - *Gahnia trifida* tussock sedgeland

[15] Salinity refers to total salt concentration and is described using electrical conductivity and measured in microseimens per centimetre (µS/cm). Freshwater is defined as being under 3 000 µS/cm; brackish is defined as between 3 000 and 10 000 µS/cm.

[16] Peat presence may be limited on some sites due to hydrological conditions, fen age, and/or whether peat layers have been removed, burnt or subsided.

    - Typha/Phragmites tall aquatic grassland
- Shrublands fringing the wetlands, notably
    - *Leptospermum lanigerum* tall wet shrubland (SA); Swamp Scrub (Victoria)
    - *Melaleuca squarrosa* wet heathland

Flora species from all these vegetation types are part of the ecological community. Historically, *Leptospermum lanigerum* (Silky Tea-tree/Woolly Tea-tree/Punung/Wiriyu) was a characteristic species of the fringing vegetation and remains so at many sites. *Gahnia trifida* (Cutting Grass) is also characteristic at many sites. Other characteristic or commonly present flora species are outlined in Appendix A.

Where fringing vegetation is not hydrologically dependant on the Tertiary limestone aquifer, at least intermittently, it is not part of the ecological community.

The complex of vegetation types within the ecological community provides habitat for numerous fauna notably small mammals, reptiles, aquatic invertebrates, fish and various birds, including waterbirds. The latter includes migratory species such as sandpipers and terns and colonially-breeding species such as egrets, ibis, cormorants, herons, spoonbills and ducks.

While most fauna are not diagnostic for the ecological community, characteristic animal species that are indicative of higher condition areas are outlined in the condition thresholds. Other characteristic fauna species commonly present are outlined in Appendix A.

5.1.2 Additional information to assist in identifying the ecological community

The following information should also be taken into consideration when applying the key diagnostic characteristics to assess if a site may include the ecological community. Landuse and disturbance history, particularly drainage and fire history, will influence the state in which an occurrence of the ecological community is currently expressed.

5.1.2.1 IDENTIFYING AN OCCURRENCE

An occurrence is a discrete and mostly continuous area of the ecological community, as defined by the key diagnostics, but can include small-scale variations, gaps and disturbances within this area. Where a wetland area has been classified as a different wetland type, i.e. has minimal interaction with groundwater or is predominantly surface water fed, such as a dune slack wetland system, it is not considered part of the ecological community.

5.1.2.2 REVEGETATION AND REGROWTH

Revegetated or replanted sites or areas of regrowth are not excluded from the listed ecological community so long as the occurrence meets the key diagnostic characteristics.

5.1.2.3 SURVEY REQUIREMENTS

Occurrences of the ecological community can vary markedly in their shape, size, condition and features. Thorough and representative on-ground surveys are essential to accurately assess the extent and condition of an occurrence (see Section 5.2 for condition classes and categories). The Index of Wetland Condition assessment procedure (DELWP 2018b) and the Index of Wetland Condition – assessment of wetland vegetation (DELWP 2018c), evaluations by Ecological Associates (2009), Deane et al. (2015), Frood and Papas (2016) and Gehrig et al. (2015) provide guidance.

The size, number and spatial distribution of surveys, plots or transects to identify flora and fauna components and vegetation condition must be adequate to represent variation across an occurrence. Sampling should address likely variation in species composition and significant

variation in the vegetation (including areas of different condition), landscape qualities and management history (where known) across the occurrence.

Recording the search effort (identifying the number of person hours spent per plot/transect and across the entire occurrence; along with the surveyor's level of expertise and limitations at the time of survey) is useful for future reference.

Whilst identifying the ecological community and its condition is possible at most times of the year, consideration must be given to the role that season, rainfall and disturbance history may play in an assessment. For example, after a drought or fire or storm one or more vegetation zones, or groups of species (e.g. macrophytes), may not be evident for a time. Timing of surveys should allow for a reasonable interval after a disturbance (natural or human-induced) to allow for regeneration of species to become evident and be timed to enable diagnostic species to be identified. At a minimum, it is important to note climate conditions and what kind of disturbance may have happened within an occurrence, and when that disturbance occurred.

5.1.2.4 OTHER NEARBY LISTED ECOLOGICAL COMMUNITIES

Other terrestrial nationally listed threatened ecological communities occur in the same bioregion as the Karst springs and alkaline fens. Table 6 outlines these ecological communities and their status at the time of listing.

Table 6. Nationally listed threatened ecological communities

EPBC-listed ecological community	Status	Likelihood of close occurrence
Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains	Critically endangered	Unlikely
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Likely

5.2 Regulated areas of the ecological community

National listing focuses legal protection on occurrences or areas of the ecological community that are the most functional, relatively natural and in comparatively good condition. These occurrences or areas are identified through certain condition and size requirements.

Condition classes and categories are used to distinguish between areas of the ecological community of different qualities, to aid environmental management decisions.

In order to be protected as a matter of national environmental significance areas of the ecological community must meet both:

- the key diagnostic characteristics (section 5.1.1) AND
- high quality (Class A), good quality (Class B) and moderate quality (Class C) condition requirements (section 5.2.1).

Table 7 outlines the different condition classes, categories and thresholds that apply to the ecological community. These are designed to assist with management and identify those occurrences that retain sufficient conservation values to be considered a matter of national environmental significance, to which the referral, assessment, approval and compliance provisions of the EPBC Act apply.

Occurrences or areas of the ecological community that do not at least meet Class C (that do not meet the minimum condition thresholds) are excluded from protection under national environment law. In many cases, the loss and degradation are irreversible because natural characteristics have been permanently removed. However, although not protected under

national environment law, many of these occurrences or areas may still retain important natural values and may be protected through state and local laws or planning schemes.

In addition, occurrences or areas that do not meet condition Class C but can be restored should not be excluded from recovery and other management actions. Suitable recovery and management actions may improve a wetland's condition, such that it subsequently can be included as part of the ecological community fully protected under the EPBC Act. Management actions should be designed to restore wetlands to high quality condition where practical.

When assessing condition of an occurrence of the ecological community it is important to also consider the key diagnostics (section 5.1.1) and other definition information (section 0).

5.2.1 Condition classes, categories and thresholds

The Index of Wetland Condition assessment procedure (DELWP 2018b) and the Index of Wetland Condition – assessment of wetland vegetation (DELWP 2018c) provide a framework for assessing the condition of ecological communities in Victoria. Evaluations by Ecological Associates (2009), Deane et al. (2015), Gehrig et al. (2015) provide a framework for assessing the condition of ecological communities in South Australia. These frameworks provide the basis of the condition classes, categories and thresholds that apply to this ecological community.

Table 7. Condition classes, categories and thresholds

Condition class	**Site components**	**Minimum occurrence size**
Class A – high quality	Sites with 6 or more site components rated as Category 3	10 ha
Class B –good quality	Sites with 4 or more site components rated as Category 2 or 3	0.5 ha
Class C – moderate quality	Sites with 2 or more site components rated as Category 2 or 3	0.1 ha

Site components	**Category 1**	**Category 2**	**Category 3**
Pool depth	≥ 0.1 m	≥ 1 m	≥ 6 m
Spring flow[1]	Seasonal low	Permanent moderate	Permanent high
Nutrient[1]	High	Moderate	Low
Aquatic native macrophyte[2] % cover of all standing water[3]	≥ 5%	≥ 20%	≥ 50%
Fringing shrub canopy[4] cover %	≥ 5%	≥ 10%	≥ 50%
Woody and herbaceous weed – exotic[5] cover %	≤ 70%	≤ 50%	≤ 5%
Grassy weed – exotic[5] cover %	≤ 70%	≤ 50%	≤ 5%
Groundwater interaction (pool) [6]	Depth to groundwater <1m below ground surface and at or above	Depth to groundwater permanently at ground surface and above surface seasonally.	Depth to groundwater permanently above ground surface

	ground level seasonally (seasonal discharge)	(permanently damp, with seasonal discharge)	(permanently discharging)
Characteristic and indicative fauna species[7]	< 3	≥ 3	≥ 9

Notes:
[1] For guidance on flow and nutrients see Ecological Associates (2009), Butcher et al. 2011a, Rigosi et al. 2015 and Shanafield et al. 2020.
[2] Exclude areas with reeds, sedges and other emergent flora, and where depth exceeds 6 m.
[3] Standing water - Macrophyte cover and attached filamentous algae (phytoplankton) cover can vary rapidly. Declines in condition can be indicated by low macrophyte cover and this is typically associated with high attached filamentous algae (Phytoplankton) cover over multiple seasons.
[4] Canopy is measured as the % of the sample site occupied by the vertical projection of foliage and woody branches (as per the National Committee on Soil and Terrain 2009). Excludes open water zone.
[5] Exotics are measured as projective canopy cover of all non-indigenous species.
[6] Groundwater should be measured from the pool centre twice a year i.e. Spring (high flow) and Autumn (lower flow).
[7] See 5.1.1 (Biological assemblages). Animal species that are indicative of higher condition include: *Antechinus minimus maritimus* (Swamp Antechinus), *Antigone rubicunda* (Brolga), *Botaurus poiciloptilus* (Australasian Bittern), *Euastacus bispinosus* (Glenelg Spiny Freshwater Crayfish), *Eulamprus tympanum* (Southern Water Skink), *Galaxiella pusilla* (Dwarf Galaxias), *Gallinago hardwickii* (Latham's Snipe), *Hesperilla chrysotricha chrysotricha* (Golden-Haired Sedge-Skipper), *Hesperilla donnysa* (Varied Sedge-Skipper), *Hesperilla idothea* (Flame Sedge-Skipper), *Litoria raniformis* (Growling Grass Frog), *Nannoperca australis* (Southern Pygmy Perch), and *Rattus lutreolus* (Swamp Rat). Many of these fauna species are threatened at the state and/or national level and need to be considered in their own right (Table A3 in Appendix A).

5.2.2 Areas critical to the survival of the ecological community

The habitat or areas most critical to the survival of the ecological community are those occurrences that are in the best condition (i.e. Class A and Class B in Table 7), or those occurrences that retain high macrophyte cover, high fringing shrubland cover and permanent high aquifer flow rates. These represent those parts of the ecological community closest to the benchmark state of the ecological community; they are the occurrences that retain the highest diversity and most intact structure and ecological function, and have the highest chance of persisting in the long-term.

However, this does not mean that areas that otherwise meet the moderate condition requirements (i.e. Class C in Table 7) are unimportant for the survival of the ecological community. Many of these occurrences occur in locations or landscape positions that are particularly important for biodiversity or function and/or may contain suites of species or habitat features that are important in a regional or local context. Hence these areas can still be critical to the survival of the ecological community.

5.2.3 Areas of high value - surrounding environment and landscape context

The surrounding vegetation and other landscape considerations will influence how important a patch is to the ecological community as a whole. Occurrences that are larger and less disturbed are likely to provide greater biodiversity value. Occurrences that are spatially linked, whether hydrologically, ecologically or by proximity, are particularly important as wildlife habitat and to the viability of those occurrences of the ecological community into the future. However, this still does not necessarily consider the full landscape context. For natural resource management activities or actions that may have 'significant impacts' and require approval under national environment law, it is important to consider the whole environment surrounding occurrences of the ecological community.

For example, in heavily drained and cleared areas, some occurrences that meet the minimum condition requirements for medium (Class B) or low quality (Class C) occur in isolation. Such occurrences require protection and could benefit from revegetation and hydrological restoration activities to link them with other occurrences. In other areas, occurrences that are interconnected to other native vegetation may not, in their current state, meet the minimum condition requirements for moderate quality, but have high conservation value. Such occurrences could benefit from restoration works to improve their condition so that they do meet higher condition requirements.

The ecological community often occurs in association with other native vegetation types. Occurrences of the ecological community that remain connected with other native vegetation have a better chance of future survival and restoration success, because connected wetlands are buffered from disturbance by the surrounding native vegetation.

The following indicators of high-value should be considered when assessing the impacts of proposed actions under the EPBC Act, or when determining priorities for protection, recovery, management and funding.

- Occurrences that meet or are closest to the high quality (Class A) condition for this ecological community. These may be based on on-site observations or known past management history.
- Occurrences with a larger area to boundary ratio – such occurrences are more resilient to edge effect disturbances such as weed invasion and human impacts.
- Occurrences within or near to a larger native vegetation remnant. Other occurrences are important as linkages among remnants, acting as ‘stepping stones’ of native remnants in the landscape. Connectivity includes actual or potential connectivity to restoration works (e.g. native plantings).
- Occurrences that occur in areas where the ecological community has been most heavily drained, cleared and degraded, or that are at the natural edge of its range, particularly where there is genetic distinction, or absence of some threats. These may include unique variants of the ecological community, e.g. with a unique flora and/or fauna composition, or an occurrence that contains flora or fauna that have largely declined across the broader ecological community or region.
- Occurrences that show evidence of recruitment of key native plant species or the presence of a range of age cohorts (including through successful assisted regeneration or management of sites). It is acknowledged, however, that the recruitment of many species, may not occur in this community unless hydrological regimes are restored.
- Occurrences with good faunal habitat as indicated by diversity of landscape, diversity of plant species and vegetation structure, presence of movement corridors etc.
- Occurrences containing nationally or state-listed threatened species.
- Occurrences with high species richness, as shown by the variety of native plant species or native fauna species (vertebrates and/or invertebrates).
- Occurrences with relatively low levels of weeds and feral animals or areas where these can be managed efficiently.

5.3 Principles and standards for conservation

To undertake priority actions to meet the conservation objective, the overarching principle is that it is preferable to maintain existing areas of the ecological community that are relatively intact and of high quality. There are good, practical reasons to do so. It is typically more cost-effective

to retain an intact remnant than to allow degradation and then attempt to restore it or another area. The more disturbed and modified an occurrence of the ecological community, the greater the recovery effort that is required. Also, intact remnants are likely to retain a fuller suite of native plant and animal species, and ecological functions. Certain species may not be easy to recover in practice, if lost from a site.

This principle is highlighted in the *National Standards for the Practice of Ecological Restoration in Australia* (Standards Reference Group SERA, 2017):

> *"**Ecological restoration is not a substitute for sustainably managing and protecting ecosystems in the first instance.***
>
> *The promise of restoration cannot be invoked as a justification for destroying or damaging existing ecosystems because functional natural ecosystems are not transportable or easily rebuilt once damaged and the success of ecological restoration cannot be assured. Many projects that aspire to restoration fall short of reinstating reference ecosystem attributes for a range of reasons including scale and degree of damage and technical, ecological and resource limitations."*
>
> *Standards Reference Group SERA (2017) – Appendix 2.*

The principle discourages 'offsets' where intact remnants are removed with an undertaking to set aside and/or restore other, lesser quality, sites. The destruction of intact sites represents a net loss of the functional ecological community because there is no guarantee all the species and ecological functions of the intact site can be replicated elsewhere.

Where restoration is to be undertaken, it should be planned and implemented with reference to the *National Standards for the Practice of Ecological Restoration in Australia*. These Standards guide how ecological restoration actions should be undertaken and are available online from the Standards Reference Group SERA (2017)[17]. They outline the principles that convey the main ecological, biological, technical, social and ethical underpinnings of ecological restoration practice.

As restoration ecology is continually developing, it is important to reflect on the experience of others who have worked on restoring the ecological community, or other wetland communities, as well as adapting restoration projects as site-level experience accumulates. The knowledge and practices of traditional owners should also be acknowledged and considered.

Wherever possible, restoration activities should aim for the best possible outcome with a clear goal of increasing the number of Category ratings to shift the degraded state towards a restored objective such as a 4-star or higher outcome (Standards Reference Group SERA (2017).

To achieve cost-effective investments in conservation management it is important to consider the likely interaction of the various management actions being undertaken at any one site, as these may be synergistic or antagonistic. There are also likely to be interactions between sites. Additionally, when allocating management resources, it is important to consider what is the minimum investment required for success and the follow-up required to secure long-term recovery (for example, for how many years should weed or fire management be repeated).

5.4 Priority conservation and research actions

Priority actions are recommended for the abatement of threats and supporting recovery of the ecological community. They are designed to provide guidance for:

[17] Society for Ecological Restoration: www.seraustralasia.com/standards/contents.html

- planning, management and restoration of the ecological community by landholders, NRM and community groups and other land managers;
- conditions of approval for relevant controlled actions under the EPBC Act; and
- prioritising activities in applications for Australian Government funding programs.

Detailed advice on actions may be available in specific plans, such as management plans for hydrology, weeds, fire or certain parks or regions. The most relevant at the time of this conservation advice was first developed are in section 4.4.

This conservation advice identifies priority conservation actions under the following key approaches:

- PROTECT the ecological community to prevent further losses;
- RESTORE the ecological community by active abatement of threats, appropriate management, restoration and other conservation initiatives;
- COMMUNICATE, ENGAGE WITH AND SUPPORT people to increase understanding of the value and function of the ecological community and encourage their efforts in its protection and recovery; and
- RESEARCH AND MONITORING to improve our understanding of the ecological community and the best methods to aid its management and recovery.

These approaches overlap in practice; and form part of an iterative approach to management that includes research, planning, management, monitoring and review.

The actions below do not necessarily encompass all actions in detail that may benefit the ecological community. They highlight general but key actions required to at least maintain survival of the ecological community at the time of preparing this Conservation Advice.

5.4.1 PROTECT the ecological community

This key approach includes priorities intended to protect the ecological community by preventing further losses to extent and integrity.

5.4.1.1 CONSERVE REMAINING OCCURRENCES

There should be no further clearance and damage to this ecological community because it has been greatly reduced in its extent.

- Remnants should be properly taken into account during the early stages of zoning, environmental water planning and development planning decisions, including strategic planning documents at state, regional and local levels.
- Protect and conserve remaining occurrences of the ecological community, including protecting potential areas of natural or managed regeneration (e.g. former fen areas that can be restored).
- Avoid hydrological changes that disrupt natural patterns of inundation, overland flows and water table levels, or that increase salinity, nutrient loads, algal blooms, sedimentation/turbidity, peat subsidence or pollution.
- Protect occurrences identified as the most intact wildlife refuges or of regional importance in formal conservation reserves. Consider other remnants for less formal conservation tenures, preferably ones that aim for protection over the long-term. This includes investigating formal conservation arrangements, management agreements and covenants to protect occurrences on private land. This is particularly important for larger occurrences or areas that link to other patches of native vegetation and are part of wildlife corridors or migration routes.

- Where regrowth is occurring, provide measures that will support regrowth to maturity (e.g. provide fencing around rather than through wetlands to minimise damage risk).
- Retain other native vegetation remnants, near occurrences of the ecological community, where they are important for connectivity, diversity of habitat and act as buffer zones between the ecological community and threats or intensive land use zones.
- Retain habitat features for fauna and flora, noting species requirements or particular vegetation structure. For example, a continuous canopy or sub canopy, particularly of *Leptospermum lanigerum* is important for threatened species such as *Antechinus minimus maritimus* (Swamp Antechinus) and *Pterostylis tenuissima* (Swamp Greenhood). Ensure that hydrological restoration and revegetation activities are coordinated and occur in the right chronological order to enable complementary and well targeted outcomes to be achieved.

5.4.1.2 Planning to minimise hydrological impacts, drainage and further clearing

- Liaise with local councils, state authorities and environmental water holders, to ensure that cumulative impacts on the ecological community are reduced as part of broader strategic planning, environmental water planning or large projects (e.g. drainage maintenance, weirs, bridges, road works, developments, changes in land use, groundwater allocation).
- Liaise with planning authorities to promote the inclusion of Karst springs and alkaline fens protection and projected tidal inundation zones in their plans/responses to climate change, sea-level rise, coastal erosion and in coastal zone management generally.

5.4.1.3 Manage actions to minimise impacts

Apply the mitigation hierarchy to avoid, then mitigate, then offset potential impacts on the ecological community from development or other actions. The priority is to avoid detrimental hydrological changes and further clearance and fragmentation of remnants.

- Plan projects to avoid the need to offset, by avoiding significant impacts to the ecological community. This includes minimising the risk of indirect impacts from actions outside but near to occurrences of the ecological community.
- In circumstances where impacts cannot be totally avoided, then they should be minimised by:
    - retaining and avoiding damage to good or high quality occurrences, which should be managed to retain or improve their condition;
    - protecting groundwater quality and levels;
    - protecting important habitat features, such as dense *Leptospermum lanigerum* shrubland as these take many years to develop and cannot be quickly replaced; and
    - protecting other important habitat for threatened and/or declining species, such as orchids, fish and arthropods e.g. butterflies, which require particular hydrological regimes, light conditions or food plants.
- Avoid activities that could cause significant hydrological change to occurrences of the ecological community:
    - Avoid constructing or managing levees, culverts, floodgates etc that will lead to permanent detrimental hydrological restrictions to occurrences of the ecological community, or that will otherwise adversely alter existing inundation regimes.

- Avoid constructing outlets/drains that detrimentally alter the saturation of peat layers in or near occurrences of the ecological community.
- Avoid building roads, causeways, weirs, bridges and other structures in a way that alters the natural hydrology.

- Ensure that fire management activities (such as creating any necessary new fire access tracks) do not have detrimental impacts on fire-sensitive species and the integrity of the ecological community. For further information on fire management see Section 5.4.2.5.

5.4.1.4 Apply buffer zones

- Protect and apply appropriate buffers, particularly of other native vegetation, around occurrences of the ecological community to minimise off-site impacts. A buffer zone is a contiguous area adjacent to an occurrence that is not part of the ecological community but is important for protecting its integrity. As the risk of indirect damage to an ecological community is usually greater where actions occur close to an occurrence, the purpose of the buffer zone is to minimise this risk by guiding land managers to be aware that the ecological community is nearby and take extra care. For instance, the buffer zone will help protect the ecological community from spray drift (fertiliser, pesticide or herbicide sprayed in adjacent land), weed invasion, polluted water runoff and other damage. The best buffer zones are typically comprised of intact remnants of other native vegetation. Fire breaks and other asset protection zones do not typically provide a suitable buffer and should be additional to a vegetated buffer.
- The recommended buffer zone is 1220 m from the outer edge of the open water component of the occurrence or from the centre of small occurrences as this distance accounts for likely influences upon the broader hydrology. A larger buffer zone should be applied, as practical, to protect occurrences that are of very high conservation value or where detrimental hydrological impacts to the unconfined aquifer are likely (See SENRMB 2019).

5.4.1.5 Prevent the introduction and spread of exotic species

- Prevent planting of known or potentially invasive species in gardens, developments and landscaping near the ecological community (DotE 2010).
- Prevent dumping of garden waste into bushland, especially in or near occurrences of the ecological community.
- Avoid the sale and planting of potentially invasive species as garden plants in areas where the ecological community occurs.
- Control runoff, for example, during and after road construction, and urban development, to prevent movement of weeds and pathogens into natural areas.
- Review the planting schedule for new developments and landscaping to ensure that potential weeds or other inappropriate plants (e.g. native plants likely to contaminate the local gene pool) are not included.
- When conducting activities in or around the ecological community, practice good biosecurity hygiene to avoid spreading weeds or pathogens (DotE 2015).
- Minimise unnecessary soil disturbance that may facilitate weed establishment. Where soil disturbance occurs within the buffer zone e.g. construction of new roads, undertake follow-up weed control for at least 3 years.
- If new incursions do occur, detect and control them early, as small infestations are more likely to be eradicated. This applies to weeds already present in the bioregion but new to a site, for example, spread of Tall Fescue (*Festuca arundinacea*). It also applies to

weeds not yet present within the bioregion but likely to become an environmental problem if introduced.

- Limit or prevent access of grazing animals and vehicles to occurrences of the ecological community (e.g. construct fences and gates) where practicable. Provide advice and support to landholders to assist with this.
- Prevent further incursions of feral animals into the ecological community and, where possible, contain stock and pets in nearby residential and agricultural areas.

5.4.2 RESTORE and MANAGE the ecological community

This key approach includes priorities to restore and maintain the remaining occurrences of the ecological community by active abatement of threats, appropriate management, restoration and other conservation initiatives. Restoration actions should be based on the best available knowledge and scientific research to maximise positive biodiversity outcomes.

Because of the limited extent and remnant nature of this ecological community, some occurrences cannot be considered to be viable in the long term without active management. The majority of stands of closed *Leptospermum lanigerum* shrubland (fens) are remnant, but with appropriate management and protection, regrowth areas can develop into dense thickets in the future.

This key approach includes priorities to restore and maintain the remaining occurrences of the ecological community by active abatement of threats, appropriate management, restoration and other conservation initiates.

- Liaise with landholders and undertake and promote programs that restore the ecological community and ameliorate threats such as drainage, clearance, grazing, degrading water quality and other human disturbance.
- Identify and prioritise areas where increased flooding and saturation of peat soils will improve the persistence of the ecological community and carbon sequestration for the medium to long term.
- Consult with Traditional Owners/Indigenous custodians and take seasonal calendars (Appendix C) into account to assist with appropriate restoration and management actions.

5.4.2.1 MANAGE HYDROLOGY

Implement /reinstate appropriate hydrological management regimes for the ecological community and the landscapes surrounding the ecological community, taking into account results from research.

- Use available ecological information, including this Conservation Advice, to understand how water regimes may impact on key species in the ecological community.
- Use available information to appropriately manage groundwater levels in recharge areas and areas adjacent to occurrences of the ecological community.
- Consider appropriate water flows and duration of nutrient loads when establishing new flooding regimes and water levels in occurrences of the ecological community; for instance, vegetation in a new proposed flood zone may need to be removed prior to raising water levels to prevent a spike of nutrients e.g. released from decomposition.

5.4.2.2 MANAGE WEEDS, PESTS AND DISEASES

Implement effective integrated control and management techniques for weeds, pests and diseases affecting the ecological community and manage sites to prevent the introduction of new, or further spread of, invasive species.

- Prioritise weeds and occurrences for which management is most urgent.
- Target control of key weeds that threaten the ecological community using appropriate methods that avoid impacts to non-target species.
- Encourage appropriate use of local native plant species in the region through local government and industry initiatives and best practice strategies.
- Ensure chemicals, or other mechanisms used to manage weeds, do not have significant adverse, off-target impacts on the ecological community.
- Control introduced pest plants and animals through coordinated landscape-scale control programs.

5.4.2.3 MANAGE TRAMPLING, BROWSING AND GRAZING

- Any grazing which may be occurring in the ecological community should cease. New fencing may be required for exclusion of stock where it is appropriate. Heavy grazing can open up the canopy and allow the invasion of weeds, such as Blackberry (*Rubus* spp.) and African Boxthorn (*Lycium ferocissimum*), that impact both the ecological community and adjacent agricultural land.
- In some situations, the dense shrublands of the ecological community are valuable to retain for shelter of stock in adjacent paddocks.
- Where native vegetation regeneration or replanting is occurring in areas where grazing occurs, provide measures to avoid grazing impacts and support regeneration to maturity, such as fencing and/or tree guards.

5.4.2.4 MANAGE INAPPROPRIATE ACTIVITIES

- Avoid or prohibit wood collection, such as for firewood, that leads to the loss and damage of trees or shrubs, or disturbs the natural litter layer and peat.
- Avoid or prohibit destructive activities such as off-road trail bike or four-wheel-driving.
- Avoid or prohibit wildflower collection.
- Avoid or prohibit rubbish dumping.
- Avoid or prohibit access by domestic pets, by containing them in nearby residential areas or keeping them on leashes.

5.4.2.5 MANAGE FIRE

Based on best available information and focused research, implement fire management regimes for the ecological community that are proven to be appropriate for the vegetation types and fire-sensitive flora and fauna present at each site, as well as the landscapes surrounding the ecological community, taking into account Indigenous cultural management and results from research:

- Use a landscape-scale approach and available local knowledge on fire histories to identify sites that may benefit from a fire for biodiversity conservation purposes and to develop fire regimes and management strategies appropriate to protect, enhance and promote conservation at each location of the ecological community. Fire management strategies at each location should take into account occurrence size, habitat features, vegetation

structure and the surrounding landscape (including property protection) to minimise damage, maintain refuges for fauna (during and after fire) and increase habitat variability.

- Identify suitable fire regimes (interval, intensity, seasonality, prevailing conditions) at each location considering information such as the maturity and seed production rates, as well as the seed germination requirements by key plant species, as well as sensitivities of fauna. Ensure fire frequencies allow sufficient recovery time for adequate regeneration of Silky/Woolly Tea Tree and other key plant species, particularly in a drying climate. It is likely that at some sites, active fire suppression will be necessary at times.
- Great care is required when imposing fire in this ecological community e.g. controlled or planned burns, particularly given the diversity of habitat, sensitivity of fauna and threatened plants, and the importance of water quality. Before burning in or near this ecological community consider alternatives such as biomass management around key assets. If planned burning of native vegetation is undertaken in or adjacent to the ecological community, consider mosaic, rotational and low intensity burning approaches when deciding on an appropriate fire regime.
- Where hazard reduction/prescribed fire is applied in the region, outside of the ecological community, ensure that potential fire escapes are appropriately risk assessed and management responses are in place to protect the ecological community.
- Fires (including planned burns) must be managed to: maintain the integrity of the ecological community and avoid disruption of the life cycles of the component species; support rather than degrade the habitat; avoid invasion of exotic species, and; avoid increased impacts of other threats such as drought, grazing or predation by feral predators. Isolated faunal populations and threatened plants are particularly vulnerable to local extinction following intense fires combined with other threats. Therefore:
    - Ensure that an invasive species risk assessment and management program is planned and budgeted for ahead of proposed burning and that all relevant research has identified these risks and that appropriate and proven management actions have resulted from the research.
    - Use available ecological information to avoid detrimental fire impacts on key and susceptible species in the ecological community; for instance, do not burn areas in or adjacent to the ecological community when key, threatened or functionally important flora and fauna are flowering, nesting or otherwise reproducing.
    - Consider weather conditions and do not burn in or adjacent to the ecological community when soil moisture is low, or dry conditions are predicted for the coming season as flora and fauna are already stressed, recovery will be too slow and erosion may occur or weeds become established while the vegetation cover is reduced.
- Monitor the outcomes of fire and the consequences from other threats, and manage within an appropriate time (for example, immediately limit access by feral predators and grazers; control weeds as they first appear with follow up treatments). Ensure the results are taken into account when planning and implementing future fire regimes. For further information on monitoring priorities see Section 5.4.4.

5.4.2.6 UNDERTAKE RESTORATION

Undertake restoration, including restoring natural hydrological regimes, bush regeneration and revegetation, of low and moderate quality occurrences to restore them to high quality, including restoration of occurrences that don't currently meet the condition thresholds for protection to a condition that does (see Table 7). Restoration works to reconnect isolated patches to other areas of native vegetation is also valuable.

- Investigate options to restore natural hydrological regimes to occurrences of the ecological community that have been adversely impacted and implement wetland restoration where appropriate. This may include removing or altering weirs, causeways, drains or other structures, where feasible and installation of levees and control structures.
- Undertake environmental watering and other activities to mitigate and reduce detrimental hydrological impacts and restore flows and water quality to springs, fens, outflow creeks and drains.
- Undertake restoration, including bush regeneration and revegetation, of poorer and moderate quality occurrences to restore them to high condition, including restoration of occurrences that don't currently meet the condition thresholds for protection to a condition that does (see Table 7).
    - Increase the area and improve ecological function of existing occurrences, for example by enhancing groundwater quality, landscape connectivity, habitat diversity and condition.
    - Consider the restoration of lower quality occurrences of the ecological community to achieve high quality condition (see Table 7).
    - Work with landholders to restore and reconnect occurrences of the ecological community and other adjacent or nearby native vegetation (including buffers).
    - Plan and implement restoration with reference to the *National Standards for the Practice of Ecological Restoration in Australia* (Standards Reference Group SERA, 2017).
    - Use local native species in restoration/revegetation projects for the ecological community and restore understorey vegetation to a structure and diversity appropriate to the site.
    - Develop a collection program, including collect seed from the ecological community for the Australian Seedbank Partnership, local community groups with expert knowledge and/or other relevant programs for use in revegetation programs. In general, use locally collected seeds, where available, to revegetate native plant species. However, choosing sources of seed closer to the margins of their range may increase resilience to climate change.
    - Ensure commitment to follow up after planting, such as the care of newly planted vegetation including maintaining appropriate hydrological needs, weeding and use/removal of tree guards.
    - Consider the landscape context and other relevant species and communities when planning and undertaking restoration works. For example, ensure adjacent ecological communities and threatened species (such as Glenelg Spiny Freshwater Crayfish, Swamp Greenhood) and migratory species are not adversely impacted by tree planting or other restoration activities for Karst springs and alkaline fens.
- Close and rehabilitate unnecessary roads and tracks and otherwise control access to restored patches.
- Implement effective adaptive management regimes using information from available research and management guidelines, for example, the *National Standards for the Practice of Ecological Restoration in Australia* (Standards Reference Group SERA, 2016), as well as relevant research or advice from local authorities.

5.4.3 COMMUNICATE, engage with and support

This key approach includes priorities to promote the ecological community to build awareness and encourage people and groups to contribute to its recovery. This includes communicating, engaging with and supporting the public and key stakeholders to increase their understanding of the value and function of the ecological community and to encourage and assist their efforts in its protection and recovery. Key groups to communicate with include landholders, land managers, land use planners, researchers, community members, Indigenous communities, schools and volunteers.

5.4.3.1 RAISE AWARENESS

- Communicate landholders/managers, relevant agencies and the public to emphasise the value of the ecological community, the key threats, its significance, and appropriate management. Encourage landholders to talk with local NRM and CMA organisations, state agencies and other knowledgeable groups, such as Landcare/Wetland care.
- Communicate with state and local government planning authorities and other relevant agencies to emphasise the value of the ecological community, the key threats, its significance, and appropriate management.
- Undertake effective community engagement and education to highlight the importance of minimising disturbance (e.g. during recreational activities) and of minimising pollution and littering (e.g. via signage).
- Inform landholders about incentives, such as conservation agreements, stewardship projects, funding and government NRM programs etc. that may apply to help look after sites on private lands.

5.4.3.2 PROVIDE INFORMATION

- Develop and enhance education programs, information products and signage to help the public recognise: the presence, including the karst spring and groundwater interaction, and importance of the ecological community; and their responsibilities under the EPBC Act and state and local regulations.
- Install signage to discourage damaging activities such as removal and disturbance of native vegetation, dumping agricultural waste and other rubbish, creating informal paths and tracks, and the use of off-road vehicles in occurrences of the ecological community.
- Install significant vegetation markers along access roads, drainage channels and access tracks to designate area of the ecological community to protect and prevent inappropriate maintenance from occurring.
- Provide land managers with information about managing fire risks and weeds for the benefit of conserving the ecological community and species.
- Promote knowledge within the wider community about local weeds and what garden plants to avoid planting. Recommend local native species for revegetation and landscaping or safe alternative plants.

5.4.3.3 COORDINATE EFFORTS

- Encourage local participation in restoration and ‘landcare’ efforts through local conservation groups, creating ‘friends of’ groups, field days and planting projects, etc.
- Liaise with local fire management authorities and agencies and engage their support in fire management of the ecological community. Request these agencies to use suitable maps and install field markers to avoid damage to the ecological community.

- Develop coordinated incentive projects to encourage conservation and stewardship of the ecological community on private land, and link with other programs and activities, especially those managed by regional Natural Resource Management groups.
- Support opportunities for Traditional Owners/custodians, Indigenous water holders or other members of the Indigenous community to manage the ecological community.
- Refer to traditional custodians with experience in Indigenous cultural management (e.g. fire) and ecological responses.
- Promote awareness and protection of the ecological community with relevant agencies and industries. For example, with:
    - state and local government planning authorities, to ensure that planning takes the protection of remnants into account, with due regard to principles for long-term conservation;
    - land owners and developers, to minimise threats associated with land conversion and development;
    - local councils and state authorities, to ensure infrastructure or development works involving substrate, hydrological or vegetation disturbance do not adversely impact the ecological community. This includes avoiding the introduction or spread of weeds.

5.4.4 RESEARCH AND MONITORING

This key approach includes priorities for research into the ecological community, and monitoring, to improve understanding of the ecological community and the best methods to aid its recovery through restoration and protection. Relevant and well-targeted research and other information gathering activities are important in informing the protection and management of the ecological community.

5.4.4.1 ECOLOGICAL FUNCTION AND REGROWTH

- Undertake/enhance research into the ecological role of *Leptospermum lanigerum*, including its role in maintaining fauna assemblages and dynamics in relation to hydrology, substrate chemistry and fire regimes.
- Research to gain a better understanding of how regrowth stands develop and how they can best be managed alongside other ecological communities, particularly those typically dominated by *Leptospermum lanigerum* in the canopy.
- Research the types of arbuscular mycorrhizal fungi and the associations with flora species within the ecological community.
- Research the development of regrowth stands of the ecological community to improve understanding of their rate and trajectory of development and evaluate convergence with undisturbed reference states.

5.4.4.2 MAPPING

- Collate existing vegetation mapping information and associated data for this ecological community and identify gaps in knowledge.
- Review and update existing state mapping to better identify and locate occurrences of this ecological community, particularly where they are currently mapped as non-protected vegetation types.

- Comprehensively map the extent and condition of the ecological community across its range:
    - support field survey and interpretation of other data such as aerial photographs and satellite images to more accurately document current extent, condition, threats, function, presence and use by regionally significant or threatened species.
    - support and enhance existing programs to model the pre-1750 extent across the entire range of the ecological community to inform restoration;
    - identify the most intact, high conservation value remnants and gain a better understanding of variation across the ecological community.
- Undertake or support and enhance survey programs to:
    - Improve mapping of sites where the ecological community is known or likely to be present.
    - Conduct targeted field surveys and ground-truth to fill data gaps and clarify the presence and condition of remnants.
    - Identify where the best, high quality remnants of the ecological community occur.

5.4.4.3 OPTIONS FOR MANAGEMENT

- Investigate key ecological interactions, such as the role of fauna and invertebrates in pollination, seed dispersal and nutrient cycling.
- Research the appropriate and integrated methods to manage pests and weeds that affect the ecological community.
- Assess the vulnerability of the ecological community to climate change and investigate ways to improve resilience through other threat abatement and management actions.
- Support and enhance research into effective landscape-scale restoration techniques for the ecological community. Investigate the interaction between disturbance types, such as hydrology changes, invasion by weeds and feral animals and fire, to determine how an integrated approach to threat management can be implemented.
- Investigate the most cost-effective options for restoring landscape function and hydrology, including re-vegetation or assisted regeneration of priority areas, potentially buffering, connecting and protecting existing occurrences and enhancing carbon sequestration.

5.4.4.4 MONITORING

- It is important that any monitoring is planned before management commences and considers what data are required to address research questions. Monitoring must also be resourced for management activities, especially for those using a novel approach, and applied during and following the management action.
    - Monitor for signs of decline, in terms of known problems e.g. overabundance of algae in the aquatic zone.
    - Monitor changes in the condition, composition, structure and function of the ecological community, including response to all types of management actions and use this information to increase understanding of the ecological community and inform recommendations for future management.

- Establish/maintain monitoring wells in the vicinity of known occurrences of the ecological community.
- Monitor aquifer and wetland water levels, nutrient levels, salinity and spring volume thresholds (i.e. water regimes) for the ecological community and determine trends over time.
- Determine aquifer water age for areas containing the ecological community.
- Determine any freshwater-saltwater interface for areas containing the ecological community.

5.4.4.5 MODELLING SEA-LEVEL RISE IMPACTS

- Identify and map areas of the ecological community most vulnerable to sea-level rise, coastal erosion and saline groundwater intrusion to inform planning that will protect areas containing the ecological community.

5.4.4.6 UNDERSTANDING FIRE

- Research to gain a better understanding of the ecological consequences of fire in the ecological community including identifying intensities, intervals, season and critical thresholds in the process of canopy closure and ground-layer displacement.
- Research the population dynamics of *Leptospermum lanigerum* in remnants with no flammable ground-layer.
- Research the use of fire in the control of invasive grass weeds and to encourage natural regeneration along remnant edges to increase size and reliance.
- Fire research should be based on minimising risks to this highly threatened ecosystem and therefore should be undertaken using more common surrogate systems and off-site investigations. Only in extreme situations should fire research be undertaken on the threatened ecosystem

6 LISTING ASSESSMENT AND RECOVERY PLAN RECOMMENDATION

6.1 Eligibility for listing against the EPBC Act criteria

On the basis of available information, it is recommended that the Karst springs and associated alkaline fens of the Naracoorte Coastal Plain is eligible for listing as endangered. This was the highest conservation category met at the time of assessment.

This assessment uses the criteria and indicative thresholds set out in the Guidelines for nominating and assessing the eligibility for listing of ecological communities as threatened according to the *Environment Protection and Biodiversity Conservation Act 1999* and the *EPBC Regulations 2000* (DEE and TSSC 2017).

6.1.1 Criterion 1 – decline in geographic distribution

Criterion 1. Decline in geographic distribution			
Category	**Critically Endangered**	**Endangered**	**Vulnerable**
Its decline in geographic distribution is **either**:	very severe	severe	**substantial**
a) Decline relative to the longer-term (beyond 50 years ago e.g. since 1750); **or**,	≥90%	≥70%	**≥50%**
b) Decline relative to the shorter-term (past 50 years).	≥80%	≥50%	≥30%

Eligible under Criterion 1 for listing as **Vulnerable**

Evidence:

The Karst springs and alkaline fens historically occurred as part of a series of wetland complexes fed by permanent springs connected hydrologically by high water tables and constant freshwater flows from the unconfined tertiary aquifer. Much of these complexes have been drained and the associated terrestrial peat fens cleared.

The data from Butcher and Brookes (2018) for Victoria were combined with South Australian data from several studies when deriving estimates of total decline across the whole of the ecological community (Table 8). The estimates for decline in Table 8 do not take into consideration the condition of remnants.

Table 8. Estimates of extent and decline of the Karst springs and alkaline fens

	Pre-1750 extent (ha)	**Current extent (ha)**	**Decline (%)**
South Australia	2058	856	59
Victoria	241	56	77
Total	2299	912	60

Source: Jones 1978; Bonifacio and Pisanu in Keith et al. 2013, Butcher et al. 2011b; Sweeney 2013; Bachmann et al. 2016; Butcher and Brooks 2018

The pre-1750 extent of the ecological community across its entire range is estimated to have been 2299 ha and its current extent is estimated to be 912 ha. These estimates account for most known occurrences of the ecological community and are considered indicative of total decline. The Committee judges that it is likely that the ecological community has undergone a decline in extent across its entire distribution of at least 60%. This represents a **substantial** decline in its geographic extent and the ecological community is therefore eligible to be listed as vulnerable under this criterion.

A smaller area of the ecological community in South Australia was estimated to have declined by ~63% by Bonifacio and Pisanu in Keith et al. (2013) and determined to be endangered (EN) under Criterion A3 (Historic decline) of the IUCN Red List of Ecosystems (Bland et al. 2016).

Criterion 2 – limited geographic distribution coupled with demonstrable threat

Criterion 2 - Limited geographic distribution coupled with demonstrable threat			
Its geographic distribution is:	**Very restricted**	**Restricted**	**Limited**
2.1. Extent of occurrence (EOO)	< 100 km^2 = <10,000 ha	<1,000 km^2 = <100,000 ha	**<10,000 km^2 = <1,000,000 ha**
2.2. Area of occupancy (AOO)	**< 10 km^2 = <1,000 ha**	<100 km^2 = <10,000 ha	<1,000 km^2 = <100,000 ha
2.3. Patch size	< 0.1 km^2 = <10 ha	**< 1 km^2 = <100 ha**	-
AND the nature of its distribution makes it likely that the action of a threatening process could cause it to be lost in:			
the Immediate future [within10 years, or 3 generations of any long-lived or key species, whichever is the longer, up to a maximum of 60 years.]	Critically endangered	Endangered	Vulnerable
the Near future [within 20 years, or 5 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years.]	Endangered	**Endangered**	Vulnerable
The Medium term future [within 50 years, or 10 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years.]	Vulnerable	Vulnerable	Vulnerable

Eligible under Criterion 2 for listing as **Endangered**

Evidence:

Extent of occurrence

The Karst springs and alkaline fens occurs within the Bridgewater IBRA subregion with occurrences near Beachport in south east South Australia to near Portland in south west Victoria. These areas include the Lower South East and East Glenelg groundwater catchments within the Gambier Karst Province (White 2005). Considering the full extent of the Karst springs and alkaline fens in South Australia and Victoria, the ecological community was determined to have a **limited** Extent of Occurrence of 361 992 ha (3620 km²) (Bonifacio and Pisanu in Keith et al. 2013; Bachmann et al. 2016; Butcher and Brooks 2018). Bonifacio and Pisanu in Keith et al. (2013) estimated the extent of occurrence for a similar but smaller ecological community confined to South Australia to be 1347.07 km² (134,707 ha) which meets the threshold for critically endangered (CR) under Criterion B1 of the IUCN Red List of Ecosystems.

Area of occupancy

The Karst springs and alkaline fens has a **very restricted** area of occupancy of 912 ha (9.1 km²) considering the full national extent of the ecological community (Bonifacio and Pisanu in Keith et al. 2013; Bachmann et al. 2016; Butcher and Brooks 2018).

The area of occupancy of the ecological community in South Australia was estimated to be endangered (EN) under Criterion B2 of the IUCN Red List of Ecosystems (Bonifacio and Pisanu in Keith et al. 2013).

Patch size distribution

Available size data for individual occurrences (Table 9) indicate the majority (84%) are less than 100 ha (1 km) in size, a threshold that is also indicative of a **restricted** geographic distribution (Bonifacio and Pisanu in Keith et al. 2013; Bachmann et al. 2016; Butcher and Brooks 2018).

Table 9. Indicative size distribution for the Karst springs and alkaline fens ecological community in South Australia.

Thresholds		**Size range (ha)**	**No. occurrences**	**% total occurrences**	**Cumulative %**
Restricted	Very Restricted	≤ 10	10	40	84
		> 10 - ≤100	11	44	
		> 100 - <1000	4	16	
		Total	**25**	**100**	

Source: Bonafacio and Pisanu 2012; Bonifacio and Pisanu in Keith et al. 2013; Bachmann et al. 2016; Butcher and Brooks 2018.

The Karst springs and alkaline fens has been extensively drained, cleared and fragmented with the majority of clearance within South Australia during the late 1800s to the 1970s (Stephens 1943; Butcher et al. 2011b; Sweeney 2012; Bachmann et al. 2016). The ecological community is faced with a number of demonstrable threats to its long-term viability (Table 4). Remnant wetlands across the national extent (South Australia and Victoria) are impacted by ongoing drainage, weed invasion and declining groundwater levels and flows and declining water quality, exacerbated by climate change.

The geographic distribution of the Karst springs and alkaline fens is severely fragmented. Historically occurrences of the ecological community were more hydrologically linked seasonally and were part of a complex of intergrading shrublands and wetlands (Stephens 1943; Bachmann 2002; Sweeney 2013; Whiterod et al. 2015). The distribution of the community now lies within a heavily cleared, agricultural landscape. It is very susceptible to edge effects and the cumulative actions of numerous threats. The capacity of most occurrences to recover and extend their boundaries is likely to be low under these circumstances.

The ecological community has a **very restricted** area of occupancy; and the Committee considers that the nature of its distribution and available evidence suggests that the collective actions of multiple threatening processes have the potential to cause loss through further decline in extent and function in the **near future**.

Criterion 3 – decline of functionally important species

Criterion 3 - Loss or decline of functionally important species			
Category	**Critically Endangered**	**Endangered**	**Vulnerable**
For a population of a native species likely to play a major role in the community, there is a:	very severe decline	severe decline	substantial decline
Estimated decline over the last 10 years or three generations, whichever is longer of:	at least 80%	at least 50%	at least 20%
to the extent that restoration of the community is not likely to be possible in:	the immediate future	the near future	the medium-term future
restoration of the ecological community as a whole is *unlikely* in	10 years, or 3 generations of any long-lived or key species, whichever is the longer, up to a maximum of 60 years.	20 years, or 5 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years.	50 years, or 10 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years.

Insufficient information to determine eligibility

Evidence:

Healthy occurrences of the Karst springs and alkaline fens contain deeply submerged aquatic macrophytes, fringing sedgeland and shrubland, primarily dominated by *Leptospermum lanigerum* (Silky/Woolly Tea-tree) shrubland, which contribute to peat fen formation. However, changes in flora species composition in the ecological community have been driven by drainage and clearance of aquatic and terrestrial vegetation, in addition to fragmentation of occurrences and changes to freshwater flows from the unconfined tertiary aquifer (Bachmann 2002; Foulkes and Heard 2003; Bachmann et al. 2016; Butcher et al. 2011a; Butcher and Brookes 2018). Bachmann and van Weenen (2001) estimate that less than five percent of the pre-1750 extent of Silky/Woolly Tea-tree shrubland remains in south east South Australia (DEWNR 2015).

Leptospermum lanigerum (Silky/Woolly Tea-tree) is a characteristic species of the Karst springs and alkaline fens which, together with other species, is associated with the formation of the alkaline peat fens component of the ecological community. Historically this species occurred in thick occurrences with a closed canopy and dense understorey of sedge (e.g. *Gahnia* spp.) and herbaceous species.

The characteristic dense stands of Silky/Woolly Tea-tree shrublands are typically elevated from adjoining sedgelands and pools of the ecological community by the layer of peat formed by the inundation of alkaline groundwater under anaerobic conditions. This dense and slightly elevated structure contributes to a shaded and cool micro-climate that is favoured by flora and fauna species that have specific habitat requirements. For example, the vulnerable *Pterostylis tenuissima* (Swamp Greenhood) occurs exclusively in Silky/Woolly Tea-tree (*Leptospermum lanigerum*) Scrub/Swamp Scrub, with the Karst springs and alkaline fens providing critical

habitat for the survival of the species and supporting at least seven percent of the known sub-population (Dickson et al. 2012).

In coastal areas of south east South Australia the vulnerable *Antechinus minimus maritimus* (Swamp Antechinus) is particularly reliant on Silky/Woolly Tea-tree dominated wetlands, preferring mature dense vegetation and thick ground cover such as the fringing zone of the Karst springs and alkaline fens (TSSC 2016a).

While the loss of Silky/Woolly Tea-tree has been invariably substantial, it still occurs as a key component of most remaining areas of the ecological community and there is insufficient data available to identify the loss of the species across the full range of the ecological community.

Overall, there has been significant overall loss of area and degradation of Silky/Woolly Tea-tree and various other flora and fauna components of the ecological community. However, data to support analysis against this criterion, and its indicative thresholds, for loss of particular functionally important species of flora or fauna within remaining occurrences is not available. No quantitative analysis has been undertaken that show the removal of any particular aquatic or terrestrial species will result in ecosystem collapse. Therefore, there is **insufficient information** to determine eligibility for this criterion at this time.

Assessment of the disruption of biotic processes or interactions under the IUCN Red List of Ecosystems found there was insufficient data to estimate the parameter under Criterion D1 (Current decline). The status of the ecological community was therefore determined to be Data Deficient (DD) against this criterion (Bonifacio and Pisanu in Keith et al. 2013).

6.1.2 Criterion 4 – reduction in community integrity

<table>
<tr><th colspan="4">Criterion 4 - Reduction in community integrity</th></tr>
<tr><th>Category</th><th>Critically Endangered</th><th>Endangered</th><th>Vulnerable</th></tr>
<tr><td>The reduction in its integrity across most of its geographic distribution is:</td><td rowspan="2">very severe</td><td rowspan="2">severe</td><td rowspan="2">substantial</td></tr>
<tr><td>as indicated by degradation of the community or its habitat, or disruption of important community processes, that is:</td></tr>
</table>

Eligible under Criterion 4 for listing as **Endangered.**

Evidence:

There have been substantial losses in extent of the ecological community and most remaining occurrences continue to be impacted by reduced flows from the tertiary unconfined aquifer, declining groundwater levels, reduced water quality and ongoing drainage. In addition, all occurrences of the Karst springs and alkaline fens have been impacted by the removal of fringing shrublands and loss or reduced flora and fauna species diversity and populations in both the aquatic and fringing zones. The ecological community now occurs in a severely fragmented state in a highly modified agricultural landscape.

Reduction in integrity through drainage, clearance and fragmentation

Historically, the ecological community occurred within a series of springs and associated fens that formed complexes. These complexes would seasonally amalgamate during the high rainfall winter period, facilitating broad distribution of many aquatic flora and fauna species (GH Gawler 1866; Ecological Associates 2009). Staged drainage commenced during the 1860s, with most

drains being built between 1949 and 1972 (Department for Water 2012). Although native vegetation clearance in the region commenced during the 1840s, drainage enabled greater areas to be developed for pasture, cropping and forestry this disrupted wetland connectivity. As a result, former wetland complexes have been fragmented and individual occurrences of Karst springs and alkaline fens are now largely isolated within an increasingly irrigated agricultural landscape (Whiterod et al. 2015).

Fragmentation due to drainage and clearance has caused a reduction in wetland size, increased the distance between individual occurrences and complexes, exposed more edges and led to greater susceptibility to further disturbances and degradation. For example, Ewens Ponds was part of the Eight Mile Creek Complex prior to drainage commencing in the 1940sbut it has now been significantly reduced in size and fragmented into five occurrences (Stephens 1943; Jones 1978; Sweeney 2012; Bachmann et al. 2016). All the occurrences are less than 100m in width and all adjoin agricultural land.

Large remnant areas with a low area/edge ratio, tend to have reduced weed and pest animal populations (Foulkes and Heard 2003). Habitat fragmentation causes degradation of native vegetation through increased edge effects, with some surrounding agricultural, horticultural and forestry practises contributing to weed infestations and higher pest animal populations (Caton et al. 2011; EPA 2014; Horn et al. 2016). Smaller, isolated fragments are less buffered against disturbances and edge effects, such as invasion by weeds that encroach from their margins or impacts from surrounding landscape and development activities such as spray drift and hydrological changes.

Targeted removal of the dense shrubland that fringe and overhang the aquatic pools and outflow streams of the ecological community has also occurred for stock and machinery access. This leads to increased summer water temperatures that, when combined with increased nutrient loads, can lead to algal growth and blooms particularly in more shallow and slower moving sections of the aquatic zones. Saddlier and Hammer (2010) also noted that a decrease in organic input from fringing vegetation contributes to reduced populations of macroinvertebrates, a major food source of fauna species such as birds, fish and amphibians.

Habitat and population fragmentation can reduce genetic flow, increase inbreeding leading to critically low genetic diversity and smaller populations within and across the ecological community for aquatic fauna species (Miller et al. 2014). Veale and Whiterod (2018) noted that three subpopulations of the Glenelg Spiny Freshwater Crayfish within the ecological community, including at Bones Pond and Little Piccaninnie, are at extreme risk of localised extinction. This species has low population numbers with many not reproductively viable. Sites within the Karst springs and alkaline fens are largely isolated and populations have low opportunities for recruitment. It was concluded that up to five sub-populations of the crayfish within the ecological community will become extinct in the next 5 to 10 years. Other aquatic fauna has also experienced similar declines. Notably, the Variegated Pygmy Perch is now restricted to two populations in the ecological community.

Reduction in integrity through hydrological changes

Ground water dependant ecosystems such as the Karst springs and alkaline fens are reliant on persistent water table levels and spring flows. Water table levels in the immediate vicinity of these groundwater dependant wetlands, are important for maintaining natural water regimes. The water regime directly influences the physical features and biological processes for the ecological community. Availability of nutrients, light, oxygen and carbon dioxide levels within the water column regulate microbial activity and plant and fauna lifecycles (Lloyd and Alexander 2003, Keith 2004).

Changes in land use, rainfall and hydrology have significantly altered the ecology of remaining occurrences of the Karst springs and alkaline fens, resulting in lower flows, deeper water tables and changing salinity levels. The altered drainage system in the Lower South East region of South Australia where the ecological community occurs covers approximately 1 875 km of drains, channels watercourses and creeks and more than 1800 structures including road bridges, culverts, inlets, sea outlet structures and regulators (Department for Water 2012). The primary functions of the drains and channels are to remove surface water and groundwater to provide more land for agriculture in the region (EPA 2014).

Since the 1990s local groundwater levels and flows from the unconfined aquifer have substantially decreased across south east South Australia. For example, Eight Mile Creek has undergone a reduction in flow of 20-30% during this period due to intensified groundwater abstraction. Ground water extraction for pivot irrigation systems was introduced in the lower south east of South Australia during the early 1990s (Figure 2) and have continued to be expanded (Figure 3. Pivot irrigation draws groundwater from the same unconfined aquifer which also feed the ecological community. This is likely to have a direct impact on flows and amplify drought impacts. The hydrology of the region where the ecological community occurs has been further impacted by periods of declining rainfall, notably the severe Millennium drought of 2010 (BOM 2019).

The structure and function of groundwater dependant ecosystems such as the ecological community are particularly impacted when extraction exceeds recharge (Murray et al. 2006). Continued drainage of remaining wetlands and surrounding land, in addition to the expansion of groundwater extraction for irrigation has compounded the impact on the hydrology of the local area. As the underlying peat dries, shrinks and evaporates (releasing carbon dioxide), localised land subsidence occurs. For example, at Ewens Ponds in the Eight Mile Creek wetland complex, Armstrong and Watson (1974) noted that between 1939 and 1958 this area subsided

Figure 2. 1997 – Centre pivot irrigation near Eight Mile Creek Complex (including Ewens Ponds, Spencer Pond)

Source: Sweeney 2012

Figure 3. 2020 – Centre pivot irrigation near Eight Mile Creek Complex (including Ewens Ponds, Spencer Pond)

Source: Google 2020.

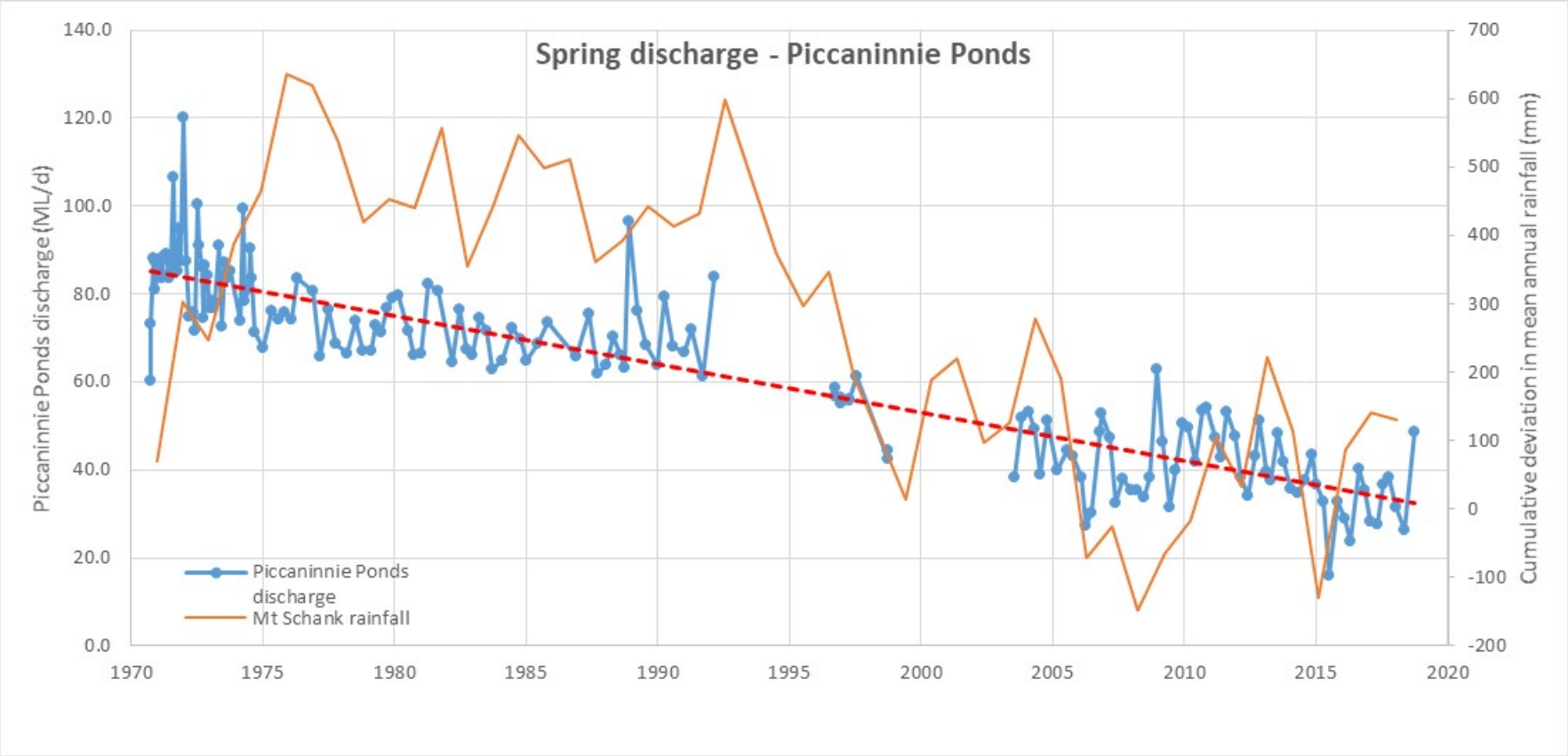
by about half a metre. As land subsides, further groundwater drainage is required to avoid flooding during wet periods and to maintain agricultural and grazing activities. During dry periods, such as the Millennium drought, irrigation also increases and exacerbates impacts.

Groundwater flows are monitored at two locations, Piccaninnie Ponds (Figure 4) and Eight Mile Creek (Figure 5). Each location contains multiple occurrences of the ecological community. The Piccaninnie Ponds site has undergone some restoration and the level of the aquatic zone has been raised. Ewens Ponds' outfall creek has been modified into a major drain.

The median spring flows at Piccaninnie Ponds in 1970 were 80.9 ML/day compared to 37.5 ML/day in 2019 (Figure 4). This is a 53.6% decrease in flow. Median spring discharge in the decade between 2009 and 2019 has decreased by about 12% (Table 9). The median spring flows at Eight Mile Creek in 1970 were 206.5 ML/day in 1970 compared to 156.4 ML/day in 2019 (Figure 5). This is an overall decrease in flow of 24.3%.

Some occurrences of the ecological community connect to the upper parts of the Tertiary limestone aquifer and typically have shallow open water such as Jerusalem and Cress Creeks. These more shallow wetlands are sensitive to the natural seasonal variation of water tables and water table fluctuations are exacerbated by irrigation in surrounding areas, which can lead to permanent wetlands transitioning to seasonal wetlands or completely drying (Harding et al. 2015; Limestone Coast Landscape Board 2020). In 2019 the expert panel assessing the Lower Limestone Coast MacDonnell Area in South Australia found that there "is a high risk of groundwater extraction from bores contributing to a water table level which in turn could result in detrimental consequences to groundwater-dependent ecosystems" (Limestone Coast Landscape Board 2020).

Figure 4. Spring discharge from Piccaninnie Ponds (ML/day) 1970 to 2019

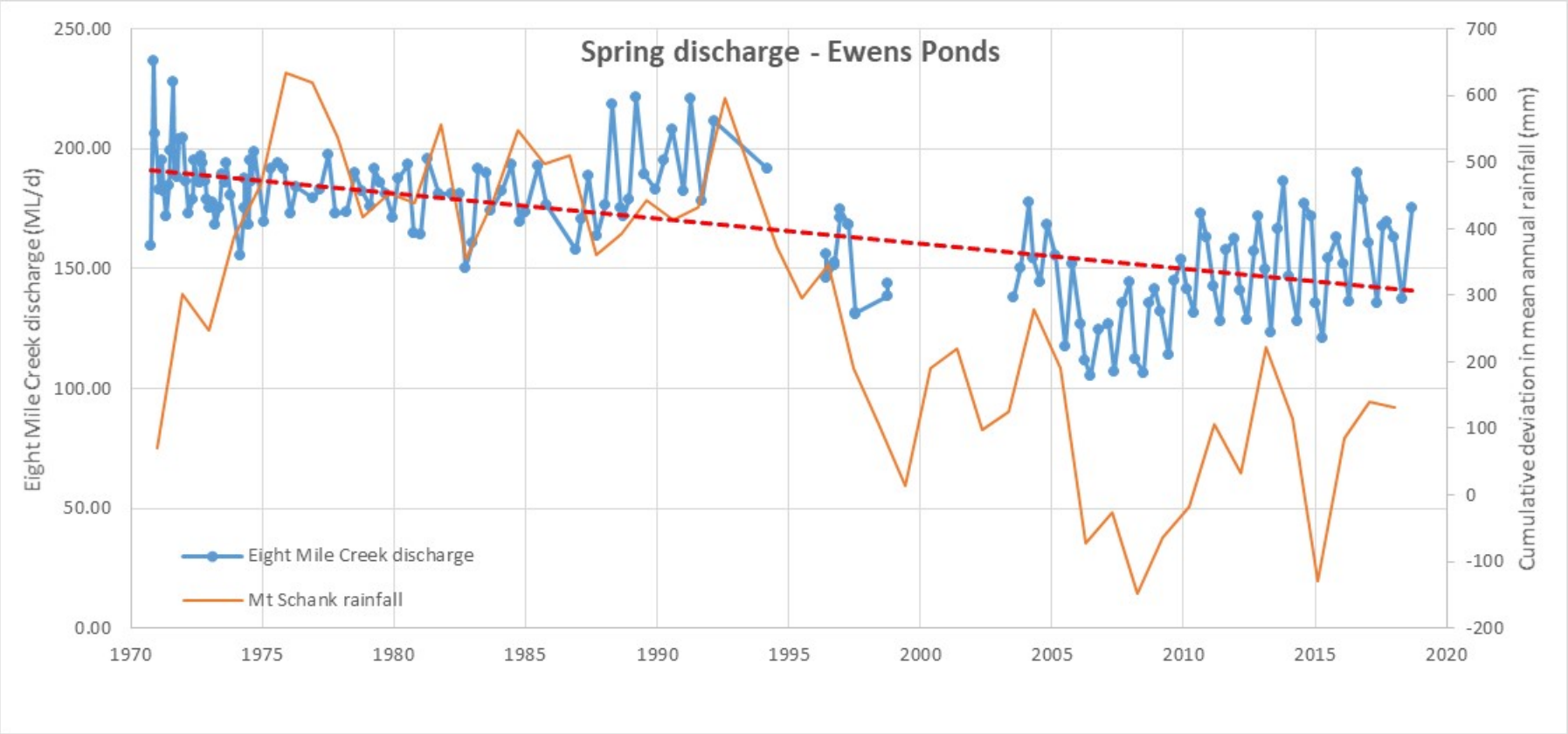


Source: DEW unpublished

Table 9. Spring discharge – Piccaninnie Ponds

Year	1970	2004	2009	2014	2019
Median flow (ML/day)	80.9	50.5	42.4	40.8	37.5

Figure 5. Spring discharge at Eight Mile Creek (ML/day) 1970 to 2019



Source: DEW unpublished

Water quality

Most springs associated with the ecological community were historically characterised by high flows with little surface level variation, low levels of sediment, salinity, nitrogen and phosphorous, high oxygen levels and high clarity which allowed good light attenuation. The high clarity and aquifer flows into the ecological community resulted in low algal growth and facilitated macrophyte dominated aquatic zones to depths exceeding three metres and as deep as 15 metres in some locations. However, increased drainage of wetlands, water abstraction for irrigation and loss of adjacent vegetation has altered water quality within the ecological community through changes in nutrient loads, salinity and the volume and duration of water flow i.e. turnover (Gillieson and Thurgate 1999; Bachmann et al. 2015; Rigosi et al. 2015; Harding et al. 2015).

Grimes et al. (1999) noted pollution events to the unconfined aquifer that flow into the ecological community in the Bridgewater Bioregion. Agricultural, forestry, industrial, sewage and stormwater discharge can leach nutrients in the form of nitrogen and phosphorous into surface flows and groundwater (Gillieson and Thurgate 1999). Algal blooms can also result from organic enrichment from decaying vegetation and through anthropomorphic activities. Slower water flow from springs within the ecological community and increased exposure to solar radiation from loss of fringing vegetation can increase water temperature. Water flow reduction can also facilitate the availability of nutrients such as dissolved nitrogen and phosphorous in sediments. These events can contribute to algal establishment and growth, independently or in combination.

During the period 1990 to 2015, disruption to aquifer flow (from permanent to seasonal) within seven (28%) occurrences of the ecological community systems has occurred with subsequent decline in the aquatic component and loss of aquatic species (Bachmann et al. 2016; Harding 2018; Veale and Whiterod 2018; Harding pers comm). Sholtz (1990) noted that following heavy rainfall, relatively nutrient-rich water from surrounding swamp catchment was flushed into the aquatic component at Piccaninnie Ponds resulting in plankton blooms. Butcher et al. (2011a), Bonafacio and Pisanu in Keith et al. (2013) estimate that the collapse threshold for Piccaninnie Ponds is 30–38 ML/day, which on current decline rates would be reached in 10 to 20 years.

Aquifer flows have declined substantially for the full extent of the ecological community in the past 10 to 15 years, with disruption of flow (from permanent to seasonal) within at least seven (28%) occurrences of the ecological community. Reductions in integrity to these systems has resulted in declines of the aquatic component and loss of aquatic species (Bachmann et al. 2016; Veale and Whiterod 2018; Harding pers comm). Given there are an additional ten occurrences (40%) in and near the Piccaninnie Ponds and Eight Mile Creek (Ewens Ponds) Complexes, ongoing flow reductions are likely to be severe for most (at least 68%) of the ecological community.

Sedimentation

Reduced water quality from sedimentation, particularly in streams and drains can lead to direct impacts such as reduced light for aquatic plants, asphyxiation of aquatic fauna and the smothering of their eggs. Sedimentation can also alter stream beds leading to a reduction in habitat variety, food availability and changed water flows. The diversity of aquatic plants and macroinvertebrates are also reduced (DSE 2007). Degradation and loss of fringing vegetation, as has happened for this ecological community, also leads to an increase in erosion and slumping of banks into the wetland which impacts on macroinvertebrates, a major dietary component and nutrient source for many fish species (Saddlier and Hammer 2010; Whiterod and Hammer 2012). Whiterod and Hammer (2012) noted evidence of bank slumping in occurrences of the ecological community at Spencer Pond and Little Piccaninnie (Jerusalem

Creek). The increase in silt in outflow streams and drains can have negative consequences for aquatic fauna species within the ecological community that require solid substrates or vegetation for spawning, such as the Variegated Pygmy Perch (Veale and Whiterod 2018).

Salinity

Salinity levels in groundwater can increase due to clearing of vegetation, increased runoff, rising water tables, lower frequency of flushing events and decreased water flow, all of which are occurring for the Karst springs and alkaline fens (Nielsen et al. 2003; House of Representatives Standing Committee on Science and Innovation 2004; Gehrig 2015). Due to the lateral flow of subsurface seepage, dissolved salts move to lower elevations. The ecological community is located at the lowest terrestrial point of the unconfined aquifer near the coast with regional water inputs from as far away as the Kanawinke Fault.

Reduced groundwater flows to the unconfined aquifer near the coast combined with tidal and seasonal influences can cause the saline seawater/fresh groundwater interface (wedge) to move inland increasing the salinity of the unconfined aquifer. Near coastal groundwater dependant ecosystems, such as the Karst springs and alkaline fens, are particularly at risk of saltwater intrusion via tidal flows into outlet streams and/or groundwater via subterranean mixing with seawater. Reduction in spring flows from the unconfined aquifer can reduce dilution and flushing rates of saline inputs into the ecological community. A freshwater–saltwater interface in the coastal aquifer has been detected at four coastal locations including within the ecological community. Rising salinity levels have been noted in the Piccaninnie Pond/Pick Swamp complex and Spencers Pond showing evidence of high salinity in some aquifer flows (Mustafa et al. 2012).

Reduction in integrity through weed invasion

Aquatic and semi-aquatic non-native plants found growing around the pools of the Karst springs and alkaline fens include Jointleaf Rush (*Juncus articulate*), Lesser Water-parsnip (*Berula erecta*) and Watercress (*Nasturtium officinale*) (Kivisalu and Farrington 2013). These invasive plants displace native species and alter hydrological flow rates and patterns (Bachmann et al. 2015).

Invasive plant species found in the fringing vegetation of the Karst springs and alkaline fens include: Annual Beard Grass (*Polypogon monspeliensis*), Fog Grass (*Holcus lanatus*), Phalaris (*Phalaris aquatica*) and Rye Grass (*Lolium rigidum*) (Kivisalu and Farrington 2013). Tall Fescue (*Festuca arundinacea*) is a particular threat to the fringing components of the ecological community due to its preference for moist areas (Bachmann et al. 2015; Weiss et al. 2017). The Arum Lilly (*Zantedeschia aethiopica*) is often spread by birds and can invade both dry and wet areas of the ecological community, often forming dense patches and outcompeting native species (Caton et al. 2011; Bachmann et al. 2015; PIRSA 2015b).

Shrubby weeds likely to complete with the taller shrub components of the ecological community, include: Italian Buckthorn (*Rhamnus alaternus*), Large-leaved Cotoneaster (*Cotoneaster glaucophyllus*) and Mirror Bush (*Coprosma repens*). Weeds of National significance include African Boxthorn (*Lyceum ferocissimum*), Blackberry (*Rubus fruticosus* ssp) and Bridal Creeper (*Asparagus asparagoides*).

Where a drying hydrological regime occurs, particularly for long periods, the native Coastal Wattle (*Acacia longifolia* var. *sophorae*) can become an invasive coloniser of wetland sites. Dense infestations of Coastal Wattle could cause up to 75% of indigenous native species to be lost from the terrestrial vegetation layer (Butcher et al. 2011a). Bachmann et al. (2015) noted this species has undergone a dramatic expansion and is considered a serious woody weed in the coastal areas where the ecological community occurs.

Spiny Rush (*Juncus acutus*) can quickly invade watercourses and other damp areas and forms dense monocultures which exclude other native species. Its presence is also indicative of changing hydrological regimes and increasing salinity levels (PIRSA 2015a).

Reduction in integrity through pest animal invasion and grazing

Several pest and feral animal species, for example foxes, cats, deer, goats, mice, pigs, rabbits and rats, have been recorded in and adjacent to the Karst springs and alkaline fens. Apart from direct predation and competition for habitat and resources, feral animals damage the ecological community by browsing and removing mature and establishing canopy species, opening up shrubland thickets and destroying soil structure. These activities help to spread weeds into the wetlands. Pest animals also reduce the ability of native plant species to regenerate, therefore limiting the capability of the ecological community to recover from disturbance.

Grazing impacts from cattle can rapidly damage or change the structure, composition and functionality of the Karst springs and alkaline fens (Whiterod and Hammer 2012, Bachmann et al. 2016). The native vegetation supported by the underlying peat and waterlogged soils of the ecological community are susceptible to direct impacts. These impacts result from browsing, trampling and pugging[18] from moderate to heavy or frequent grazing by livestock such as dairy cattle. Pugging can alter soil structure, surface drainage and infiltration, impede vegetation regrowth, lead to weed spread and density, and exacerbate the leaching of potassium and nitrogen from the soil (Agriculture Victoria 2011). Cattle access to the fringing shrubland component of the ecological community has occurred in at least 28% of Karst spring and alkaline fen occurrences including Little Piccaninnie, Spencer Pond and Stratmans Pond resulting in severe trampling of vegetation and further fragmentation (Bachmann et al. 2015).

Grazing and trampling directly removes fringing vegetation, particularly from the margins of waterbodies which is used by fauna species, such as the Growling Grass Frog, for shelter and movement corridors while plant predation by stock can prevent regeneration of habitat. Similarly, removal of vegetation affects microclimate, including humidity levels, at ground level (Clemann and Gillespie 2012). Loss of riparian habitats through unrestricted stock access can have long-term impacts as it can affect bank stability within the ecological community leading to slumping, erosion, sedimentation, reduced water quality and increased water temperature (Saddlier and Hammer 2010, Bachmann et al. 2016).

Conclusion

The integrity of the ecological community has been severely compromised, at both local and landscape scales through various types of local degradation and past broad scale vegetation clearing and ongoing landscape changes. Continued drainage of springs and wetlands, with decreased groundwater discharge due to changed landuse, reduced rainfall, increased drawdown and reduced aquifer recharge has caused flows to severely decline across the geographic distribution of the ecological community. Many occurrences have freshwater flows that have transitioned from permanent to seasonal resulting in declining water quality. Coastline aquifer vulnerability in general is likely to increase due to the sea-level rises and increase in storm tides. Rising salinity levels have been noted in two occurrences of the ecological community (Mustafa et al. 2012).

There has been a reduction in integrity through hydrological changes, increased fragmentation and invasive species impacts. This has affected ecological processes and resulted in a subsequent decline and/or change to flora and fauna within the ecological community, consistent with a **severe** reduction in integrity across most of its geographic distribution. If these

[18] Pugging occurs when cows and other hard hooved livestock compact damp soils causing damage to the soil structure, affecting water infiltration and vegetation in the groundlayer.

changes are ongoing, it could lead to the eventual loss of the ecological community within the **near future**.

Assessment of environmental degradation (change in an abiotic variable) under the IUCN Red List of Ecosystems found that the status of the ecological community in South Australia is Critically Endangered (CR) under Criterion C1 (Current decline).

Under IUCN Criterion C2 (Future decline): It was considered that 85.5% of the area of the ecological community in South Australia was projected to be impacted by salt water intrusion by 2070, 8 years beyond the 50-year assessment time frame. Given this projected extent of degradation, and assuming that inundation with sea water results in degradation with relative severity of 100%, it was found that the status of the ecological community is Critically Endangered (CR).

6.1.3 Criterion 5 – rate of continuing detrimental change

Criterion 5 - Rate of continuing detrimental change			
Category	**Critically Endangered**	**Endangered**	**Vulnerable**
Its rate of continuing detrimental change is:	very severe	severe	substantial
as indicated by a) degradation of the community or its habitat, or disruption of important community processes, that is:			
or b) intensification, across most of its geographic distribution, in degradation, or disruption of important community processes, that is:			
5.1 An observed, estimated, inferred or suspected *detrimental change* over the *immediate*[#] past or projected for the *immediate* future of at least:	80%	50%	30%

Insufficient data to determine eligibility under Criterion 5

Evidence:

The ecological community is undergoing continuing detrimental change arising from threats outlined in Section 3, Threats. Threats associated with human disturbance are likely to increase with growing agricultural and forestry developments and landuse changes. In addition, changes in rainfall volumes and seasonality, are likely to continue impacting the ecological community, including increasing drought and storm severity due to climate change.

The hydrology of south east South Australia has been extensively modified by a combination of private and government drainage schemes commenced in 1860, land clearance and water abstraction. Abstraction of groundwater across the region for industry and agriculture has resulted in a decline in groundwater discharge rates throughout the wetland complexes in the Lower Limestone Coast area (Gillieson and Thurgate 1999; Rigosi et al. 2015; Shanafield et al. 2020).

The ecological community has undergone a decline in geographic distribution, decline in condition and a significant investment in ongoing management is required, in the form of invasive species control and in some cases supplementary planting and water management at a local and regional level, to avoid a further increase in the rate of continuing detrimental change. Restoration of some wetland water levels has been undertaken, e.g. Pick Swamp and

Piccaninnie Ponds, but these areas are still impacted by upstream land uses (forestry and/or groundwater extraction for irrigation) which intercept groundwater flows and contribute to reduced spring volumes. Although these sites are locally managed, aquifer flow is still governed by hydrological interactions at a regional level (Gillieson and Thurgate 1999; Rigosi et al. 2015; Shanafield et al. 2020).

Good quality freshwater discharge from unconfined aquifers springs within the Karst springs and alkaline fens are typically clear with low suspended solids, high oxygen levels (4-10 mg/L), stable temperatures (15-18°C). Spring discharges for the ecological community were historically high in volume (Bachmann et al. 2015). These conditions contributed to naturally limited algal growth and supported a macrophyte dominated aquatic zone. High water quality from the aquifer and macrophyte dominance within Piccaninnie Ponds and Ewens Ponds are a key component of their ecological character (Butcher et al. 2011b; Shanafield et al. 2020). High aquifer flows historically flushed the algae out and prevented establishment in the aquatic zones. Rigosi et al. (2015) showed the main factors controlling the risk of regime shift in Ewens Ponds are phosphorus availability and flow rate. However, when flows are reduced, both phosphorus and nitrogen are likely to stimulate algal growth. Excessive algal growth is a threat to the aquatic components of the Karst springs and alkaline fens. Although often present within the open water component of the ecological community, under particular conditions, such as high nutrient loads, algae can multiply rapidly and form high-density blooms (Rigosi et al. 2015; Shanafield et al. 2020). Pelagic and epiphytic algae can outcompete macrophytes in open water spring systems such as the Karst springs and alkaline fens causing habitat degradation and loss of aquatic endangered species. Algal growth can cover aquatic vegetation such as *Ranunculus* spp. consequently decreasing light availability to the sediment-rooted macrophytes and shifting from a clear-water macrophyte-dominated state to a highly turbid algae-dominated state (Rigosi et al. 2015; Shanafield et al. 2020).

There is an overall trend of reductions in groundwater volumes and rainfall in the Bridgewater bioregion and therefore within the Karst springs and alkaline fens (Figure 4 and 5). The majority of the ecological community is located at the lowest point of the landscape near the coast and are downstream of agricultural and forestry activities. Groundwater extraction is the primary source for irrigation in the region. During the period 1990 to 2015, disruption to flow (from permanent to seasonal) within seven (at least 28%) occurrences of the ecological community has occurred with subsequent decline in the aquatic component and loss of aquatic species (Bachmann et al. 2016; Veale and Whiterod 2018; Harding pers comm). Although no quantitative data on timeframes is available, at least one occurrence in Victoria (Lake Mombeong) has lost its natural outflow stream (Butcher et al. 2018; Bachmann pers comm 2020). Austral Research and Consulting (2019) noted intensive forestry is undertaken adjacent to this wetland.

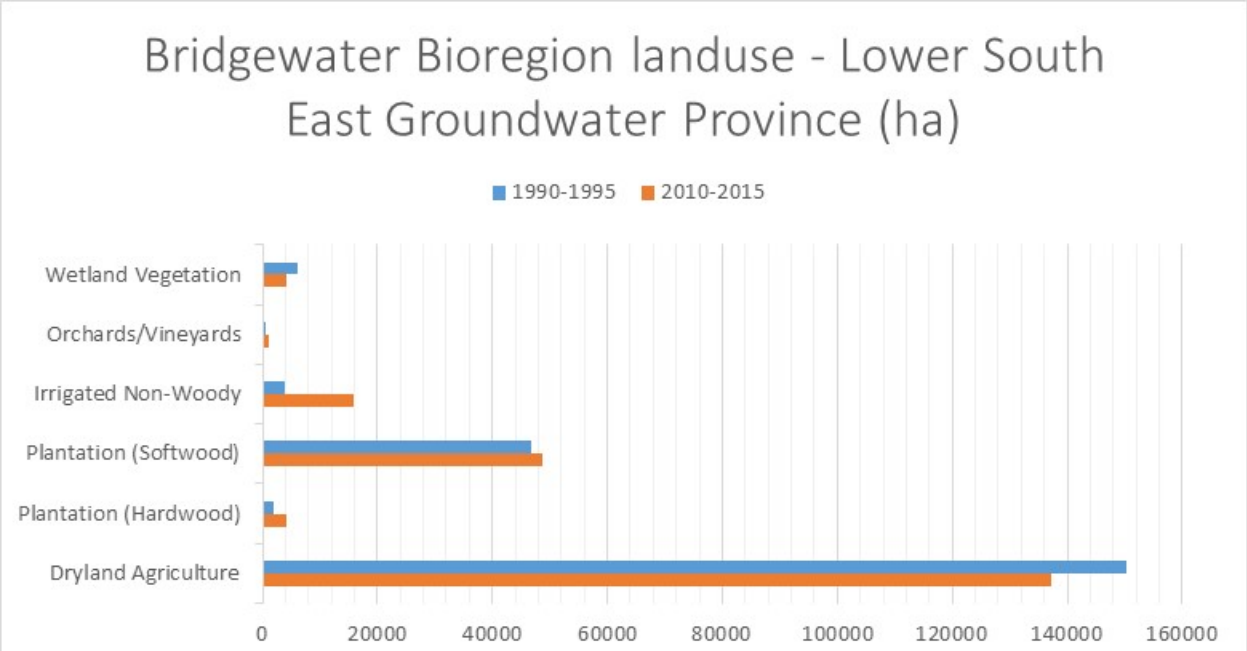
Rigosi et al. (2015) noted the majority (>80%) of wetland systems sampled in south east South Australia between 2008-2014 contained nutrient levels that exceed the Australian and New Zealand fresh water quality guidelines. Ongoing episodic cyanobacteria blooms and epiphytic algal growth have indicated deteriorating water quality in some aquatic components of the ecological community (Carmody 2006, Carpenter et al. 2011). Projected spring output indicates that the aquatic component of the ecological community can shift from a macrophyte to algae dominated system when flow declines beyond a critical level (Carey et al. 2012; Rigosi et al. 2014).

Changes in landuse in the Bridgewater Bioregion for 1990–2015 (Figure 6 and 7) indicate an 8.6% reduction in dryland agriculture, a 305% increase in irrigated land and a 33% decrease in wetland area from 6161 ha down to 4125 ha (DEWNR 2017). Given the intensification of irrigation and groundwater demand in the immediate past and seasonal shifts in rainfall (Figure 4 and 5) combined with the continued drainage of areas adjacent to the ecological

community and associated subsidence, serious ongoing degradation to the ecological community is likely across most of its range.

Interpreted ages of groundwater discharging at Ewens Ponds, suggests residence times in the aquifer of 23 to 37 years (Rigosi et al. 2015; Wood 2011). That is, water discharging in the springs was recharged 23 to 37 years ago. These 'apparent ages' likely represent a mixture of multiple flow paths of different 'age' discharging at the spring, rather than a discrete body of water recharged two to three decades past. The spring discharge is part of a regional flow system where discharge is related to groundwater level (gradient) which is influenced by factors such as recharge and extraction (flux), which may vary seasonally in response to rainfall. Therefore, discharge at the springs is likely to show an ongoing seasonal fluctuation, in relation to seasonal variation in climate and extraction (and subsequent variation in groundwater level). However, longer-term changes in water quality can be observed, given the apparent residence time of groundwater in the aquifer and historical rates of fertiliser application (Wood pers comm).

Figure 6. Landuse change in the Lower South East Groundwater Province of the (IBRA) Bridgewater Bioregion



	Dryland Agriculture	Plantation (Hardwood)	Plantation (Softwood)	Irrigated Non-Woody	Orchards/Vineyards	Wetland Vegetation
1990-1995	150224	1815	46812	3915	524	6161
2010-2015	137233	4274	48788	15860	1063	4125

Source: (DEWNR 2017)

Taking into account the estimated age of the groundwater entering Ewens Ponds (approximately up to 23 years), future trends in nutrient concentrations were estimated by Rigossi et al. (2015) and Shanafield et al. (2020) by examining fertilizer use in Australia since the time that the groundwater entered the system. A rise in use of both fertilisers for agricultural use from 1991 to 1998 (Fertilizer Industry Federation of Australia 2011) are expected to enter Ewens Ponds via groundwater inflows in the near future, with peak nutrient loads estimated to occur in 2024 to 2037. Given fertilisers have been applied regionally, other occurrences of the ecological community in the same groundwater catchment are likely to be impacted. However,

there is limited equivalent data for other sites such as Piccaninnie Ponds. The combination of landuse change and associated demand for groundwater abstraction, nutrient loads and declines in aquifer flow for Eight Mile Creek suggest that critical thresholds for algal growth may be reached in the near future. Given the Ewens Ponds complex is now fragmented into five (20%) wetland occurrences and the areas immediately adjacent, Cress Creek, Deep Creek, Hitchcox Drain and Jerusalem Creek contain up to five (20%) wetland occurrences, projected impacts may range from 20 to 40% of Karst springs and alkaline fens sites.

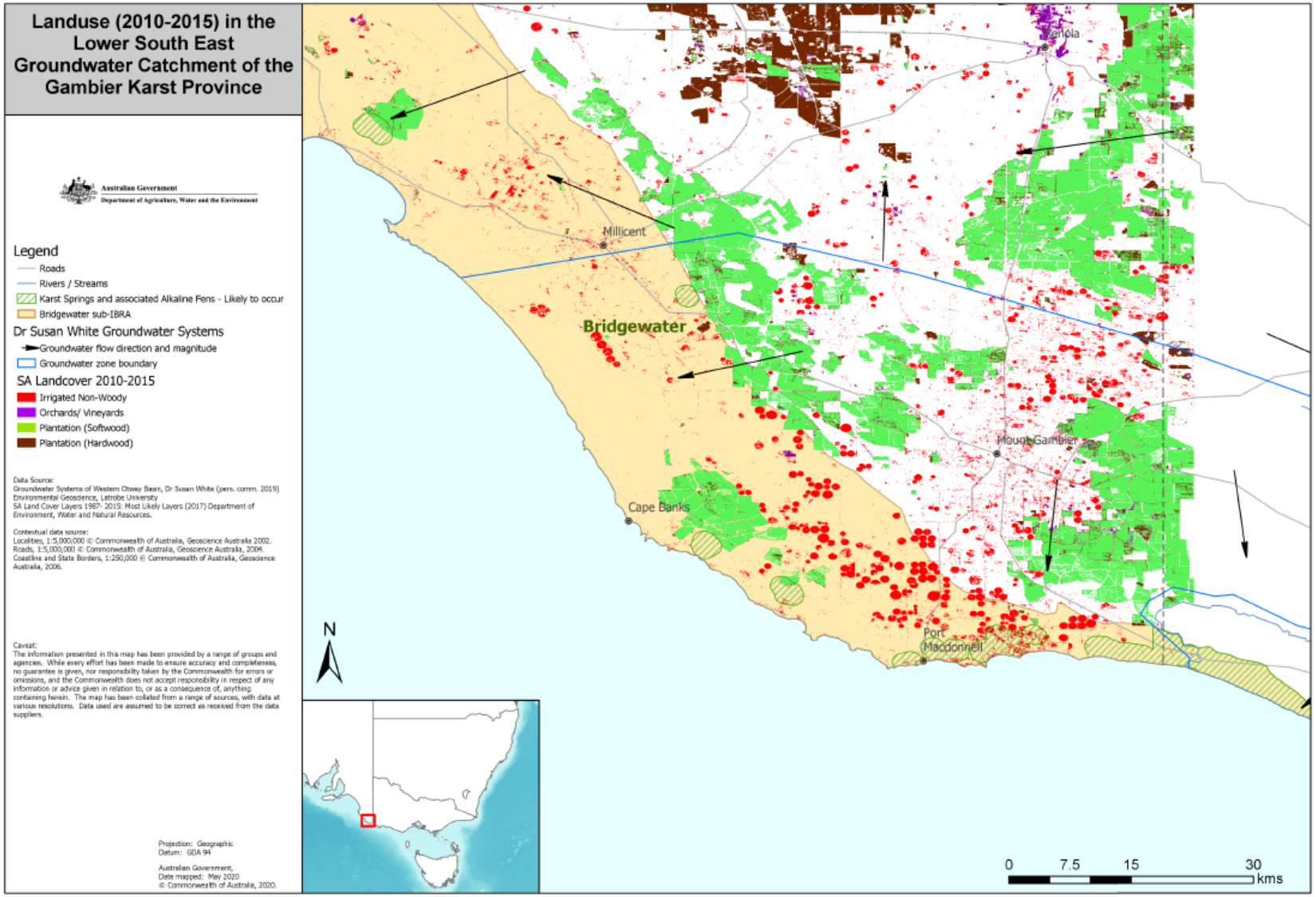
Condition assessment of habitat and outflows associated with seven occurrences of the Karst Springs and alkaline fens was undertaken by Whiterod and Hammer (2012) during and following the Millennium drought (2009). Although aquatic habitat remained consistent or increased in area between 2006 to 2011, emergent habitat and edge vegetation was more degraded and overall vegetation cover was generally lower in 2011. Filamentous algae were found to be common or increasing in five (20%) Karst spring and alkaline fens, displacing macrophytes as the dominant aquatic lifeform in two. It was concluded that either fringing vegetation or aquatic flora was declining in seven sites representing at least 28% of the ecological community.

The Glenelg Spiny Freshwater Crayfish (Crayfish *Euastacus bispinosus*) is endemic to south west Victoria and south east South Australia, specifically the ecological community in the South Australian distribution (Honan 2004; TSSC 2016b). It is a long-lived (~26 years) top aquatic predator within the Karst springs and alkaline fens requiring flowing well-oxygenated good quality water (Whiterod et al. 2014). In a study undertaken by Veale and Whiterod (2018), the population of the species was sampled from 2014 to 2018 in all seven sites within the ecological community and two other outlying locations.

The Veale and Whiterod (2018) study, undertaken within the same area as the Whiterod and Hammer (2012) study, found a small population with about 35% of males being aberrant (male and female gonopores) and potentially reproductively unviable, indicating limited breeding potential. The Crayfish in Spencer Pond was 12 times more abundant during 2006/07 than in 2017/18. Veale and Whiterod (2018) concluded based on the fragmented and isolated nature of sites, declining population size and breeding capacity and decline in water flows that up to five (71%) sub-populations within the ecological community (Hitchcox Drain – Bones Pond; Isolated – Clarke Park; Jerusalem Creek – Little Piccaninnie; Cress Creek – Bubbling spring; and Piccaninnie Ponds – Donovans Drain) will become extinct in the next 5 to 10 years. This represents 20% of the Karst Springs and Alkaline Fens extent.

Hydrological changes combined with the continued drainage and abstraction of groundwater in areas adjacent to and within the ecological community have contributed to flow disruption for outfall streams in seven occurrences (28%) of Karst springs and alkaline fens. The disruption of these processes has led to ongoing declines in characteristic species such as crayfish. However, there is no data or timeframes for outflow stream disruption across the entire ecological community. As such, there is **insufficient information** for the relevant timeframes and rate of detrimental change to determine the eligibility of the ecological community for listing under this criterion.

Figure 7. Landuse (2010–2015) in the Lower South East Groundwater Catchment South Australia



Criterion 6 – quantitative analysis showing probability of extinction

Criterion 6 - Quantitative analysis showing probability of extinction			
Category	**Critically Endangered**	**Endangered**	**Vulnerable**
A quantitative analysis shows that its probability of extinction, or extreme degradation over all of its geographic distribution, is:	at least 50% in the immediate future.	at least 20% in the near future.	at least 10% in the medium-term future.

Insufficient data to determine eligibility under Criterion 6

Evidence:

Sea-level rise will lead to inundation of parts of the coastal zone, foredune erosion and retreat and saline intrusion into coastal waterways and wetlands via surface flow, storm tide and incursion into the freshwater unconfined aquifer. Low-elevation coastal floodplains and estuaries will be affected. At least 54% of remnant occurrences of the Karst Springs and Alkaline Fens are estimated to be at ≤ 2 m elevation above current sea-level (BOM 2017). A study of a coastal groundwater dependent ecosystem on the lower south east of South Australia by Harding et al. (2015), noted a 2050 projection of a 0.3m increase in sea water level would result in coastal dune retreat of 18 to 28 m and 51 to 81 m in a 1 in 100 year storm surge. Although Harding et al. (2015) concluded direct impacts of the study area due to sea water inundation was unlikely under this scenario, storm surge water could potentially influence the wetland basin via outlet drains. This is likely to be a more significant issue by 2100.Caton et al. 2011 estimated a 0.20 metre sea-level rise by 2030 and a sea-level rise of 0.80 metres by 2070 leading to an increase of tidal flooding to some coastal swamps from the Victorian border to the Coorong. Wetlands with low elevation and/or with drains or outflows streams to the marine environment, such as Eight Mile Creek complex and Piccaninnie Ponds complex were at greatest risk of tidal flooding particularly during extreme storm events. However, revised estimates taking into account terrestrial coastal structures such as dune stability and height and the marine environment, i.e. seabed and currents, indicated that by 2070 sea-level rise for the coastal areas between Portland (Vic) and Victor Harbour (SA) would be 0.30 (low) to 0.45 (high) metres (CSIRO and Bureau of Meteorology 2017). Under this scenario, the impacts from direct overland seawater inundation is not likely for the majority (< 10%) of the ecological community due to landscape position, structure of outflow streams and stream volume (CSIRO and Bureau of Meteorology 2015; NCCARF 2017; Coastal Risk Australia 2019).

Direct flooding from sea-level rise can be projected for the ecological community with a risk of impacts to low lying locations where some occurrences of the ecological community are located. However, there is no quantitative analysis of tidal incursions for the entire geographic distribution of the Karst springs and alkaline fens. In addition, there is little data available for salinity levels and its origins, for example seawater intrusion of groundwater, for most remnant areas. As such, there is insufficient information for the relevant timeframes to determine the eligibility of the ecological community for listing under this criterion.

No quantitative IUCN analysis was available to assess the risk of collapse to the ecological community. Under Criterion E, the status of the ecological community was concluded to be Data Deficient (DD) (Bonifacio and Pisanu in Keith et al. 2013).

6.2 Recovery plan recommendation

A recovery plan is not recommended for this ecological community at this time.

The main threats to the ecological community and the priority actions required to address them are largely understood.

The Conservation Advice sufficiently outlines the priority actions needed for this ecological community and many of the threats affecting the ecological community are best managed at a landscape scale, coordinated with management of other ecological communities. In addition, a number of existing documents are relevant to the management and/or recovery of this ecological community or the threats to it, outlined in section 4.4.

Therefore, listing under national environment law, provision of the information contained within this Conservation Advice and implementation of the priority conservation actions are sufficient to guide protection and recovery of this ecological community.

7 APPENDIX A - SPECIES LISTS

This Appendix lists the assemblage of native species that characterises the ecological community throughout its range at the time of listing, particularly characteristic and frequently occurring vascular plants at section 7.1 and macroscopic animals at section 7.2 (based on the sources cited). The ecological community also includes fungi, cryptogamic plants and other species; however, these are relatively poorly documented.

The species listed in section 7.1 and 7.2 may be abundant, rare, or not necessarily be present in any given occurrence of the ecological community, and other native species not listed here may be present.

Species presence and relative abundance varies naturally across the range of the ecological community based on factors such as historical biogeography, soil properties (e.g. moisture, chemical composition, texture, depth and drainage), topography, hydrology and climate. They also change over time, for example, in response to disturbance (by drainage, fire, or grazing), or to the climate and weather (e.g. seasons, floods, drought and extreme heat or cold). The species recorded at a particular site can also be affected by sampling scale, season, effort and expertise. In general, the number of species recorded is likely to increase with the size of the site.

Scientific names used in this Appendix are nationally accepted names as per the Atlas of Living Australia, as at the time of writing.

7.1 Flora

Table 1. Characteristic and frequently occurring flora

Scientific name	**Common name**
Upper layer (*canopy trees and shrubs >1m; typically > 5m*)	
Eucalyptus ovata	Swamp Gum
Leptospermum lanigerum	Silky Tea-tree, Woolly Tea-tree, Wiriyu (B), Punung (G)
Leucopogon parviflorus	Coast Beard-heath, Ngu(r)li
Melaleuca halmaturorum	Blistered Paper-Bark
Melaleuca squarrosa	Scented Paper-bark
Ozothamnus ferrugineus	Tree Daisy
Groundlayer (*herbs and shrubs typically <1m*)	
Acaena novae-zelandiae	Bidgee-widgee
Asperula subsimplex	water Woodruff
Brachycome graminea	Grass Daisy
Centella cordifolia	Centella
Epilobium billardieranum ssp. *billardieranum*	Variable Willow-herb
Epilobium pallidiflorum	Showy Willow-herb
Goodenia humilis	Swamp Goodenia
Hydrocotyle laxiflora	Stinking Pennywort
Hydrocotyle muscosa	Mossy Pennywort

Scientific name	**Common name**
Hydrocotyle pterocarpa	Wing Pennywort
Hydrocotyle sibthorpioides	Shining Pennywort
Hydrocotyle verticillata	Pennywort
Leptinella spp.	Cotula
Lilaeopsis polyantha	Australian Lilaeopsis
Lobelia anceps syn *Lobelia alata*	Angled Lobelia
Persicaria sp.	Smartweed, Knotweed
Prasophyllum frenchii	Maroon leek-orchid
Pterostylis tenuissima	Swamp Greenhood
Ranunculus amphitrichus	Water Buttercup
Ranunculus inundatus	River Buttercup
Ranunculus papulentus	Large River Buttercup
Ranunculus pentandrus var. *pentandrus*	Inland Buttercup, Smooth Buttercup
Ranunculus sessiliflorus	Smallflower Buttercup
Ranunculus spp.	Buttercups
Samolus repens	Creeping Brookweed
Senecio biserratus	Jagged Fireweed
Tetragonia implexicoma	Bower spinach
Urtica incisa	Scrub Nettle
Viola hederacea	Native Violet
Grasses, sedges and rushes	
Amphibromus recurvatus	Dark Swamp Wallaby-grass
Baumea articulata	Jointed Twig-sedge
Baumea arthrophylla	Fine Twig-sedge
Baumea juncea	Bare Twig-sedge
Baumea laxa	Lax Twig-sedge
Baumea rubiginosa	Soft Twig-sedge
Carex fascicularis	Tassel Sedge
Cladium procerum	Leafy Twig-rush
Crassula helmsii	Swamp Stonecrop
Cyperus laevigatus	Boredrain Sedge
Eleocharis acuta	Common Spikerush
Eleocharis gracilis	Slender Spike-sedge
Eleocharis sphacelata	Tall Spikerush, Ma-bil, Kaya
Gahnia clarkei	Tall Saw-sedge

Scientific name	Common name
Gahnia trifida	Cutting Grass
Isolepis fluitans	Floating Club-sedge
Isolepis platycarpa	Flat-fruit Club-sedge
Juncus procerus	Tall Rush
Juncus spp.	Rush
Phragmites australis	Common Reed
Schoenoplectus pungens	Sharpleaf Rush, Sharp Club-rush, Three-Square
Schoenoplectus tabernaemontani syn. *Schoenoplectus validus*	River Club-rush
Schoenus spp.	Bog-sedge
Triglochin striata	Streaked Arrowgrass
Typha domingensis	Bulrush, Narrowleaf Cumbungi, Mir-nat (B), Yumatch (G)
Typha orientalis	Bulrush, Broadleaf Cumbungi
Aquatic	
Callitriche spp.	Water-starwort
Cycnogeton procerum syn. *Triglochin procerum*	Water Ribbons
Cycnogeton spp. syn. *Triglochin procera* s.l.	Water Ribbons
Isolepis inundata	Swamp Club-rush
Lemna disperma	Common Duckweed
Lemna minor	Lesser Duckweed, Common Duckweed
Lemna trisulca	Ivy Leaf Duckweed
Lepilaena australis syn. *Althenia australis*	Austral Water-mat
Lepilaena cylindrocarpa syn. *Althenia cylindrocarpa*	Water Mat
Myriophyllum crispatum	Upright Water Milfoil
Myriophyllum salsugineum	Amphibious Water Milfoil
Myriophyllum simulans	Water Milfoil
Myriophyllum variifolium	Varied Water Milfoil
Myriophyllum verrucosum	Red Water Milfoil
Myriophyllum spp.	Water Milfoils
Potamogeton ochreatus	Blunt Pondweed
Ruppia polycarpa	Water Tassel
Spirodela punctata	Thin Duckweed
Stuckenia pectinata syn. *Potamogeton pectinatus*	Fennel Pondweed, Sago Pondweed
Vallisneria australis syn.*Vallisneria spiralis*	Ribbon Weed

Scientific name	Common name
Wolffia sp.	Duckweed
Algae	
Abaena spp.	
Anabaena spp.	
Batrachospermum boryanum	
Chaetomorpha linum	
Chara globularis	
Cladophora aegagropila	
Enteromorpha intestinalis	
Enteromorpha prolifera	
Lyngbya spp.	
Oscillatoria spp.	
Porphysiphon spp.	
Spirogyra spp.	
Vaucheria spp.	

Source: Scholz 1990; Bachmann 2002; Foulkes and Heard 2003; Ecological 2009; Aldridge et al. 2011; Butcher et al. 2011a; Butcher et al. 2011b; Bachmann et al. 2015; DEWLP 2016; Austral Research and Consulting (2019); DELWP 2019b.

Table 11. Threatened flora (at May 2020)

Scientific name	Common name	SA	Victoria	National
Myriophyllum variifolium		Near threatened		
Prasophyllum frenchii	Maroon Leek-orchid	Endangered	Endangered	Endangered
Pterostylis tenuissima	Swamp Greenhood	Vulnerable	Vulnerable	Vulnerable
Ranunculus inundatus	River Buttercup	Near threatened		
Triglochin procerum syn *Cycnogeton procerum*	Water Ribbons	Near threatened		

Source: SA: National Parks and Wildlife Act 1972; VIC: Flora and Fauna Guarantee Act 1988; National: Environment Protection and Biodiversity Conservation Act 1999.

Table 12. Weed species that may occur in or adjacent to the ecological community

Scientific name	Common name
Anagallis arvensis syn *Lysimachia arvensis*	Pimpernel
Asparagus asparagoides	Bridal Creeper (WONS)
Berula erecta	Lesser Water-parsnip
Centaurium erythraea	Common Centaury
Cirsium vulgare	Spear Thistle

Scientific name	Common name
Coprosma repens	Mirror Bush
Cotoneaster glaucophyllus	Cotoneaster
Dipogon lignosus	Dolichos Pea
Euphorbia paralias	Sea Spurge
Festuca arundinacea	Tall Fescue, Williams Grass
Holcus lanatus	Yorkshire Fog Grass
Hypochoeris radicata	Cat's Ear
Juncus acutus	Spikey Rush
Juncus articulata	Jointleaf Rush
Leontodon saxatilis	Hairy Hawkbit
Lolium rigidium	Rye Grass
Lycium ferocissimum	African Boxthorn (WONS)
Lythrum junceum	Mediterranean Loosestrife
Lysimachia arvensis syn *Anagallis arvensis*	Scarlet Pimpernel
Phalaris aquatica	Bulbous Canary-grass
Poa pratensis	Kentucky Blue Grass
Polygala myrtifolia	Polygala
Polypogon monspeliensis	Annual Beard Grass
Prunella vulgaris	Self-heal
Rhamnus alaternus	Italian Buckthorn
Rorippa nasturtium-aquaticum syn. *Nasturtium officinale*	Watercress
Rosa rubiginosa	Briar Rose
Rubus fruticosa	Blackberry (WONS)
Sonchus oleraceus	Common Sow-thistle
Trifolium fragiferum var. *fragiferum*	Strawberry Clover
Trifolium subterraneum	Subterranean Clover
Ulex europaeus	Gorse
Zantedeschia aethiopica	Arum Lilly

Source: Bachmann 2002; Foulkes and Heard 2003; Taylor 2006; Butcher et al. 2011a; Sweeney 2013; Bachmann et al. 2015; DELWP 2018a.

7.2 Fauna

Some species may be resident in Karst springs and fens and use it as key habitat while other species may only be transient within the ecological community.

Table 13. Fauna that may occur in the ecological community
Bk – Boandik, G – Gunditjmara
B – Bonn, C – CAMBA, CE – Critically Endangered, E – Endangered, J – JAMBA, M – Migratory, T – Threatened, NT – Near Threatened, R – ROCAMBA, Ra – Rare, V = Vulnerable

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Mammals				
Antechinus minimus maritimus	Swamp Antechinus	V	E	T
Austronomus australis	White-striped Freetail Bat			
Chalinolobus gouldii	Gould's Wattled Bat			
Chalinolobus morio	Chocolate Wattled Bat			
Hydromys chrysogaster	Water Rat/Rakali, murung (G)			
Isoodon obesulus obesulus	Southern Brown Bandicoot (eastern), Kari, Karuwi	E	V	
Macropus fuliginosus	Western Grey Kangaroo, Kuwayn (Bk)			
Miniopterus orianae bassanii	Southern Bentwing Bat	CE	E	CE
Myotis macropus	Large-footed Myotis			
Nyctophilus geoffroyi	Lesser Long-eared Bat			
Ozimopos planiceps syn *Mormopterus planiceps*	South-eastern Free-tailed Bat/Little Mastif Bat			
Potorous tridactylus tridactylus	Long-nosed Potoroo, Paruk (G)	V	E	T
Rattus fuscipes	Bush Rat			
Rattus lutreolus	Swamp Rat			
Tachyglossus aculeatus	Short-beaked Echidna, Wilangalak (G)			
Wallabia bicolor	Swamp Wallaby		V	
Birds				
Acanthagenys rufogularis	Spiny-cheeked Honeyeater			
Acanthiza chrysorrhoa	Yellow-rumped Thornbill			
Acanthiza lineata	Striated Thornbill			
Acanthiza pusilla	Brown Thornbill			

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Accipiter cirrocephalus	Collared Sparrowhawk			
Accipiter fasciatus	Brown Goshawk			
Acrocephalus australis	Australian Reed-Warbler	B		
Alauda arvensis	Eurasian Skylark			
Anas castanea	Chestnut Teal			
Anas gracilis	Grey Teal, Krayn (G)			
Anas superciliosa	Pacific Black Duck, Turna (B), Muyi (G)			
Anseranas semipalmata	Magpie Goose, Patom (Bk)		E	NT
Anthochaera carunculata	Red Wattlebird			
Anthochaera chrysoptera	Little Wattlebird			
Anthus novaeseelandiae	Australasian Pipit			
Antigone rubicunda	Brolga, Wandi, Kurun		V	V
Apus pacificus	Pacific Swift	C, J, R		
Aquila audax	Wedge-tailed Eagle, Ngiri (Bk), Ngiyanggar(a) (G)			
Ardea alba	Great Egret			
Ardea pacifica	White-necked Heron, (Pangka (G)			
Arenaria interpres	Ruddy Turnstone	M, B, C, J, R	Ra	V
Aythya australis	Hardhead			V
Biziura lobata	Musk Duck, Krum (Bk), Puripart (G)		Ra	V
Botaurus poiciloptilus	Australasian bittern, Pulan (G)	E	V	E
Bubulcus ibis	Cattle Egret			
Cacatua tenuirostris	Long-billed Corella, Kurukitj			
Cacomantis flabelliformis	Fan-tailed Cuckoo			
Calamanthus fuliginosus	Striated Fieldwren			
Calidris acuminata	Sharp-tailed Sandpiper	M, B, C, J, R		
Calidris alba	Sanderling	M, B, C, J, R	Ra	NT
Calidris ferruginea	Curlew Sandpiper, Wiruk (G)	CE, M, B, C, J, R		E
Calidris ruficollis	Red-necked Stint	M		
Caligavis chrysops	Yellow-faced Honeyeater			

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (s266B)

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Cereopsis novaehollandiae	Cape Barren Goose		Ra	
Ceyx azureus	Azure Kingfisher		E	NT
Chalcites basalis	Horsfield's Bronze-cuckoo			
Chalcites lucidus	Shining Bronze-cuckoo			
Charadrius bicinctus	Double-banded Plover	B		
Charadrius ruficapillus	Red-capped Plover			
Chenonetta jubata	Australian Wood Duck, Pinyang(g)u (Bk), Ngawuk (G)			
Chlidonias hybrida	Whiskered Tern	M		
Chlidonias leucopterus	White-winged Black Tern	M, C, J, R		NT
Chroicocephalus novaehollandiae	Silver Gull			
Cincloramphus cruralis	Brown Songlark			
Cincloramphus mathewsi	Rufous Songlark			
Circus approximans	Swamp Harrier	M		
Cisticola exilis	Golden-headed Cisticola			
Colluricincla harmonica	Grey Shrike-thrush			
Coracina novaehollandiae	Black-faced Cuckoo-shrike			
Cormobates leucophaea	White-throated Treecreeper			
Corvus coronoides	Australian Raven, Waa (G)			
Corvus mellori	Little Raven			
Corvus tasmanicus	Forest Raven			
Cygnus atratus	Black Swan, Kunuwara (G)			
Dacelo novaeguineae	Laughing Kookaburra, Kuwatang (B), Kunith (G)			
Dasyornis broadbenti	Rufous Bristlebird			T
Egretta garzetta	Little Egret		Ra	T
Egretta novaehollandiae	White-faced Heron			
Elanus axillaris	Black-shouldered Kite			
Elseyornis melanops	Black-fronted Dotterel			
Eolophus roseicapilla	Galah			

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (s266B)

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Eopsaltria australis	Eastern Yellow Robin, Pulun potj (G)			
Epthianura albifrons	White-fronted Chat			
Erythrogonys cinctus	Red-kneed Dotterel			
Falco berigora	Brown Falcon			
Falco cenchroides	Nankeen Kestrel			
Falco longipennis	Australian Hobby			
Falco peregrinus	Peregrine Falcon		Ra	
Falcunculus frontatus	Crested Shrike-tit		Ra	
Fulica atra	Eurasian Coot, Kuwayi, Kuwi (G)			
Gallinago hardwickii	Latham's Snipe	B, J, R	Ra	NT
Gallinula tenebrosa	Dusky Moorhen			
Gavicalis virescens	Singing Honeyeater			
Grallina cyanoleuca	Magpie-lark, T(j)ulip (G)			
Gymnorhina tibicen	Australian Magpie, Kilin (Bk), Kiri (G)			
Haematopus fuliginosus	Sooty Oystercatcher		Ra	NT
Haematopus longirostris	Australian Pied Oystercatcher		Ra	
Haliastur sphenurus	Whistling Kite			
Hieraaetus morphnoides	Little Eagle			
Himantopus leucocephalus	Black-winged Stilt			
Hirundapus caudacutus	White-throated Needletail	V, C, J, R		V
Hirundo neoxena	Welcome Swallow, wiyt-wiyt (G)			
Hydroprogne caspia	Caspian Tern	J		NT
Hypotaenidia philippensis	Buff-banded rail			
Larus pacificus	Pacific Gull			
Lewinia pectoralis	Lewin's Rail		V	T
Malurus cyaneus	Superb Fairy-wren, Partpartitj (G)			
Melithreptus brevirostris	Brown-headed Honeyeater			
Microcarbo melanoleucos	Little Pied Cormorant			
Mirafra javanica	Horsfield's Bushlark			

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Morus serrator	Australasian Gannet, Pakurum (G)			
Neochmia temporalis	Red-browed Finch			
Neophema chrysogaster	Orange-bellied Parrot	CE	E	CE
Neophema chrysostoma	Blue-winged Parrot		V	
Neophema elegans	Elegant Parrot		Ra	
Nesoptilotis leucotis	White-eared Honeyeater			
Nycticorax caledonicus	Nankeen Night-Heron			
Ocyphaps lophotes	Crested Pigeon, Kuren (Bk), Warik (G)			
Oriolus sagittatus	Olive-backed Oriole		Ra	
Pachycephala olivacea	Olive Whistler		V	
Pachycephala pectoralis	Golden Whistler			
Pachycephala rufiventris	Rufous Whistler			
Pelecanus conspicillatus	Australian Pelican, Kart pirap (G)	M		
Petrochelidon ariel	Fairy Martin			
Petrochelidon nigricans	Tree Martin			
Pezoporus wallicus	Eastern Ground Parrot		E	T
Phalacrocorax carbo	Great Cormorant, Kruwandam (Bk), Walongkarang (G)			
Phalacrocorax sulcirostris	Little Black Cormorant, Ngapkuwi mi-iyar (G)			
Phalacrocorax varius	Pied Cormorant			NT
Phaps elegans	Brush Bronzewing, Kuri (G)			
Phylidonyris novaehollandiae	New Holland Honeyeater			
Platalea flavipes	Yellow-billed Spoonbill			
Platalea regia	Royal Spoonbill, Kuruk kunawar (G)			NT
Platycercus elegans	Crimson Rosella, Kart-karti (G)			
Podiceps cristatus	Great Crested Grebe		Ra	
Poliocephalus poliocephalus	Hoary-headed Grebe			
Poodytes gramineus	Little Grassbird			

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Porphyrio melanotus	Australasian Swamphen			
Porzana fluminea	Australian Spotted Crake			
Psephotus haematonotus	Red-rumped Parrot			
Ptilotula penicillata	White-plumed Honeyeater			
Rhipidura fuliginosa	Grey Fantail			
Rhipidura leucophrys	Willie Wagtail, Prin-prin (G)			
Sericornis frontalis	White-browed Scrubwren			
Spatula rhynchotis	Australasian Shoveler			
Stagonopleura bella	Beautiful Firetail		Ra	
Sternula albifrons	Little Tern	B, C, J, R	E	T
Stictonetta naevosa	Freckled Duck		V	E
Stipiturus malachurus	Southern Emu-wren, Wirinwit (G)		V	
Streptopelia chinensis	Spotted Dove			
Synoicus ypsilophora	Brown Quail, Pirm-pirm (Bk), Talyawart (G)			
Tachybaptus novaehollandiae	Australasian Grebe			
Tadorna tadornoides	Australian Shelduck	M		
Thalasseus bergii	Crested Tern	J		
Threskiornis moluccus	Australian White Ibis, Tirim kuwi (G)			
Threskiornis spinicollis	Straw-necked Ibis			
Todiramphus sanctus	Sacred Kingfisher, Panpan kuna-mang (G)			
Tribonyx ventralis	Black-tailed Nativehen			
Tringa glareola	Wood sandpiper	M, B, C, J, R	Ra	V
Vanellus miles	Masked Lapwing			
Vanellus tricolor	Banded Lapwing			
Zapornia tabuensis	Spotless Crake			
Zosterops lateralis	Silvereye			
Amphibians				
Crinia signifera	Common Eastern Froglet			
Geocrinia laevis	Smooth Frog		NT	
Limnodynastes dumerilii	Eastern Banjo Frog, Pupatu thuwinam (Bk)			

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Limnodynastes peronii	Brown-Striped Frog			
Limnodynastes tasmaniensis	Spotted Grass Frog			
Litoria ewingii	Brown Tree Frog			
Litoria raniformis	Growling Grass Frog, Southern Bell Frog	V	V	
Neobatrachus pictus	Painted Frog			
Neobatrachus sudellae	Sudell's Frog			
Reptiles				
Acritoscincus duperreyi	Eastern Three-Lined Skink			
Amphibolurus muricatus	Jacky Lizard		NT	
Anepischetosia maccoyi syn *Nannoscincus maccoyi*	Highlands Forest Skink/Salamander Skink		E	
Austrelaps superbus	Lowland Copperhead			
Bassiana duperreyi	Eastern Three-lined Skink			
Chelodina longicollis	Eastern Long-Necked Turtle, Puwat			
Drysdalia coronoides	White-Lipped Snake		NT	
Eulamprus tympanum	Southern Water Skink		NT	
Hemiergis peronii	Lowlands Earless Skink			NT
Lerista bougainvillii	South-Eastern Slider			
Liopholis whitii	White's Skink			
Lissolepis coventryi	Swamp Skink/Eastern Mourning Skink		E	T
Notechis scutatus	Tiger Snake, Wangaluk (G)			
Pseudemoia entrecasteauxii	Southern Grass Skink			
Pseudomoia rawlinsoni	Glossy Grass Skink		E	NT
Pseudonaja textilis	Eastern Brown Snake			
Tiliqua nigrolutea	Blotched Blue-Tongue, Warr yuruk			
Tiliqua rugosa	Sleepy Lizard			
Fish				
Acanthopagrus butcheri	Black Bream			

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Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Afurcagobius tamarensis	Tamar River Goby			
Aldrichetta forsteri	Yelloweye Mullet			
Anguilla australis	Southern Shortfin Eel, kuya (Bk), kuyang (G)			
Atherinosoma microstoma	Smallmouth Hardyhead			
Gadopsis marmoratus	River Blackfish, Yeri tjaa (G)			
Galaxias brevipinnis	Climbing Galaxias			
Galaxias maculatus	Common Galaxias			
Galaxias truttaceus	Trout Galaxias			
Galaxiella pusilla	Dwarf Galaxias	V		T
Galaxiella toourtkoourt	Little Galaxias			
Geotria australis	Pouched Lamprey			
Mordacia mordax	Shorthead Lamprey, Kuyang dak (G)			
Nannoperca australis	Southern Pygmy Perch			
Nannoperca obscura	Yarra Pygmy Perch	V		T
Nannoperca variegata	Ewen Pygmy Perch	V		T
Neochanna cleaveri	Australian Mudfish			T
Prototroctes maraena	Australian Grayling	V		T
Pseudaphritis urvillii	Congolli			
Pseudogobius olorum	Bluespot Goby			
Tasmanogobius lasti	Scary's Tasmangoby			
Arthropods (See Bachmann 2002)				
Adversaeschna brevistyla	Blue-spotted Hawker			
Amarinus lacustris	Freshwater Crab			
Amarinus spp.	Freshwater Crab			
Amegilla pulchra	Blue-banded Bee			
Arrenurus spp.				
Atalophlebia aurata	Mayfly			
Atalophlebia australis	Mayfly			
Atriplectides dubius	Caddisfly			
Austroagrion spp.	A damselfly			
Austrocerca tasmanica	A stonefly			
Austrogammarus spp.	An amphipod crustacean			

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Austrolestes analis	Slender Ringtail			
Austrolestes annulosus	Blue Ringtail			
Austrolestes psyche	Cup Ringtail			
Austrolestes spp.	A damselfly			
Austropyyrgus spp.	Freshwater snail			
Austrosimulium furiosum	Blackfly			
Candalides hyacinthinus form *Josephina*			Ra	
Candalides hyacinthinus	Common Dusky Blue			
Chironomus spp.	Midges			
Centroptilum elongatum	Baetid mayfly			
Crocothemis nigrifrons	Black-headed skimmer			
Diemeniana euronotiana	Velvetback			
Dinotoperla brevipennis	A stonefly			
Diplacodes bipunctata	Wandering Percher			
Dispar compacta	Barred Grass Skipper			
Diplacodes melanopsis	Black-headed Percher			
Dixidae family	Midges			
Engaeus sericatus	Hairy Burrowing Crayfish			V
Engaeus strictifrons	Portland Burrowing Crayfish			V
Erina hyacinthina hyacinthina			Ra	
Euastacus bispinosus	Glenelg Spiny Freshwater Crayfish, Konkro	E	Cr	
Geitoneura klugii	Klug's Xenica			
Geocharax spp.	A swamp yabby			
Haliplus gibbus	A water beetle			
Hellyethira simplex	A caddisfly			
Hemicordulia tau	Tau Emerald			
Hemiphlebia mirabilis	Ancient Greenling			
Hemianax papuensis	Australian Emperor			
Hesperilla chrysotricha	Golden-Haired Sedge-Skipper			
Hesperilla donnysa	Varied Sedge-Skipper			
Hesperilla idothea idothea	Flame Sedge-Skipper			

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Heteronympha cordace wilsoni	Bright-eyed Brown			
Heteronympha merope merope	Common Brown			
Heteronympha penelope penelope	Shouldered Brown			T
Hydrodroma spp.	A freshwater crab			
Hygrobia spp.	An aquatic beetle			
Ischnura aurora	Aurora Blue-tail			
Ischnura heterosticta	Common Blue-tail			
Junonia villida	Meadow Argus			
Koorrnonga pilosa	A mayfly			
Lampides boeticus	Long-tailed Pea-blue			
Lingora aurata	A caddisfly			
Lingora spp.	Caddisflies			
Nacaduba biocellata biocellata	Doublespotted Lineblue			
Nacaduba biocellata	Two-spotted Line-blue			
Notalina spira	A caddisfly			
Nousia fuscula	A mayfly			
Ocybadistes walkeri hypochlora	Dart			
Offadens spp.	Mayflies			
Oreixenica kershawi kununda	Striped Xenica		V	
Oreixenica lathoniella	Silver Xenica			
Oribatida order	Moss mites			
Orthetrum caledonicum	Blue Skimmer			
Oxus spp.	A water mite			
Paracalliope spp.	An amphipod crustacean			
Paratya australiensis	Australian Paratya, Glass Shrimp, Yapitj (G)			
Procordulia jacksoniensis	Eastern Swamp Emerald			
Rheotanytarsus spp.	Chironomid midge			
Simulium ornatipes	A blackfly			
Synthemis eustalacta	Swamp Tiger-tail			

Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Taractrocera papyria papyria	White-Banded Grass-Dart		Ra	
Taschorema Complex	Caddisflies			
Theclinesthes serpentatus	Salt-bush blue			
Thraulophlebia conspicua	A mayfly			
Thraulophlebia inconspicua	A mayfly			
Tisiphone abeona albifasci	Sword-Grass Brown		V	
Trapezites symmomus	Splendid Ochre			
Trapezites symmomus soma	Symmomus Rush-skipper			
Triplectides australis	A caddisfly			
Ulmerophlebia pipinna	A mayfly			
Vanessa itea	Australian Admiral			
Vanessa kershawi	Australian Painted Lady			
Yoyetta abdominalis	Tea-tree Firetail			
Zizina otis labradus	Common Grass-blue			
Molluscs				
Ascorhis tasmanica	A freshwater snail			
Chloritobadistes victoriae	A freshwater snail			
Elsothera funerea	A freshwater snail			
Emmalena tumidula	A carnivorous land snail			
Excellaoma retipora	A freshwater snail			
Glyptophysa spp.	A freshwater snail			
Glyptophysa gibbosa	Narracan River corrugated mussel			
Gratilaoma aslini	A freshwater snail			
Gratilaoma globula	A freshwater snail			
Huntiana murrayana	A freshwater snail			
Hyridella narracanensis	Southern River Mussel, Wataru (Bk), Thimbun (G)			
Laomavix collisi	Collis' pinhead snail (L)			
Magilaoma penolensis	Penola pinhead snail (L)			
Musculium (*Sphaerinova*) *tasmanicum tasmanicum*	A freshwater snail			

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Scientific name	Common/Indigenous name	Conservation status (at May 2020)		
		EPBC Act	SA	VIC
Paralaoma caputspinulae	Prickle pinhead snail (L)			
Pisidium (*Euglesa*) *etheridgei*	A freshwater snail			
Posticobia spp.	A freshwater snail			
Prolesophanta dyeri	Dyer's Carnivorous Snail (L)			
Robinsoniana speranda	Adelaide Pinwheel Snail			
Scelidoropa gatliffi	Gatliff'S Pinwheel Snail (L)			
Scelidoropa officeri	Circular Head Pinwheel Snail			
Scelidoropa tamarensis	Tamar River Pinwheel Snail (FW)			
Sphaeriidae family	A pea mussel			
Succinea australis	A land snail			

Source: Smith and Kershaw 1979; Bachmann 2002; Foulkes and Heard 2003; Churchill 2008; Butcher et al. 2011b; Bachmann et al. 2015; Wilson and Swan 2010; Aldridge et al. 2011; Whiterod and Hammer 2012; Haywood and Richter 2013; Veale and Whiterod 2014; Atlas of Living Australia 2018; Grund 2019.

8 APPENDIX B - RELATIONSHIP TO OTHER VEGETATION CLASSIFICATION AND MAPPING SYSTEMS

Ecological communities are complex to classify. Reference to vegetation and mapping units as equivalent to the ecological community, at the time of listing, should be taken as indicative rather than definitive. A unit that is generally equivalent may include elements that do not meet the key diagnostics and minimum condition thresholds. Conversely, areas mapped or described as other units may sometimes meet the key diagnostics for the ecological community. Judgement of whether the ecological community is present at a particular site should focus on how the site meets the description (section 2), the key diagnostic characteristics (section 5.1.1) and minimum condition thresholds (section 5.2.1).

On-ground assessment is vital to finally determine if any wetland occurrence is part of the ecological community.

8.1 Relationship to the National Vegetation Information System (NVIS)

Under the National Vegetation Information System (NVIS), vegetation associated with the Karst Rising Springs can be classified within:

Major Vegetation Group (MVG)

- 17 – Other Shrublands
- 21 – Other Grasslands, Herblands, Sedgelands and Rushlands

Major Vegetation Subgroup (MVS)

- 32 – Other shrublands
- 38 – Wet tussock grassland with herbs, sedges or rushes, herblands or ferns
- 58 – Leptospermum forests and woodlands
- 63 – Sedgelands, rushes or reeds
- 64 – Other grasslands

8.2 Relationship to South Australian vegetation classifications

There are no vegetation types formally recognised as threatened in South Australia which correspond with the national ecological community. However, the Karst springs and alkaline fens corresponds best to the following vegetation types noted in the Provisional List of Threatened Ecosystems in South Australia (Native Vegetation Council 2019):

- *Baumea arthrophylla* Sedgeland in drainage lines and depressions – Vulnerable
- Freshwater wetlands eg *Triglochin procerum* Herbland – Endangered
- *Gahnia filum* Sedgeland in drainage lines and depressions – Vulnerable
- *Gahnia trifida* Sedgeland in drainage lines and depressions – Endangered
- *Leptospermum lanigerum* Closed Shrubland in non-saline wetlands – Endangered

South East Regional Floristic descriptions that correspond to the ecological community include:

- SE0019 – *Leptospermum lanigerum*, *Ozothamnus ferrugineus*, +/-*Leucopogon parviflorus* tall shrubland over *Epilobium billardierianum* ssp. *billardierianum*, *Acaena novae-zelandiae* forbs
- SE0023 – *Typha domingensis* tall closed sedgeland over *Samolus repens*
- SE0083 – *Baumea juncea, +/-Gahnia trifida* mid sedgeland

- SE0098 – *Phragmites australis*, *Typha domingensis* tall grassland

The national ecological community may also include the following wetland vegetation components (WVC) (Ecological Associates 2009; Harding unpublished):

- WVC 1.6 – *Leptospermum lanigerum* tall wet shrubland
- WVC 1.9 – *Gahnia trifida* tussock sedgeland
- WVC 1.11 – Freshwater emergent sedgeland
- WVC 2.16 – *Melaleuca squarrosa* wet heathland
- WVC 2.17 – Typha/Phragmites tall aquatic grassland
- WVC 2.18 – Karst rising spring – open water component

  WVC 2.20 – Freshwater open aquatic herbland

8.3 Relationship to Victorian vegetation classifications

The Karst springs and alkaline fens corresponds with the Victorian wetland Ecological Vegetation Class (EVC):

- Swamp Scrub (EVC 53) - Bioregional conservation status of Endangered in the Bridgewater Bioregion

The following Ecological Vegetation Classes may also be included as part of the Karst springs and alkaline fens when predominantly hydrologically supported by the tertiary unconfined aquifer:

- Calcareous Sedgy Shrubland (EVC A106)
- Aquatic Sedgeland (EVC 308)
- Calcareous Wet Herbland (EVC 591)
- Aquatic Herbland (EVC 653)
- Tall Marsh (EVC 821)
- Sink-hole Wetland (EVC 908)
- Submerged Aquatic Herbland (EVC 918)
- Gahnia Sedgeland (EVC 968)
- Swamp Scrub / Gahnia Sedgeland Complex (EVC 2004)

9 APPENDIX C - INDIGENOUS PEOPLE, CULTURAL VALUES AND THE KARST SPRINGS AND ALKALINE FENS ECOLOGICAL COMMUNITY

9.1 Traditional custodians

The Indigenous people of south east South Australia (Boandik – People of the reeds) and south west Victoria (Gunditjmara – which includes the sea country and river forest country) understood and managed their natural landscapes for thousands of years. Archaeological evidence from sites at Budj Bim and Tower Hill Victoria conforms with the Indigenous oral traditions of these regions (Matchan et al. 2019) which indicates a strong and continuing connection with the land and water of the region that dates to about 35,000 years.

9.2 Species of Indigenous cultural value and the traditional use of resources from the ecological community

A wide variety of plant and animal resources from within the Karst springs and alkaline fens were used for food, water, medicinal use and materials to build camps by the Indigenous Boandik and Gunditjmara peoples, some of which were described by Smith (1880). In the region where the ecological community occurs, Indigenous diets fluctuated seasonally as resource availability varied. For example, extensive flooding of the wetland systems occurred during the wet winter months. This made access and habitation difficult in the low swampy areas which contained the Karst springs and alkaline fens. Clarke (2015b) noted that during the warm spring and summer seasons, the availability of wetland food plants like bulrushes and club-rushes were at their highest. Collecting bulrush rhizomes was best undertaken in the wetlands in drier seasons and were pulled by the young stems when the flowering heads were still present. The long pale rhizomes were used as a food source and the chewed fibre kept for string making (Clarke 2015b). Indigenous seasons and resources for south east South Australia and south west Victoria are given in Table 14 and Gunditjmara Country in Table 15.

Some wetland plant species had special uses and cultural associations for local Indigenous people who used the Karst springs and alkaline fens. For example, Aboriginal people used drinking straws that were made from Common Reed (*Phragmites australis*). Smith (1880) noted that this plant was part of Boandik mythology, where the giant being Brit-ngeal drew water from a cave pool with a long drinking reed. Necklaces were also made by threading short sections of thin reeds together which the Boandik refer to as Boo-in kool and Gunditjmara as Taku(r)n. Other known Indigenous uses for some plants that occur in the wetlands of the Bridgewater subregion are given in Table 16 and 17.

For the Boandik, food was classified as either Booang (vegetable) or Tooman (flesh). Booang included roots, tubers, rhizomes, greens, gum, nectar, fruits, seeds and fungi that occurred in the region with many rhizome and greens being seasonally available in the ecological community. Booang were also important food and habitat sources for animal and edible insect species (Clarke 2015b). The animal resources (Tooman) likely to occur in association with the ecological community that were used for food, hides and other resources include swamp wallaby, kangaroo, potoroo, fish, turtle and many waterbird species.

Table 14. Indigenous seasons for south east South Australia and south west Victoria

Season	Month	Event
Kurra Kalalaba Kroynmi_Putha (Kangaroo and grass seed time) Late spring to early summer	November to December	Time of plenty / Land begins to dry from greens to browns Wildflowers and Lilies in flower / Young marsupials are out of the pouch / Birds are feeding their young with baby birds preparing to leave the nest / Kangaroos, wallabies and wombats are active feeding on fresh native grasses and growth / Fish spawning / Set Fish traps as season warms / Bentwing-bats congregate at maternity cave to give birth / Coastal Mallee in Flower / Mistletoes in flower / Grass trees flowering / Whales migrate South to Antarctica / Seed Collecting begins with Native grasses they are tall with seed heads flowering and seeding / Pea flowers begin to seed such as Kennedias, Swansonias, Dillwynia, Pultenaeas etc. / Insects, bees and ants active till Autumn / Echidnas dig for ants / Eucalyptus germinating / Wedge-tailed eagles are breeding / Migrant birds return to Tasmania for breeding season such as Orange-bellied Parrots
Karalaba Wita Karomarna (Shell and wattle seed time) High summer	December to January	Longest day - shortest night / Coastal living / Fishing season abundant with seafood and shellfish / Fire danger season / Wattle seed gathering and Wattle seed damper prepared / Bursaria and Banksia in flower soaked in water to make traditional energy drink / Cumbungi in growth time to gather / Fruiting season: Native Cherry, Currant-bush, Dianella, Elderberry / Seed collecting season: Acacia species, native grasses, Lomandra, Old Man's Beard, Senecio, Pomaderris, Native Geranium, Hop-bush, Velvet-bush. / Season of butterflies / Hooded Plover eggs on beach and chicks hatching until February / Red-tailed Black Cockatoo migrate to Buloke country for season feeding on Buloke (January to March)
Kuyaba Yurrenga Karomarna (Sugar and eel time) Late summer	February to March	Hot temps northerly winds / Coastal living / Fishing season / Fire danger season / Swamps and drains are dry / Water table at its lowest point / Wetlands drying as yabbies and Galaxia hibernate in the mud / Turtles find refuge / Eel trapping season / Moths emerge and provide food for birds and mammals / Seasonal fruit gathering - Muntries, Pigface and Sweet Apple-berry, Coastal dune flower berry, Boobialla and Cherry Ballart / Wattle sap collected for food, resin and glue / Seed collection season: Banksia, Xanthorrhoea, Gahnia and sedges / Blue Gum in flower, Dryland Tea-tree begins to flower / Germination of: Dianella, Gahnia, Current-bush and native grasses
Kulayu Marapina (Cultural ceremonial time) Autumn	April to May	Country starts to cool down / Mild weather / rainbow season / no wind and first rains / cobwebs / dew mornings / Families migrated inland to woodlands and higher ground near wetlands for winter / Set up camps / Gathering together for hunting and cultural ceremony / Make coats from possum and kangaroo skins / Make fish traps / Kangaroos and wallabies feeding on new growth / Reptiles less active / Seed collecting season: Bursaria seed, Coastal Rosemary, Seaberry Saltbush, Cushion bush, Scavola. / Germination of: Lomandra and Banksia seed / Bursaria late May into June / Mistletoe, Cherry Ballart and

Season	Month	Event
		bush tomato fruiting / Sheoak pollinating and Dryland Tea-tree in full flower / In woodlands Heath flowering / Still days first frosts / Soil warmth and rainy days bring fungi and mushrooms / Waterholes filling up and animals moving to higher ground / Birds flock and migrate north / Orange-bellied parrot start migration to the mainland across Bass Strait – over wintering and feeding on Coastal wetlands in Victoria and Southern South Australia / Snakes go into hibernation / Eagles building nests / Possums mating / Prepare ground for planting season / firestick farming / mammals are active feeding on fresh growth / Emus nesting
Karueu Ngulaba Karipamu (Emu camp and story time) Deep winter	June to August	Wettest and coldest time of year / Longest night and shortest day / Sun is low and shadows long / Wetlands and drains flowing at highest point / Ground water levels rise and swell / Rock shelters and caves were used for winter shelter / Sitting by the fire, campfire stories about creation, lore, hunt and gather and connection to country / Acacias in flower / Collect and sow Knobby Club-rush seed / Bentwing-bats migrate to over wintering caves / Male Emus raising their young ones / Yam Daisy and lily tubers dug, collected and cooked in underground ovens / Honey Pots and Cherry Ballart fruiting / Native spinach lush for picking / Swamp Gums in flower / Southern right whales birthing in southern coastal waters / Echidna train - Echidna breeding season / Birds start building nests and ducks and swans start breeding in August
Kulabas Puthu Karomarna (Egg and orchid time) Mid-early spring	September to October	Longer days and rise in temperature / Change in season brings storms, spring showers and changeable weather / Rainbow season / Brolga pair up for breeding season / Breeding season for many marsupials / Late planting season / Nesting birds / Orchids, Lilies and Yam Daisies begin to flower / Snakes and lizards become active / Tadpole season / Yabbies are crawling and turtles breeding / Kangaroo Apple blossom / Fish traps set / Fish spawning season begins / Egg season / The warmth energises growth and the food chain in wetlands / Germination of Melaleuca, Leptospermum, Allocasuarina, Olearia, Ozothamnus, Hakea, Dodonaea / native grasses, Lily's and all coastal, understory and wetland species / Migrant birds return

Source: Natural Resources South East 2014. Acknowledgement for calendar information and Aboriginal language: Kathy Bell, Doug Nicholls and Des Hartman.

Table 15. The six seasons of Gunditjmara Country (south west Victoria)

Season	Month	Event
Drying out time	November to January	North winds blow and the weather heats up; grasses seed and dry off; reptiles become active.
Big dry	January to April	Waterholes dry up; creeks are at their lowest; eels, yabbies, frogs and turtles retreat into mud; bulrush shoots and orchid tubers are harvested; people move to the coast, feeding on muntries, Coastal Beard Heath and other berries, and seafood.
Early wet	April to June	Heavy dews; burning season; Old Man weed begins to grow in the wetlands.
Big wet	May to September	Heavy rains; rivers and creeks burst their banks; cold days and nights; wetlands fill; frogs call and Brolgas dance.
Flowering time	August to November	Plants bloom, bees and other insects become active; eels swim upstream; birds nest, eggs available; silly winds blow in all directions; tadpoles.
Fattening up	October to November	Chicks and young are reared; fish and eels feed in shallows; grass and shrubs grow; yam daisy and lily tubers are harvested; bees are busy making honey.

Source: Parks Victoria 2015

Table 16. Species of cultural significant that occur in the ecological community.

Scientific name	Common/Indigenous name	Use
Carex spp.	Sedge	Fibres used for baskets, mats and fishtraps
Cycnogeton procerum syn. *Triglochin procerum*	Water Ribbons	Tubers steamed in an earth oven. Small green fruits which develop on the spike can also eaten.
Gahnia spp.	Sedge	Fibres used for baskets, mats and fishtraps
Hyridella narracanensis	Southern River Mussel, Mimit (G)	Food and the shell use for scraping fibres for use as twine.
Isolepis spp.	Sedge	Fibres used for baskets, mats and fishtraps
Juncus spp.	Rush	Fibres used for baskets, mats and fishtraps
Leptospermum lanigerum	Silky Tea-tree, Punung (G), Wiriyu (Bk), Woolly Tea-tree	Straight stems for spear shafts (Wiriyu thir), fishing poles and snaring rods
Leucopogon parviflorus	Coast Beard-heath, Taark (G)	Underground shoots Charr-ak (G) were eaten raw or roasted in coals. The long, straight flowering stems were used for spear shafts.
Persicaria sp.	Smartweed, Knotweed	Edible fruit
Phragmites australis	Common Reed	Stems used for spears (der, jeran, Ponggal) Leaves were used to make bags and baskets
Tetragonia implexicoma	Bower spinach	Foliage and fruit eaten
Typha spp.	Bulrush, Cumbungi, Mirnat	Roots (rhizomes) were steamed in an earth oven, the outer layer was stripped off, and the starchy fibrous inner part was tied in a simple knot. This was then chewed to remove the starch, which tastes like potato. The remaining fibre was dried, soaked, scraped with mussel shells, and then rolled on the thigh to give very strong string for making large nets which were used to catch ducks and fish. Finer string was made from the leaves. The young shoots which appear in early summer were eaten raw.

Source: Smith 1880; Blake 2003a; Blake 2003b; Natural Resources South East 2014; Gale 2014; Clarke 2015a; Clarke 2015b

Table 17. Resources of cultural significance that occur in the Karst springs and alkaline fens

Item	**Bunganditj**	**Gunditjmara**
Catching waterfowl		T(h)irang paki
A woven conical bag/basket for trapping eels		Ngarapayn
Hunting bag made from rush		Pinik
Swamp reed/sedge		Putitj
Spawn of frogs or fish		Tulut
Fishing with a reed spear		Yapin
Reed spear		Thark
Spring (water)		Papkupa paritj
Swamp	Luwung	Manmut
Tea-tree spear	Wiriyu thir	

Source: Smith 1880; Blake 2003a; Blake 2003b; Natural Resources South East 2014; Clarke 2015a; Clarke 2015b

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