9 Phytoplankton Assemblage

9.1 Introduction

This section provides a baseline description of the phytoplankton assemblage of Merimbula Bay based upon a review of existing information and field survey data to address potential concerns from the aquaculture and fishing sector that discharge of treated wastewater may cause an increased risk of phytoplankton blooms and in particular harmful algal blooms (HABs). The regional and local occurrence of phytoplankton blooms and HABs that can be detrimental to aquaculture and humans is discussed, and finally an assessment of potential effects of Project construction and operational phase activities to the phytoplankton assemblage is presented.

9.2 Background

Phytoplankton are a diverse group of microalgae that includes planktonic members of diatoms, dinoflagellates, cyanobacteria (blue-green algae), silicoflagellates and rhapidophytes among many others. They are vital to the primary productivity of aquatic ecosystems and are an important component of biogeochemical and atmospheric CO_2 cycles. Phytoplankton productivity (*i.e.* growth and abundance) is highly variable dependent on hydroclimatic conditions and the supply of essential elements carbon (C), nitrogen (N), phosphorous (P), silica (Si) as well as trace metals and vitamins in approximate C:Si:N:P ratio of 106:15:16:1, known as the Redfield ratio. Nitrogen is generally the limiting nutrient in marine and estuarine systems and increased nutrient supply from diffuse and point source inputs can significantly alter amounts of bioavailable nitrogen and influence the natural background levels of phytoplankton in a waterway. In the Merimbula region, diffuse sources contributing significant amounts of bioavailable nitrogen to the nearshore zone include episodic oceanic upwellings of slope water and catchment flood flow events, while the discharge of treated wastewater would be a point source input. When phytoplankton significantly increase in abundance they are referred to as being in a state of 'bloom'.

Phytoplankton blooms are a growing phenomenon worldwide, in some cases related to increasing eutrophication and modification of water bodies, as well as marine climate change (Gilbert, 2020). Three major types of blooms are distinguished – those that are harmless water discolorations, those that are harmful to marine organisms (*i.e.* fish kills due to clogging of fish gills and/or resulting from anoxic conditions) and those that produce toxins that bioaccumulate in seafood products and that are harmful to humans (Hallegraeff *et. al.* 2003). Harmful algal blooms are referred to as HABs.

Studies have shown that discharge of treated wastewater to the marine environment can cause changes in nutrient stoichiometry that can alter the community composition of the local phytoplankton assemblage (Pan and Rao 1997). Changes in nutrient loads have been correlated with shifts from diatom-dominated to flagellated-dominated phytoplankton assemblages and in some locations in China, resulted in an increased occurrence of HAB events (Gilbert, 2020).

9.2.1 Physical Setting – South Eastern Australia

The East Australian Current (EAC) is a major factor controlling phytoplankton dynamics in the south eastern Australian region. The EAC delivers a series of mesoscale eddies into south-eastern Australian coastal waters that subsequently interact with coastal upwelling provinces to produce a highly energetic and complex coastal system (Ridgway and Hill, 2012). Observations over the past 60 years show that the EAC has intensified (poleward extension of approximately 350 km) and undergone significant warming (2.28°C/century) (Ridgway and Hill, 2012). This warming trend is expected to continue, with impacts predicted for the marine ecosystem, including phytoplankton diversity and productivity (Hallegraeff *et al.,* 2012). Even though sporadic phytoplankton research has been undertaken over the past 80 years in this important coastal region, the first long-term time-series studies have only recently been completed.

9.2.2 South Eastern Australia - Phytoplankton Community

In south eastern Australia, phytoplankton data have been collected from only a few nearshore sites, and temporal coverage is limited (Ajani *et al.,* 2016 and references therein). In 1942, the Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Fisheries and Oceanography designated a coastal sampling station offshore from Port Hacking, Sydney (known as Port Hacking 50 m or PH_{50m}). A second station, Port Hacking 100 m (PH_{100m}) was designated in 1954 and was the focus of many subsequent phytoplankton and hydrological investigations.

Short-term studies (less than 5 years) at both the PH_{50m} and PH_{100m} coastal stations examined phytoplankton pigments (Humphrey, 1960; 1963, Hallegraeff, 1981); biomass (Grant and Kerr 1970, Grant 1971); and species composition (Jeffrey and Carpenter 1974; Hallegraeff and Reid 1986, Ajani *et al.* 2001b). A meta-analysis of the most common phytoplankton species collected from five separate studies conducted from 1965 to 2012 at PH_{100m} showed that species composition identified in the 1965–1966 and 1978–1979 periods differed significantly from those identified in the three more recent studies (Ajani *et al.* 2016).

A total of 309 taxa were enumerated over this 50-year period within the functional groups diatoms, dinoflagellates, coccolithophorids, raphidophytes, chrysophytes, silicoflagellates, euglenophytes, prasinophytes, chryptophytes, cyanobacteria, and prymnesiophytes (**Appendix G-1**). The 20 dominant taxa for each sampling period make up 92%–99% of the total phytoplankton abundance and were predominantly diatoms. Species in the top 20 for all campaigns (noting differences in sampling methodologies as outlined in Ajani *et al.,* 2014a) belong to the diatom genera *Pseudo-nitzschia, Leptocylindrus, Chaetoceros*, and *Thalassiosira*. The recent emergence of the tropical species *Trichodesmium erythraeum* (cyanobacterium) and *Bacteriastrum* spp. (diatom) into the top 20 taxa from 1997 onward is of particular significance in light of ocean warming in this region (Ajani *et al.,* 2014a, b) (**Figure 9-1**). Although the datasets may have differed from one another in terms of sampling methodologies (nets vs. discrete bottle samples) and possible range extensions of some species into the region, it is also likely that advances in systematic knowledge of species of phytoplankton present in the region, and the skills and knowledge of the authors, have influenced these results.

Figure 9-1 Twenty most abundant phytoplankton taxa and their abundance per sample across the 11-year sampling period (1998-2009). Taxa are listed in order of decreasing average abundance. Larger circles correspond to taxa with higher abundances in a sample (cells L^{-1}) (from Ajani *et al.* 2014a, b)

9.2.3 Natural Variation in Phytoplankton Community

Investigations in south-eastern Australia have identified multiscale variability in both the abundance and composition of phytoplankton. Short-term (days to weeks), within-year (seasonal), and interannual-to-decadal variability have been identified, with the differentiation as well as the interaction of these scales of variability providing insight into the major driving factors controlling phytoplankton dynamics in this region (**Figure 9-2**). From the early days of sampling, a distinct periodicity was noted by Dakin and Colefax (1933, 1940) in phytoplankton abundance, with a characteristic austral spring diatom bloom erroneously claimed to be similar to that recognized in the Northern Hemisphere. By the 1970s, however, seasonal signals in phytoplankton biomass had revised the interpretation of episodic spring blooms and noted them coinciding with intermittent slope water intrusions bringing cold, nutrient-rich (phosphate, silicate, and nitrate) water into the euphotic zone (Hallegraeff and Reid, 1986, Ajani *et al*., 2001b). Phytoplankton blooms, therefore, as represented by fluorometer-inferred chlorophyll a, were found to be more related to hydrological events of wind- and current-driven upwelling rather than seasonal overturn of water masses.

In 1998, in response to community and scientific concerns about the apparent increases in the frequency and magnitude of marine phytoplankton (algal) blooms since the commissioning of three deep-water ocean outfalls in the Sydney region, the NSW EPA commenced a 3-year study to assess the relative importance of natural and anthropogenic nutrients on the development of such phytoplankton blooms. It was observed that wastewater plumes generally remained submerged and sewage derived nitrogen was mainly in the form of ammonia. Episodic slope water intrusions were the principal source of nitrogen in the form of nitrate to coastal waters especially during spring and summer and were found to drive most phytoplankton blooms in the nearshore zone (Pritchard *et al.,* 1999). However, by considering simulations of near field wastewater plume behaviour in relation to long term ambient nutrient patterns, Pritchard *et al.* (2001) identified specific periods of the year and depth intervals with maximum risk of outfall impacts, such as the upper half of the water column during late summer.

In addition to sporadic upwelling/downwelling events, a distinct seasonal cycle in phytoplankton community composition has been observed at PH_{100m}, with richness peaking in the winter (Hallegraeff and Reid, 1986, Ajani et al., 2014a, b). The spring and summer blooms are characterized by a clear successional pattern, beginning with small diatoms (*i.e. Asterionellopsis, Thalassiosira, Skeletonema, Pseudo-nitzschia*, and *Chaetoceros),* followed by larger diatoms (i.e. *Ditylum, Leptocylindrus, Eucampia, Rhizosolenia, Melosira,* and *Thalassiothrix)* and concluding with dinoflagellates, most notably species of the genera *Ceratium* and *Protoperidinium* (Hallegraeff and Reid 1986, Ajani *et al.* 2001b).

Based on the observed strengthening of the EAC over the past approximately 60 years (Hill *et al.,* 2008) and its importance in controlling phytoplankton biomass in New South Wales coastal waters, the abundance and composition of microphytoplankton collected from PH_{100m} were subsequently examined from 1998 to 2009 (Ajani *et al.,* 2014a, b). As one of the longest phytoplankton time-series datasets in the Southern Hemisphere, this study reported a total of 152 taxa, from 90 different genera, with *Thalassiosira cf. partheneia* and *Trichodesmium erythraeum* the dominant species over this decade. Data revealed a decline in dinoflagellate abundance and a simultaneous shift in the proportional composition from dinoflagellates to diatoms (Ajani *et al.,* 2014a, b).

Interannual community composition was found to be driven predominantly by temperature and season, but all other environmental variables examined (salinity, nitrate, silicate, mixed-layer depth, mixed-layer temperature, degree of stratification, wind, and the Southern Oscillation Index) were minor drivers in community composition.

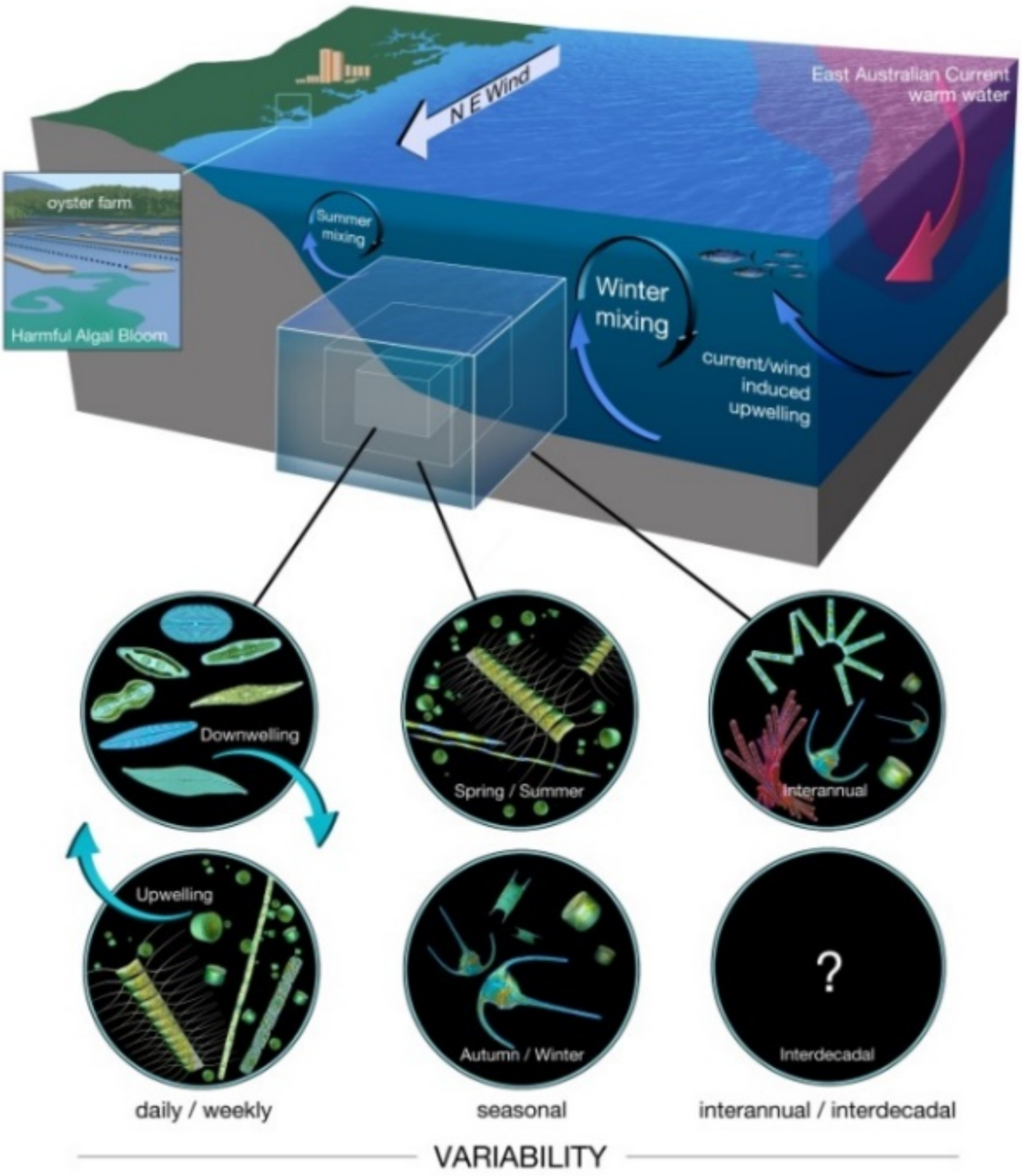


Figure 9-2 A schematic diagram showing the spatial context of variability in phytoplankton in south-eastern Australian coastal waters

(Note - the smallest box represents the daily/weekly changes in the phytoplankton community due to downwelling/upwelling; the second-largest box represents the seasonal changes in phytoplankton; and the largest box represents the changes observed on an interannual/decadal timescale. Any interdecadal signal is yet to be examined indicated by '?').

9.2.4 Phytoplankton Blooms and HABs

Phytoplankton blooms are a growing phenomenon worldwide, in some cases related to increasing eutrophication and modification of water bodies, as well as marine climate change (Gilbert et al. 2020). While many blooms are harmless, blooms of certain phytoplankton species can produce toxins (HABs) that can cause detrimental harm to fisheries, aquaculture, and recreational use of coastal environments. Note that this section is discussing blooms of microalgae not macroalgae (i.e. seaweed) that can also form nuisance blooms. The important difference is that blooms of macroalgae are not harmful to humans.

In Australia there is a select group of biotoxin-producing marine and estuarine phytoplankton species that have been documented to cause impacts in terms of seafood poisonings, the deaths of fish or other marine life, and direct human impacts due to skin exposure or respiratory complaints. The types of poisoning syndromes documented in Australia can be divided into those that only impact humans or the marine food chain through the ingestion of seafood (Amnesic Shellfish Poisoning [ASP], Diarrhetic Shellfish Poisoning [DSP], Neurotoxic Shellfish Poisoning [NSP] and Paralytic Shellfish Poisoning [PSP]), as well as those causing the deaths of marine life, or those causing human skin irritations or breathing difficulties. Marine life that has accumulated levels of these biotoxins does not look or smell differently to other seafood, and therefore, without careful monitoring programs employing microscopy-based phytoplankton identification and chemical analyses, it is not possible to detect whether seafood poisoning could occur as a result of HABs.

A brief description of the types of poisoning syndromes documented in Australia and the phytoplankton taxa responsible is provided below.

Amnesic Shellfish Poisoning

In humans, this type of poisoning is caused by the accumulation of domoic acid. Domoic acid acts as a neurotoxin, crossing into the brain and interfering with nerve signal transmission. Symptoms range from vomiting, nausea, seizures, diarrhoea, headaches, dizziness, disorientation, short term memory loss, and permanent brain damage. Species found to contain domoic acid in Australia to date have been:

Pseudo-nitzschia australis	*Pseudo-nitzschia cuspidata*	*Pseudo-nitzschia multistriata*

Over the 2005-2016 period, two amnesic shellfish toxin (AST) events were reported from Merimbula Lake (2007 and 2010) and one from Pambula River estuary in 2012 (refer **Section 9.3** below). None resulted in harm to humans.

Diarrhetic Shellfish Poisoning

In humans, the toxin okadaic acid and its analogs cause Diarrhetic Shellfish Poisoning (DSP). Symptoms include diarrhoea, nausea, vomiting and cramps. No fatalities from DSP have ever been recorded. The species that has been documented to cause DSP in Australia to date is *Dinophysis acuminata*:

Dinophysis acuminata	-	-

Over the 2005-2016 period, no diarrhetic shellfish toxin (DST) events were reported from either Merimbula Lake or Pambula River estuary (refer **Section 9.3** below).

Paralytic Shellfish Poisoning

In humans, Paralytic shellfish poisoning is caused by the alkaloid toxin saxitoxin and its analogs. Paralytic shellfish poisoning has caused several illnesses in Australia, which have a range of symptoms including nausea, vomiting, diarrhoea, abdominal pain, tingling or burning lips, gums, tongue, face, neck, arms, legs, and toes. The species that have been documented to produce saxitoxin and its analogs, referred to as the Paralytic Shellfish Toxins (PST), from Australian waters to date are:

Alexandrium pacificum	*Alexandrium australiense*	*Alexandrium fundyense*
Alexandrium minutum	*Gymnodinium catenatum*	*Dolichospermum sigmoideum* (fresh

		and brackish water only)

In addition, other types of toxins that have been reported to be produced from microalgal species in Australia, including maitotoxin, palytoxin, yessotoxin, and other groups. To date, these generally have not caused a problem with seafood consumption in Australia.

Over the 2005-2016 period, two PST events were reported from Merimbula Lake (2007 and 2014) and one from Pambula River estuary in 2016 (refer **Section 9.3** below). None resulted in harm to humans.

Fish killing toxic algal blooms
The deaths of large numbers of fish and other marine/estuarine life, including benthic invertebrates, have occurred in Australia due to blooms of several microalgal species. Sometimes this has occurred in aquaculture ponds or settings, while in other cases it is in bays or estuaries. In NSW, blooms linked to fish kills are a regular phenomenon, with ~20 such instances reported in NSW annually (section author P. Ajani *pers. obs.).* In some cases, the toxins involved in these events have been found and the toxic mechanism is well known. In other cases, the mechanisms of toxicity are less well known. The species that have caused large scale fish kills in Australia to date are:

Amphidinium carterae	*Karlodinium veneficum*	*Karenia mikimotoi*
Karenia umbella	*Takayama pulchella*	*Chattonella marina*
Heterosigma akashiwo	-	-

Toxic blooms with direct human effects, causing skin or breathing difficulties
There are several species of marine/estuarine and freshwater phytoplankton that can have direct health impacts on recreational users of the estuary such as those swimming, fishing, boating, and spending time beside the water. These impacts are either through skin contact, which can cause irritation, or through respiratory problems if toxins are inhaled. The species that have been found in Australia and have the potential for causing skin irritations for swimmers are:

Amphidinium carterae	*Karlodinium veneficum*	*Ostreopsis siamensis*
Ostreopsis ovata	*Moorea producens*	*Nodularia spumigena*
Microcystis spp. (fresh and brackish water only)	*Dolichospermum sigmoideum,* (fresh and brackish water only)	*Noctiluca scintillans*

Species that have the potential to cause respiratory problems, and where cases have been reported elsewhere in the world, are:

Karenia brevis	*Karenia brevisulcata*	*Ostreopsis siamensis*
Ostreopsis ovata	*Chattonella marina*	-

Of these, the two species that have not been as yet found in Australia are *K. brevis* and *K. brevisulcata,* while the other species are present and, in some cases, common.

9.2.5 NSW Food Authority Shellfish Monitoring Program

In 2003, the NSW Food Authority's shellfish quality assurance program (NSWSQAP) initiated fortnightly phytoplankton monitoring in 76 harvest areas within 31 oyster growing estuaries across the state to screen for harmful phytoplankton taxa and provide early detection of potential biotoxin events.

A meta-analysis of this data revealed a total of forty-five harmful taxa across all NSW estuaries with species richness latitudinally graded for rivers and an increasing number of taxa southward (Ajani *et al.,* 2013). There were significant differences (within an estuary) in harmful species abundance and richness for 11 of 21 estuaries tested. Where differences were observed, these were predominately due to species belonging to the *Pseudo-nitzschia delicatissima* group, *Dinophysis acuminata*, *Dictyocha octonaria* and *Prorocentrum minimum* with a consistent upstream versus downstream pattern emerging. Temporal (seasonal or interannual) patterns in harmful phytoplankton within and among estuaries were highly variable. Examination of harmful phytoplankton in relation to recognised estuary disturbance measures revealed species abundance correlated to estuary modification levels and flushing time, with modified, slow flushing estuaries having higher abundance. Harmful species richness correlated with bioregion, estuary modification levels and estuary class, with southern, unmodified lakes demonstrating greater species density.

A review of NSWSQAP data applicable to Merimbula and Pambula estuaries is provided in Section 9.3 below.

9.3 Review of Existing Data

Review of existing datasets relevant to the study includes:

- Phytoplankton monitoring data collected by the oyster growers of Pambula and Merimbula Lakes as part of the NSWSQAP and available from NSW Food Authority; and
- Incidences of past regional (*i.e.* Twofold Shelf Bioregion) and localised phytoplankton bloom events (data held by OEH Coastal Sciences Section).

9.3.1 Phytoplankton Community of Pambula and Merimbula estuaries

Phytoplankton monitoring data for Pambula and Merimbula estuaries collected under the NSWSQAP included:

- fortnightly total species counts for time period 12/6/2012 to 10/6/2013, and 3/8/2014 to 9/6/2015 from Merimbula Lake Site 2 (**Figure 9-3**); and
- scan of nuisance and potentially harmful species from two sites in Merimbula Lake and two sites in Pambula River estuary (**Figure 9-3**) over the period 2005-2016.

For Merimbula Lake, a list of total species enumerated over time periods 12/6/2012 to 10/6/2013, and 3/8/2014 to 9/6/2015 is provided in **Appendix G-2**. For the first sampling period (2012 to 2013) the maximum concentration of any phytoplankton species was the harmless small chain forming diatom cf. *Skeletonema costatum* with a maximum cell density of 4,000,000 cells/L occurring on the 21/1/2013. For the second period (2014-15), a harmless diatom cf. *Leptocylindrus minimus* reached peak cell densities of 4,500,000 cells/L on 15/2/2015.

Like most estuaries in NSW, potentially harmful algal taxa have been recorded from both Pambula and Merimbula estuaries, but these taxa are typically recorded at low to very low levels and have not been a cause for concern. Phytoplankton action limits (PALs) for potentially harmful phytoplankton taxa are set out in the *Marine Biotoxin Management Plan* (NSW Food Authority, 2015) and provided in **Appendix G-3**. Review of phytoplankton counts of potentially harmful species exceeding the NSW Food Authority's phytoplankton action limits (PALs) over the period 2005 to 2016, had the following findings:

For Merimbula Lake site 1 there was a total of 12 PAL exceedances involving six different harmful taxa (three diatoms and three dinoflagellates).

- *Pseudo-nitzschia delicatissima* group on two occasions;
- *Pseudo-nitzschia fraudulenta/australis* on four occasions;
- *Pseudo-nitzschia subpacifica/heimii* on two occasions;
- *Dinophysis acuminata* on one occasion;
- *Dinophysis caudata* on two occasions; and
- *Alexandrium catenella/fundyense* on one occasion.

For Merimbula Lake site 2 there was a total of 12 PAL exceedances involving four different taxa,

- *Pseudo-nitzschia delicatissima* on 6 occasions;
- *Pseudo-nitzschia fraudulenta/australis* on one occasion;
- *Pseudo-nitzschia pungens/multiseries* on one occasion; and
- *Dinophysis caudata* on four occasions.

No exceedances were reported for Pambula site 16.

For Pambula site 17 there was a total of six PAL exceedances involving three different taxa.

- *Pseudo-nitzschia fraudulenta/australis* on one occasion,
- *Alexandrium catenella/fundyense* on four occasions*;* and
- *Dinophysis caudata* on one occasion

For both estuaries, exceedances of PALs have been an occasional occurrence and not all PAL exceedances resulted in a positive toxin detection. A summary of positive toxin detections in shellfish at both Merimbula and Pambula lakes over the monitoring period 2005 to 2016 is provided in **Table 9-1**. Species associated with ASTs in Merimbula were *Pseudo-nitzschia delicatissima* group, *Pseudo-nitzschia fraudulenta/australis, Pseudo-nitzschia pungens/multiseries,* whilst in Pambula they were *Pseudo-nitzschia pungens/multiseries.* Species associated with PST in Merimbula were unconfirmed whilst in Pambula Lake it was *Alexandrium catenella/fundyense.*

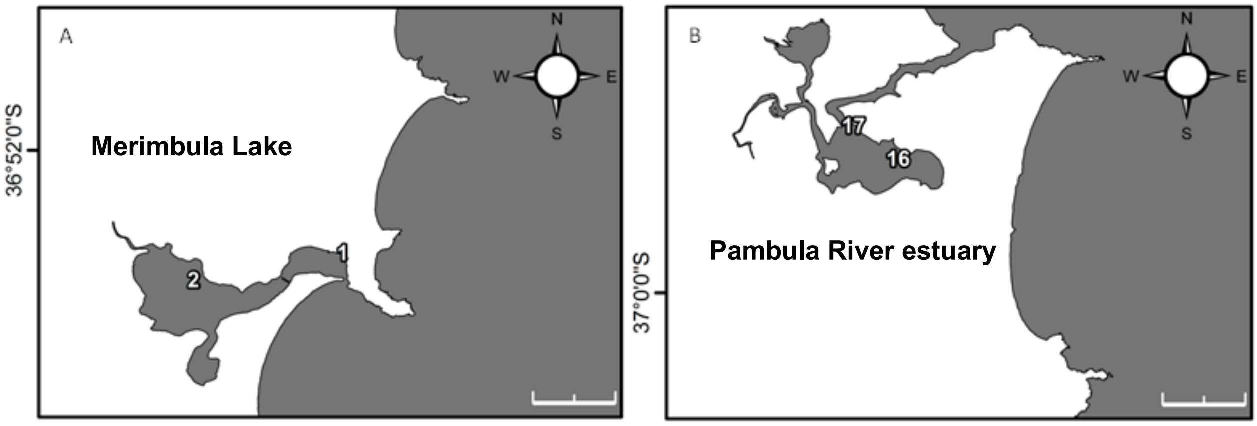


Figure 9-3 NSW Food Authority shellfish QA phytoplankton monitoring locations

Table 9-1 Summary of positive toxin detections in shellfish flesh across all years sampled from Merimbula and Pambula Lakes (2005-2016)

	AST		PST		DST	
Year	Merimbula	Pambula	Merimbula	Pambula	Merimbula	Pambula
2005	-	-	-	-	-	-
2006	-	-	-	-	-	-
2007	X	-	X	-	-	-
2008	-	-	-	-	-	-
2009	-	-	-	-	-	-
2010	X	-	-	-	-	-
2011	-	-	-	-	-	-
2012	-	X	-	-	-	-
2013	-	-	-	-	-	-
2014	-	-	X	-	-	-
2015	-	-	-	-	-	-
2016	-	-	-	X	-	-
TOTAL	2	1	2	1	-	-

Note:
AST – Amnesic shellfish toxin
PST – Paralytic shellfish toxin
DST - Diarrhetic shellfish toxin
X = positive toxin detection

9.3.2 Past Occurrences of Phytoplankton Blooms in the Twofold Shelf Bioregion

Thirty kilometres south of Merimbula and Pambula is Twofold Bay, where significant mussel aquaculture production occurs, and regular monitoring of phytoplankton is conducted. Phytoplankton blooms that have occurred in Twofold Bay in the past include the harmless dinoflagellate *Noctiluca scintillans* (April 2013) with blooms of potentially harmful diatoms (*Pseudo-nitzschia*) and dinoflagellates (*Alexandrium* and *Dinophysis*). Positive toxin detections in shellfish from this region include two x ASTs in 2012 (*P. delicatissima* group), two x PSTs in 2012 and 18 in 2016 (see below) with causative species identified as *Alexandrium fundyense*, *Alexandrium ostenfeldii*, and an unconfirmed sp. Three DSTs have been reported (one in 2005 and two in 2011) with *Dinophysis acuminata* and another unconfirmed sp. as the species associated with these positive biotoxin results.

The 2016 event was attributed to the dinoflagellate *Alexandrium fundyense* and resulted in the closure of mussel aquaculture in Twofold Bay for an 8-week period until toxin levels decreased to below the regulatory limit for two consecutive samples one week apart. The closure was also expanded by the NSW Food Authority to include the commercial lobster, abalone and sea urchin fisheries. No human illnesses were reported at this time. While the highest cell concentrations of *Alexandrium fundyense* were reported from Twofold Bay, evidence of the bloom was detected in other south coast shellfish harvest areas including Pambula Lake and elevated concentrations (1,200-15,000 cells^{-l}) of *Alexandrium fundyense* were detected along the coastal shelf up to 13 km north and 21 km south of Twofold Bay around this time.

As described above, blooms of phytoplankton can be stimulated by upwelling events that bring intrusions of nutrient-rich slope water to the coastal zone. These upwelling events can occur at any time but are typical in spring and summer. Occasionally these blooms may include high abundances of potentially harmful taxa such has occurred in Twofold Bay in the past.

9.3.3 Visual Algal Bloom Reports – Merimbula Bay

For Merimbula Bay, OEH records contain four documented reports of algal bloom events over the past 20-year period (*pers. comm.*, T. Ingleton, OEH). Of these, three were drift macroalgae washed up on the beach. However, in February 2003 a large red tide was reported in Merimbula Lake and was identified as the large and harmless dinoflagellate *Noctiluca scintillans.* Similarly, in April 2013 a bloom of *N. scintillans* was widespread along the coastal zone from Bermagui to Eden (**Figure 9-4**). No toxic effects from red tides of *N.*

scintillans are known to humans, but it is possible that direct skin contact with this type of algae could cause skin irritation. The high ammonia content of the cell's vacuole may also irritate fish (which generally avoid the bloom areas). As a precaution, therefore, it is always advised that people not come into direct contact with any discoloured water.

While blooms of drift macroalgae have been a common occurrence in Merimbula Bay, no records of toxic phytoplankton blooms have as yet been reported although that would be partly due to absence of monitoring. It is acknowledged that DPIE records do not contain all occurrences of algal blooms (macroalgae or phytoplankton) and many other bloom events may have occurred though have not been documented.

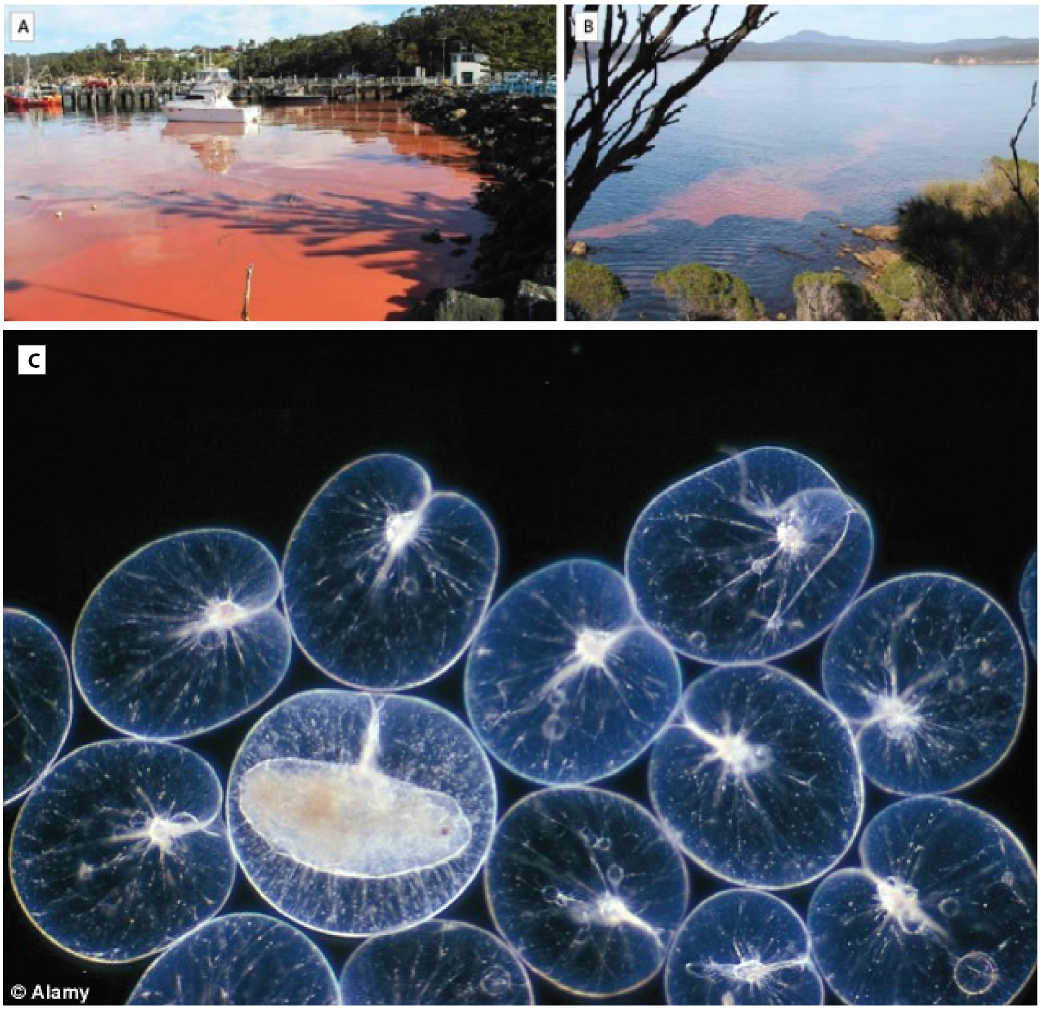


Figure 9-4 The large red-tide forming dinoflagellate, *Noctiluca scintillans*

A, B. Blooms of *Noctiluca scintillans* in Twofold Bay, Eden, April 2013 (photos by Jenny Robb, published in Narooma News), C. *Noctiluca scintillans* under microscope (photo by http://www.alamy.com/)

9.4 Field Survey

Data regarding the phytoplankton assemblage at the local scale exists for the oyster growing estuaries (Merimbula and Pambula) and nearby Twofold Bay. However, no data existed for the Merimbula Bay coastal region. Therefore, a field survey comprising four monitoring rounds was completed to address this data gap and provide a baseline description of the phytoplankton assemblage for the Merimbula Bay coastal region.

9.4.1 Sampling sites and Approach

Five sites were sampled including three within Merimbula Bay (MBWQ20, MBWQ40, HAY30), one northern reference site off Tura Beach (TURA20) and one southern reference site off Quondolo Beach (QUON20) as shown in **Figure 9-5**. Sites corresponded with ocean water quality monitoring sites (**Table 9-2).**

Table 9-2 Summary of phytoplankton sampling sites

Site Code	Rationale
HAY30	Existing water quality monitoring site, 20 m depth
QUON20	Quondolo Beach, southern water quality reference site, 20 m depth
MBWQ40	Existing northern water quality reference site, 40 m depth, outer Merimbula Bay
MBWQ20	Existing water quality monitoring site, 20 m depth, inner Merimbula Bay
TURA20	Tura Beach, northern water quality reference site, 20 m depth.

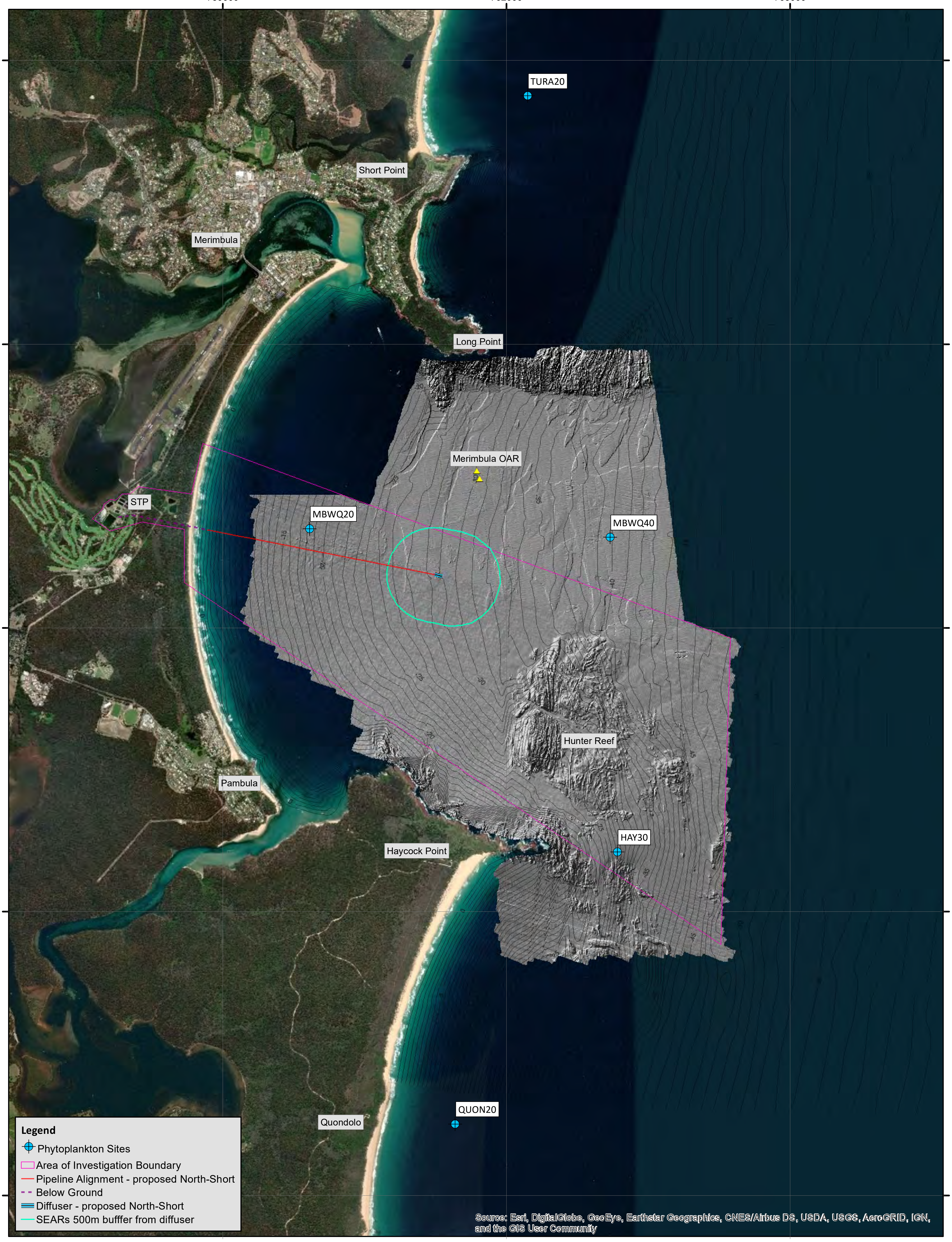
The following tasks were conducted for each site:

- Water samples for analysis of total phytoplankton species composition were collected using a plankton tow net (20 µm mesh, 245 mm diameter, 1.2 m length) with an attached 120 ml plastic jar drawn vertically through the water column from the maximum depth at each of the five sites. Samples were immediately preserved with Lugols solution and returned to the laboratory for taxonomic analysis of community composition.
- Additionally, a 1 L surface water sample was collected from a depth of 0.5 m for phytoplankton counts from each site. Once back in the laboratory, water samples were gently concentrated using vacuum filtration on to a 5 µm millipore filter. Filters were then washed with filtered seawater to a final volume of 10 ml.
- Water quality depth profiles were recorded at each site using a YSI 6600-V2_4 sonde calibrated prior to sampling. *In-situ* measurement of water quality included parameters pH, temperature, dissolved oxygen, salinity, turbidity and chlorophyll a. A discrete water sampler was used to collect a sample from mid-water depth at each site for laboratory analysis of nutrients (NH3, NO2, NO3, TN, TP, FRP, Chl a).

9.4.2 Phytoplankton analysis

Phytoplankton taxa were identified and enumerated to the lowest possible taxonomic level by Dr Penny Ajani. A total phytoplankton list for Merimbula Bay region was composed by attempting to identify all phytoplankton taxa present in the samples to species level.

The length of time devoted to enumerating taxa in each sample varied from 1 to 2 hr, as determined using the timed interval protocol of the Australian Rivers Assessment System (http://ausrivas.ewater.com.au). Phytoplankton abundance was estimated by counting up to 100 cells of the most dominant taxa using the Lund cell method (APHA 10200F; Hotzel and Croome 1999). For some taxa, species-level identification was not possible using routine light microscopy. In such instances, individuals were identified to genus (i.e. *Chaetoceros, Pseudo-nitzschia* and *Thalassiosira*).



N

Scale = 1:35,000

0 495 990 1,980 Meters

Notes:

1. Elgin phytoplankton sampling conducted on 21/11/17, 1/10/19, 29/1/20 and 7/4/20 (upwelling).
2. Southern bathymetry data reported by Marine and Earth Sciences in 2017.
3. Northern bathymetry data reported by Southern Divers and Total Hydrographic in 2017.

Project: MERIMBULA STP UPGRADE AND OCEAN OUTFALL ENVIRONMENTAL ASSESSMENT

Client: AECOM AUSTRALIA

Title: PHYTOPLANKTON SAMPLING SITES

Date: 04 October 2020

Version: 1 | Size: A3

elgin

FIGURE 9-5

Coordinate System: GDA 1994 MGA Zone 55
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000
False Northing: 10,000,000.0000
Central Meridian: 147.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

Document Path: D:\Elgin Associates Dropbox\Elgin_GIS\New_South_Wales\BVSC GIS Data\Merimbula EIS\1. MXD Mapping Files\Figure_10-5_Phyto_Sites_04October2020.mxd

9.5 Results

9.5.1 Oceanographic conditions and Depth Profiling

Field surveys targeted a range of oceanographic conditions including weak to no current, a south-flowing current, a north-flowing current and an upwelling event. The ocean currents and sea surface temperature (SST) recorded for southern NSW by the Integrated Marine Observing System (IMOS) is provided in **Figure 9-6.** A description of the oceanographic conditions for each sample event is provided in **Table 9-3** below that also provides the temperature differential observed between surface and bottom waters.

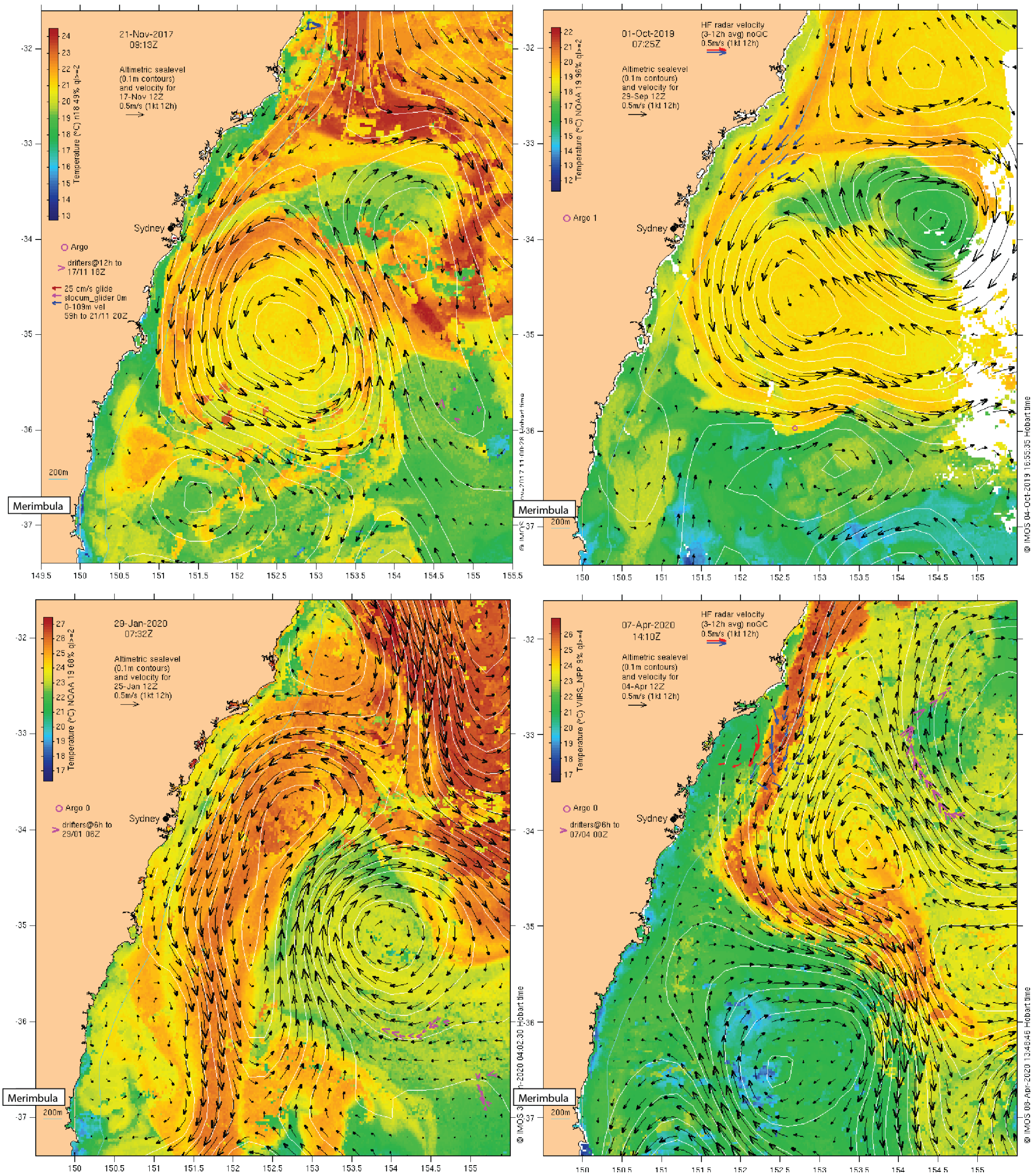


Figure 9-6 Ocean currents and sea surface temperature as recorded by the Integrated Marine Observing System (IMOS) during field survey sampling events (Refer http://oceancurrent.imos.org.au/SNSW/latest.html)

The criteria for defining a potential upwelling event included observations of the regional current and sea surface temperature charts, a temperature differential between surface and bottom waters of 4-6 ºC or greater, in conjunction with elevated nitrogen concentrations as indicated by laboratory analysis. On this basis, it was concluded that field sampling events on 21/11/17, 1/10/19 and 7/4/2020 were indicative of the phytoplankton assemblage at varying stages of an upwelling event. Depth profiles charts and a summary of physico-chemical water quality are provided in **Appendix G-4**.

Table 9-3 Temperature differential observed between surface waters and bottom waters at each location over the four monitoring events

Event	Location					Comment
	HAY30	QUON20	MBWQ40	MBWQ20	TURA20	
Event 1 21/11/17	2.2 ºC	3.0 ºC	**4.9** ºC	3.4 ºC	1.4 ºC	The IMOS chart shows the waters offshore from Merimbula influenced by a relatively weak counter-clockwise eddy with an inshore upwelling of cooler waters along the Far South Coast region indicated by blue coloration (**Figure 9-6**). Depth profiles show vertical mixing between surface and bottom waters was variable between sites as evidenced by temperature differential between surface and bottom waters. Evidence of potential upwelling detected at MBWQ40 as evidenced by temperature differential at MBWQ40. No lab data to confirm.
Event 2 1/10/19	0.4 ºC	0.0 ºC	1.2 ºC	0.3 ºC	1.0 ºC	The IMOS chart shows the waters offshore from Merimbula are characterised by weak currents and the EAC is well north of the Twofold Shelf bioregion and exerting minimal influence (**Figure 9-6**). Weak to no discernible current observed at all sites. Water column well mixed as evidenced by depth profile chart that showed little variation between surface and bottom waters. Total nitrogen levels reported between 0.148 and 0.203 mg/L and above the ANZG (2018) WQO of 0.12 mg/L. Majority of nitrogen in organic forms represented by high algal levels in the water column, indicative of bloom conditions post-upwelling.
Event 3 29/1/20	**4.2** ºC	3.0 ºC	**4.4** ºC	0.7 ºC	0.8 ºC	The IMOS chart shows the waters offshore from Merimbula are influenced by strong southerly flow of the EAC (**Figure 9-6**). This was having variable effects for nearshore waters with moderate to strong N-flowing current evident at MBWQ40 and HAY30 but no current observed at other sites. Some ash from summer bushfires was noted on water surface. Temperature differential greater than 4ºC noted at MBWQ40 and HAY30, although lab data does not indicate this to be due to upwelling of slope water with nitrate levels low.
Event 4 7/4/20	**4.3** ºC	1.1 ºC	**6.9** ºC	2.4 ºC	3.1 ºC	The IMOS chart shows the waters offshore from Merimbula are influenced by counter-clockwise eddy of the EAC (**Figure 9-6**). Effects of this eddy field were notable at MBWQ40 and HAY30 sites with very strong S-flowing current observed but little to no current observed at other sites. This is also reflected in depth profile chart that show surface water temperatures at TURA20, MBWQ20, and QUON20 all cooler and relatively unaffected by the boundary current conditions. Total nitrogen levels reported between 0.157 and 0.218 mg/L and above the ANZG (2018) WQO of 0.12 mg/L. Majority of nitrogen reported as nitrate confirming this as indicative of an upwelling event, the phytoplankton assemblage has yet to respond to the pool of bioavailable nutrients.

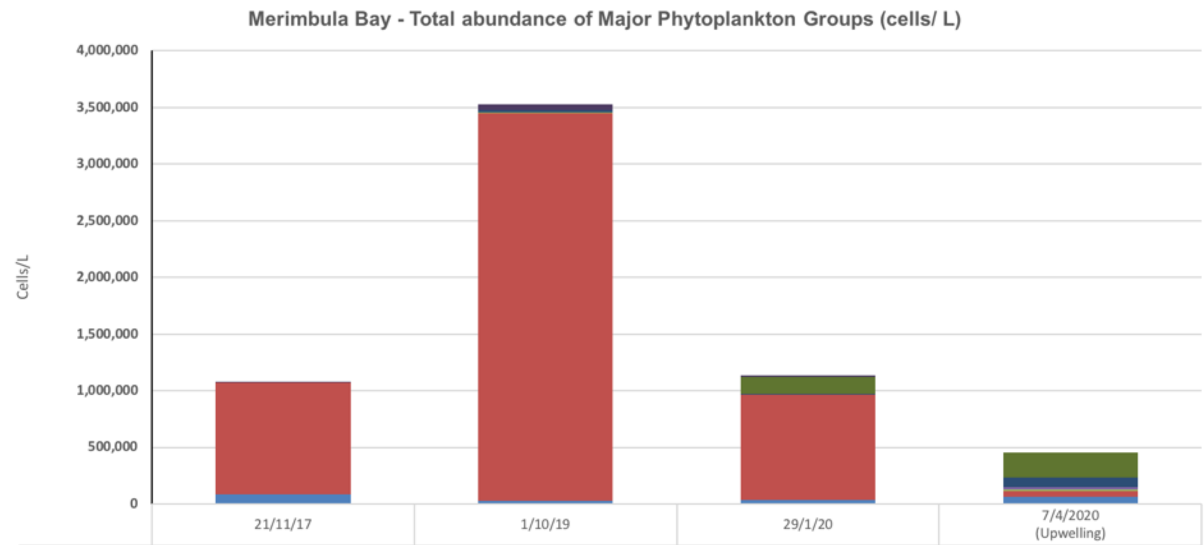
Note – Temperature differential between surface and bottom waters greater than 4 ºC provided in bold text and shaded grey.

9.5.2 Phytoplankton Assemblage of Merimbula Bay

A total of 85 phytoplankton taxa were recorded across all sites from vertical net tows represented by 43 diatoms, 35 dinoflagellates, 3 prasinophytes, 1 dictyochophyte, 1 cryptomonad, 1 coccolithophorid, and 1 cyanobacterium (**Appendix G-5**). As stated in the methods, for some taxa species-level identification is not possible using routine light microscopy and in such instances, individuals were only identified to genus level (i.e. *Chaetoceros, Pseudo-nitzschia* and *Thalassiosira*). It is possible that significant cryptic diversity exists within these identified genera.

The variable abundance of the major phytoplankton groups derived from cell counts of surface waters is provided in **Figure 9-7**. A raw cell count dataset is provided in **Appendix G-6**. Trends that are evident from the dataset include:

- Diatoms were the most diverse group and typically accounted for between 80 to 90% of total abundance with the exception of the upwelling event on 7/4/2020 where the assemblage was dominated by the tropical cyanobacteria *Trichodesmium erythraeum* (48% of total abundance), and diatoms were a minor component of that assemblage.
- Dinoflagellates were the second most diverse group and typically accounted for 1 to 8% of total phytoplankton abundance.
- Highest phytoplankton abundance was reported from the 1/10/2019 event which was dominated by three diatom taxa – *Thalassiosira, Chaetoceros* and *Pseudo-nitzschia*, that are typically reported in spring blooms in SE Australia.
- Overall there was relatively little difference in the phytoplankton assemblage between sampling sites for each sampling event, but there were clear differences in the assemblage composition among sampling events as shown in MDS plot in **Figure 9-8**.



	21/11/17	1/10/19	29/1/20	7/4/2020 (Upwelling)
Other	1,000	52,000	19,000	0
Cyanobacteria	0	0	149,000	218,000
Silicoflagellates	0	0	0	1,000
Coccolithophorids	0	21,000	2,000	86,000
Raphidophyceae	0	0	0	0
Euglenophyceae	0	0	0	0
Cryptophyceae	0	0	0	23,000
Prasinophyceae	0	6,000	0	14,000
Diatoms	989,000	3,422,000	933,000	47,000
Dinoflagellates	86,000	30,000	36,000	65,000

Figure 9-7 Phytoplankton abundance (cells/L) by major taxonomic groups

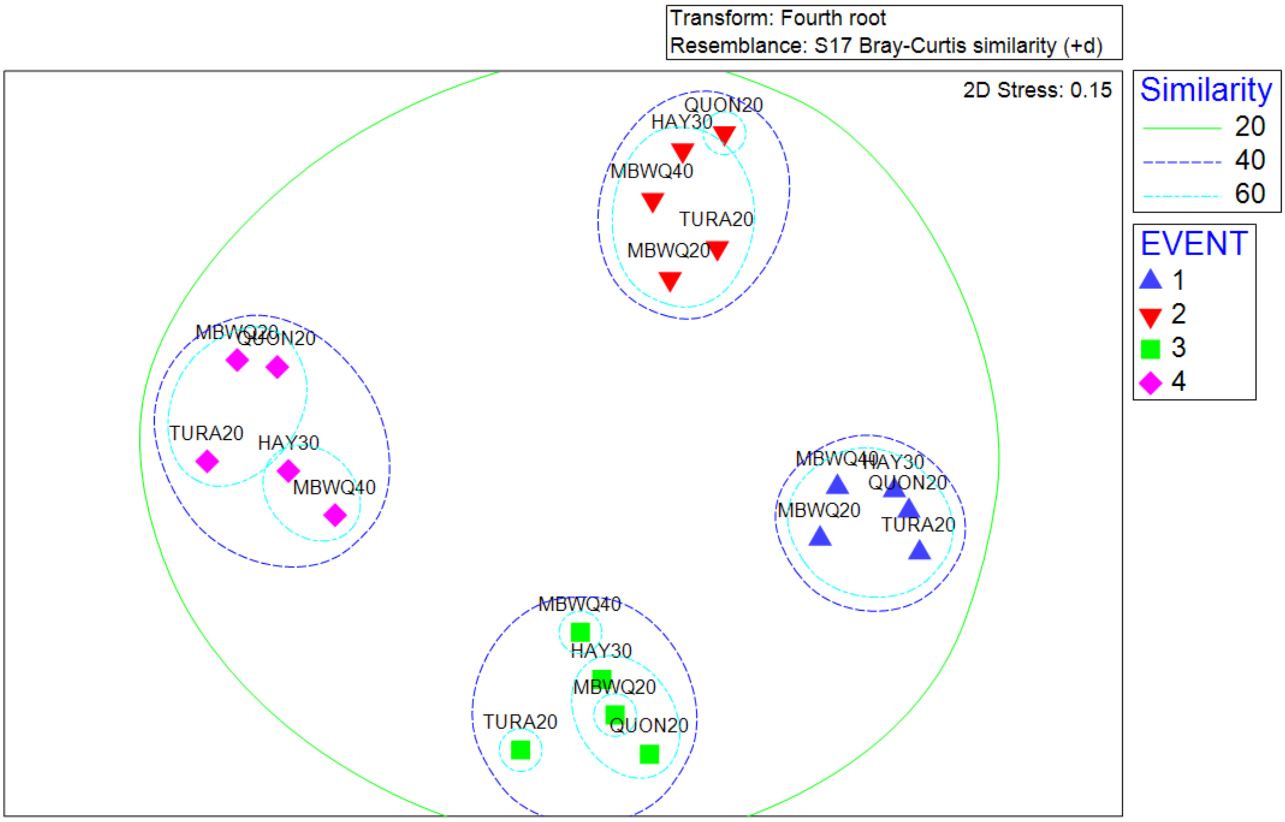


Figure 9-8 MDS plot of Merimbula Bay region phytoplankton assemblage over four events (2017-2020)

Key observations reported from each sampling event are provided below.

Event 1 - 21/11/2017 (probable upwelling event)

Samples were dominated by harmless chain forming diatoms (*Proboscia alata, Chaetoceros, Cerataulina pelagica, Leptocylindrus danicus* and *Thalassiosira*), typically seen during an upwelling event along this coastline (**Figure 9-9**). There was little difference observed between sites and there was no indication of any harmful species blooming. Water quality depth profiles show vertical mixing between surface and bottom waters was variable between sites as evidenced by temperature differential between surface and bottom waters. Evidence of potential upwelling detected at MBWQ40 as evidenced by temperature differential at MBWQ40. No lab data to confirm.

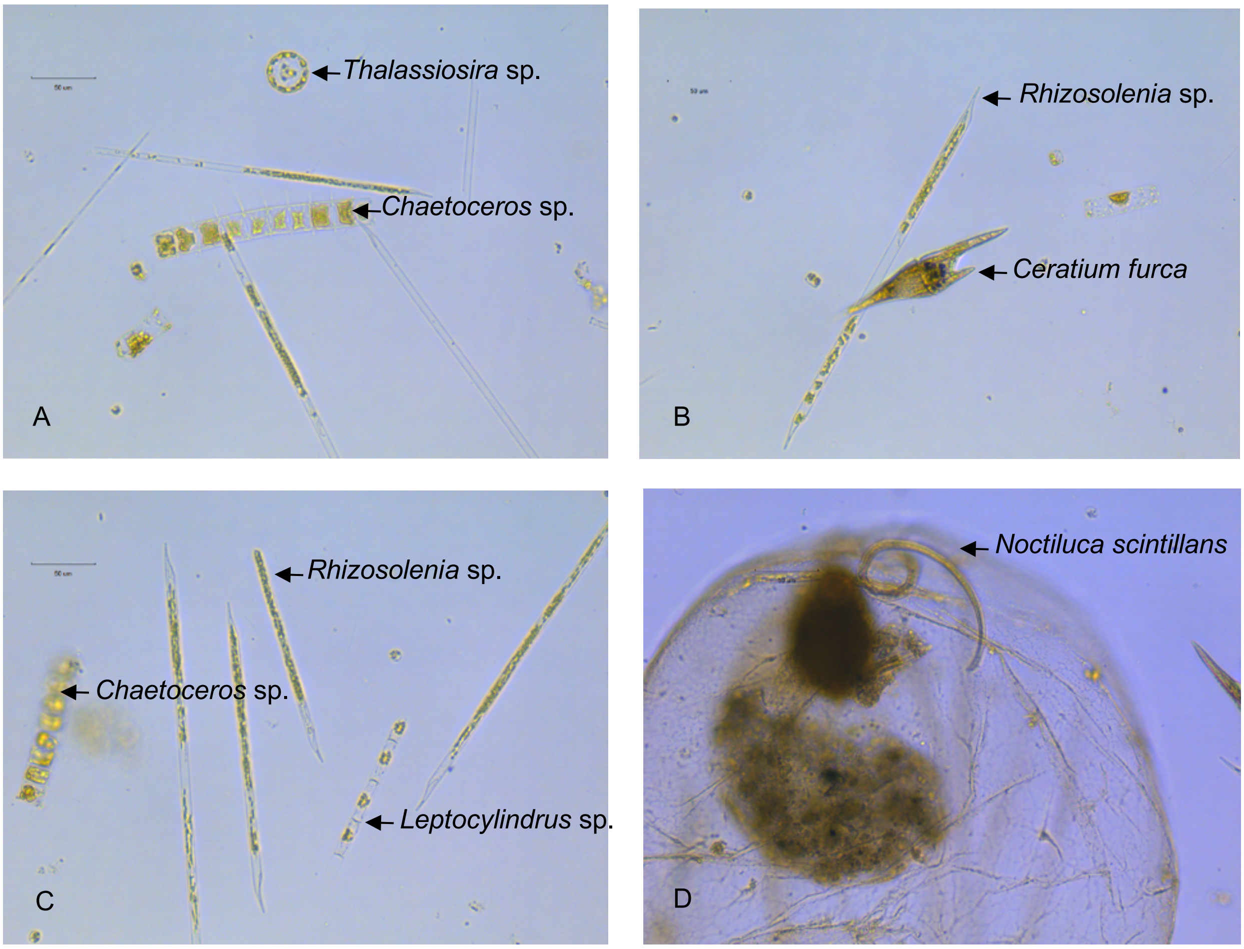


Figure 9-9 Dominant phytoplankton taxa from Merimbula Bay region, 21 November 2017 (Images P. Ajani)

Event 2 - 1/10/2019 (post upwelling event)

Phytoplankton abundance was highest on 1/10/2019 compared to all other monitoring events. Depth profiling indicated the water column to be well-mixed with no residual signs of an upwelling event (**Appendix G-4**). However, total nitrogen levels were reported between 0.148 and 0.203 mg/L and above the ANZG (2018) WQO of 0.12 mg/L. The majority of this nitrogen was in organic forms having been assimilated by the algal biomass in the water column, and indicative of a spring bloom conditions that likely resulted from an earlier upwelling event.

Samples were dominated by the mucilage-forming diatom *Thalassiosira* (**Figure 9-10**) and the chain-forming *Chaetoceros* and *Pseudo-nitzschia*, that are typically reported from spring blooms in SE Australia. Overall, there was little difference between cell abundance or taxa diversity across all sites, and cell densities are within the range previously documented for upwelling events along SE Australia. It is worth noting that certain species of *Pseudo-nitzschia* are cosmopolitan marine diatoms responsible for the production of the domoic acid (DA), a potent neurotoxin which can bioaccumulate in the food chain and cause amnesic shellfish poisoning (ASP) in animals and humans. A total of twenty-one species of *Pseudo-nitzschia* have now been characterized from Australian coastal waters, with four confirmed as DA producers: *P. australis, P. multistriata, P. cuspidata* and *P. delicatissima*. *Pseudo-nitzschia* cannot be identified to species level with light microscopy. Instead, electron microscopy or molecular characterisation is necessary to delineate to species.

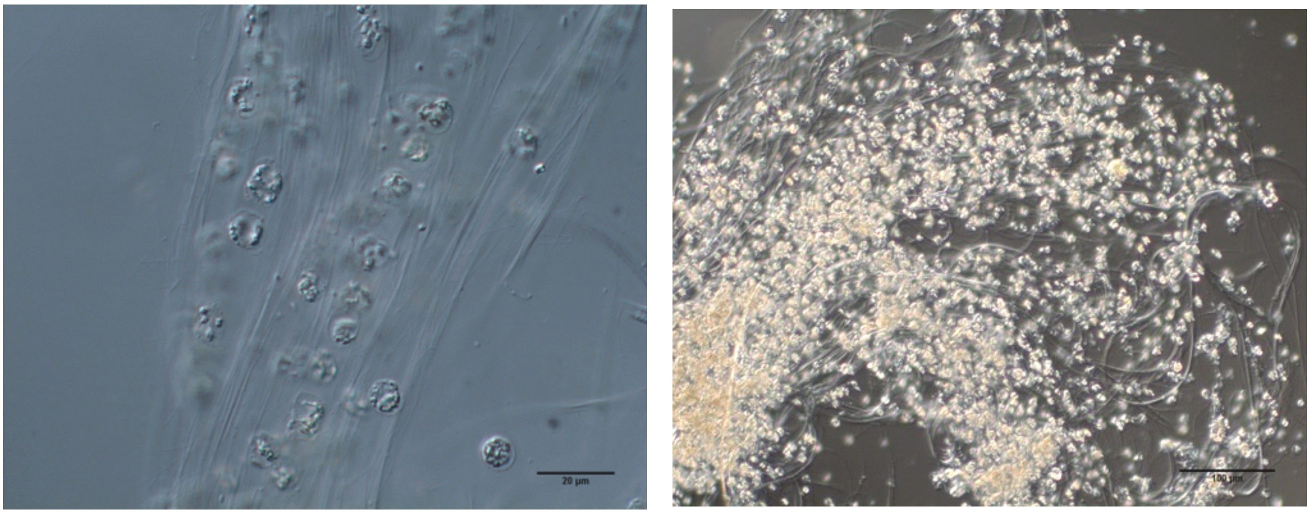


Figure 9-10 Micrographs of mucilage-forming diatom *Thalassiosira*, one of three dominant taxa observed in the bloom in Merimbula Bay region, 1 October 2019 (Images P. Ajani)

Event 3 - 29/1/2020

The phytoplankton assemblage in January 2020 was dominated by the chain forming diatom *Leptocylindrus danicus*, and the tropical cyanobacteria *Trichodesmium erythraeum,* both harmless (**Figure 9-11**). The latter is transported south from the Coral Sea in the East Australian Current and commonly forms red, sawdust-like blooms in the ocean during summer period. A variety of dinoflagellates were also present, albeit in low abundance, but very common for summer. The marine diatom *Leptocylindrus* is a major component of phytoplankton blooms worldwide and in SE Australia. In context of climate change and the predicted future strengthening of the EAC there is potential for higher frequency of upwelling events (Snyder *et al.* 2003) that may alter the seasonal abundance and distribution of phytoplankton assemblage along the east Australian coast, with recent investigations recommending *Leptocylindrus danicus* as a suitable indicator for climate change effects in the SE Australian marine region (Ajani *et al.* 2016).

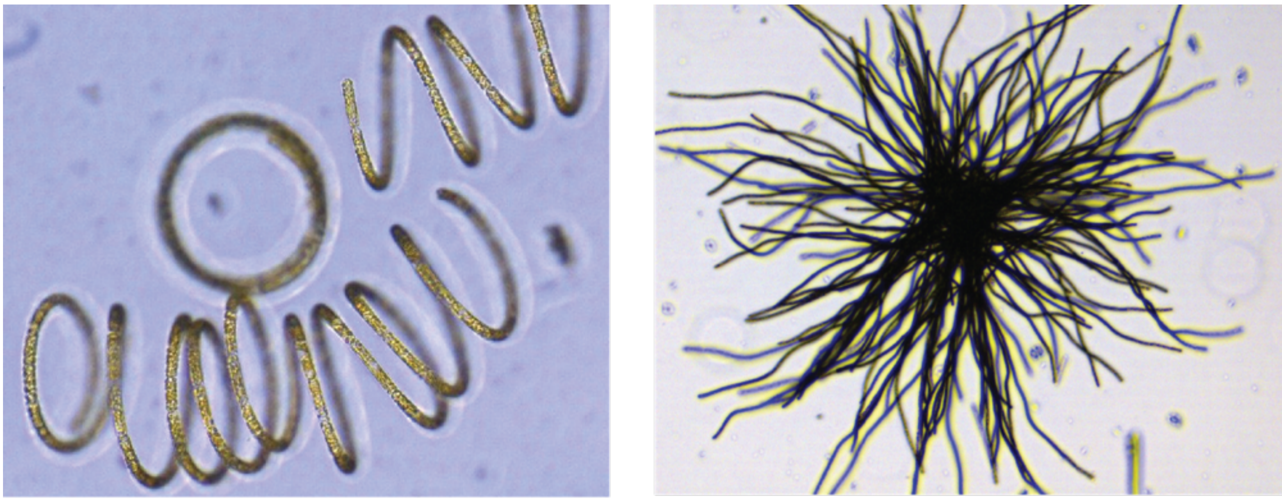


Figure 9-11 Micrographs of chain forming diatom *Leptocylindrus danicus* (left), and the tropical cyanobacteria *Trichodesmium erythraeum* (right), observed in the bloom in Merimbula Bay region, 29 January 2020 (Images P. Ajani)

Event 4 - 7/4/2020 (upwelling event)

The April 2020 sampling event captured the phytoplankton community during the early stages of an upwelling event as indicated by the overall low total phytoplankton abundance compared to other sampling events (**Figure 9-7**), highest phytoplankton diversity with no algal group significantly more dominant than another, and high levels of bioavailable nitrate present in the water column and not yet assimilated by the phytoplankton. The assemblage was characterised by a diverse range of dinoflagellates that were very low in abundance, typical for the autumn period in SE Australia. The tropical cyanobacteria *Trichodesmium erythraeum* was the most abundant taxon that typically peaks in abundance in March to April when the EAC can be at its strongest.

9.6 Key Findings

The phytoplankton assessment provides background description of phytoplankton community of south-eastern Australia and the main environmental factors known to control broad bioregional phytoplankton dynamics. The assessment included a field survey program that sampled the phytoplankton assemblage of the Merimbula Bay region under a range of oceanographic conditions that included an upwelling event.

Key findings include:

- Long-term monitoring data for eastern Australia (collected from Port Hacking sites PH_{50} and PH_{100}) show that phytoplankton assemblages, abundance and species composition; vary over short-term (days to weeks), within-year (seasonal), and over years (interannual-to-decades). At least 309 taxa have been recorded from the Port Hacking monitoring sites although the phytoplankton community is typically dominated by 20 dominant taxa mostly belonging to diatoms.
- The East Australian Current (EAC) is a major factor controlling phytoplankton dynamics in the south eastern Australian region. Interannual community composition has been found to be driven predominantly by temperature and season, with other environmental variables (salinity, nitrate, silicate, mixed-layer depth, mixed-layer temperature, degree of stratification, wind, and the Southern Oscillation Index) minor drivers in community composition.
- Blooms of phytoplankton (*i.e.* increased biomass as represented by fluorometer-inferred chlorophyll a concentrations) can occur when upwellings of slope water bring cold, nutrient-rich (phosphate, silicate, and nitrate) water into the euphotic zone. In SE Australia, upwelling events are driven by the the southward flowing EAC and its eddy field with other hydrological factors such as persistent strong NE winds also driving upwellings at the local scale.
- Historical records collected over a 20-year period by DPIE indicate a bloom of the harmless dinoflagllate *Noctiluca scintillans* has been recorded from Merimbula Bay in 2003, though this was a widespread bloom affecting a large portion of the far south coast region at the time. It is noted that other bloom events may have occurred but have not been reported or recorded by DPIE. A bloom of the potentially harmful dinoflagellate *Alexandrium fundyense* was reported along the NSW far south coast region in 2016 resulting in the closure of mussel aquaculture, abalone and lobster fishery in Twofold Bay for eight-week period. No human illnesses were reported from that event.
- For estuarine systems, Merimbula Lake and Pambula River estuary, fortnightly monitoring for nuisance and potentially harmful phytoplankton taxa over 2005-2016 period reported the occasional exceedance of phytoplankton action limits (PALs) of several potentially harmful taxa with positive detections of biotoxins in oyster flesh for a minor proportion of those PAL exceedances. While potentially harmful taxa are known to occur in most estuaries in NSW they are typically in low abundance and not cause for concern. However, maintaining and protecting water quality is important to reducing future risk of potential HAB events.
- A field survey campaign to characterise the phytoplankton assemblage of Merimbula Bay was conducted on 21/11/2017, 1/10/2019, 29/1/2020 and 7/4/2020. A total of 85 phytoplankton taxa were recorded across all sites from vertical net tows represented by 43 diatoms, 35 dinoflagellates, 3 prasinophytes, 1 dictyochophyte, 1 cryptomonad, 1 coccolithophorid, and 1 cyanobacterium. Diatoms were the most diverse group and typically accounted for between 80 to 90% of total abundance

followed by dinoflagellates as the second most diverse group that typically accounted for 1 to 8% of total phytoplankton abundance.

- During an upwelling event on 7/4/2020 the assemblage was dominated by the tropical cyanobacteria *Trichodesmium erythraeum* (48% of total abundance) and diatoms were a minor component of that assemblage.

Phytoplankton assemblage dynamics in the marine environment are highly variable and operate at large biogeographic scales responding to broadscale nutrient inputs and environmental factors. For the SE Australian region, the assemblage shows seasonal trends associated with EAC effects and some of these typical trends were detected in the field sampling at Merimbula Bay for the summer to autumn period that was sampled. The local phytoplankton assemblage of Merimbula Bay is therefore likely indicative of the broader bioregional assemblage at any point in time.

9.7 Potential Impacts of the Project on Phytoplankton Assemblage

Potential effects of Project construction and operational phase activities considers the possible negative and positive effects to the phytoplankton assemblage of Merimbula Bay. An analysis of potential impacts upon, and risk to aquaculture from promotion of toxic algal blooms is specifically addressed in **Section 12 - Aquaculture**.

9.7.1 Construction Phase Effects

Construction phase activities would be localised and are not expected to result in a change in water quality conditions (*i.e.* increased levels of nutrients or change in water temperature, pH) that would influence phytoplankton community dynamics. Therefore, it is unlikely that construction phase activities would have a positive or negative effect on the phytoplankton assemblage of Merimbula Bay.

9.7.2 Operational Phase Effects

Potential operational phase effects on the phytoplankton assemblage of Merimbula Bay considers the following factors:

- The discharge of treated wastewater containing nutrients to the mixing zone from the proposed ocean outfall, and
- The addition of PAC dosing to the treatment process at the STP to reduce phosphorus in the treated wastewater.
- Under existing conditions, the beach-face outfall has discharged treated wastewater to Merimbula Bay since 1971. Upgrades to the STP to improve wastewater quality and disposal at the proposed ocean outfall diffuser would provide improved dispersion of the treated wastewater compared to existing conditions.

The marine environment is generally considered to be oligotrophic (*i.e.* contain low available nutrients) and it is widely understood that among all the possible limiting elements, nitrogen most frequently limits primary productivity (Lobban and Harrison, 1994).

The discharge of treated wastewater to the ocean outfall would include levels of nutrients that exceed the MWQOs and in particular, high levels of bioavailable forms of nitrogen, nitrate and ammonium, that would provide a localised stimulus for increased primary productivity. Dispersion modelling shows that under most conditions, nutrient levels would dilute rapidly and meet MWQOs or natural background conditions within a 25 m mixing zone. As the wastewater would be buoyant and rise upwards in the water column, it is likely that the majority of this nutrient load would be assimilated by phytoplankton within the mixing zone with only a minor proportion available to other marine flora in the mixing zone that includes benthic microalgae and may include drift algae on occasion when present within Merimbula Bay.

Under worse-case conditions such as wet weather flows coinciding with stagnant current conditions that may occur a minor proportion of time (i.e. 1% of time), MWQOs would be met within 200 m of the discharge point. Under this scenario the stimulus for increased primary productivity may extend in scale. However, for both typical and worse-case conditions, the scale of nutrient availability would be considered minor when compared to the concentrations of nutrients supplied to coastal waters during regional-scale upwelling events or following catchment flood flow events.

Phytoplankton blooms occur on a large biogeographic scale and the seasonal influence of the East Australian Current (EAC) is an important factor controlling phytoplankton dynamics in south-eastern Australia. The local phytoplankton assemblage of Merimbula Bay is therefore likely indicative of the broader bioregional assemblage at any point in time. While the Project may provide stimulus for increased primary productivity, it would be localised and small in scale such that potential effects on the phytoplankton assemblage (i.e. change in species composition and abundance) would be masked by changes driven by environmental factors operating at broader bioregional, ocean basin scales.

The inclusion of PAC dosing in the upgrade of the STP for increased removal of phosphorus from the treated wastewater, would reduce the total phosphorus load discharged to the Bay. Whilst primary productivity in marine waters is largely limited by nitrogen nutrients, phosphorus is also an essential nutrient for algal growth. A reduction in phosphorus load in the treated wastewater discharge is a mitigation measure to reduce the overall contribution of nutrients available for algal growth in the Bay.

9.8 Conclusion

It is considered unlikely that Project construction phase activities would have a positive or negative effect on the phytoplankton assemblage of Merimbula Bay. For the operational phase, the discharge of nutrients to the mixing zone would provide a localised stimulus for increased primary productivity where it is expected that the majority of this nutrient load would be assimilated by phytoplankton within the 25 m mixing zone. However, the overall effect this may have on the phytoplankton assemblage of Merimbula Bay would be minimal. This finding is based on the nutrient discharge being localised, small in scale compared to episodic nutrient inputs from upwellings and catchment flood events, and an understanding that phytoplankton assemblage dynamics of Merimbula Bay (i.e. change in species composition and abundance) are more likely to be influenced by environmental factors operating at broader bioregional, ocean basin scales.

10 Drift Algal Biomass

10.1 Introduction

Drift algae discussed in this section refers specifically to macroalgae or seaweed that is no longer attached to substrate and drifting freely over the seabed or as rafts on the sea surface according to ocean currents and local hydrodynamic conditions.

Accumulations of drift algae biomass on a major scale have been a historical issue for the communities of Merimbula and Pambula. This section presents a brief review of the occurrence of drift algae in Merimbula Bay based on the following information:

- *Merimbula Bay Algal Bloom Study* (Elgin, 2013);
- Water quality data collected by BVSC during the Merimbula Background Ocean Water Quality Monitoring program (2014-15, 2015-16); and
- Visual surveillance monitoring of the nearshore beach zone for drift algal biomass conducted during marine ecology investigations between 2017 and 2020.

The potential effects of the Project construction and operational phases on drift algae within Merimbula Bay is evaluated.

10.2 Background

Drift algae is a natural occurrence in the marine environment that can comprise a wide array of species that have been dislodged from their point of attachment and can accumulate on the seabed. The species composition of these accumulations can provide a reliable indication of the marine flora at regional and local scales with the occasional misleading presence of a species that has travelled far beyond its natural distribution range.

When drift algae occur in large biomass and accumulate in the nearshore zone or estuaries, it can reduce amenity, recreational use and is commonly regarded as a 'nuisance algal bloom'. A bloom of algae is simply prolific growth in response to environmental conditions resulting in high abundance or biomass. The use of the term bloom here refers specifically to macroalgae, those algae that are conspicuous to the naked eye, none of which are harmful to humans either through primary or secondary contact. Blooms of macroalgae are distinct from blooms of microalgae which as discussed in **Section 9 – Phytoplankton**, some can be harmful and referred to as harmful algal blooms (HAB). The occurrence of nuisance algal biomass is common to many coastal embayment's around the world and often symptomatic of eutrophication of waterways due to human activities. However, a winter-spring or spring-summer bloom is a natural seasonal occurrence for many macroalgal species due to a range of environmental factors that provide stimulus for prolific growth and development of significant biomass.

The majority of macroalgae require hard substrata and a point of attachment for survival and there are few algae that naturally occur as free-living or unattached drift algae. This is important for understanding the origin of drift algal biomass, as the location where drift algae accumulate is a function of local hydrodynamics and is not necessarily a reliable indicator or where the biomass originally developed. Nevertheless, many algae once detached from a firm anchorage point can persist in the environment for some time, continue to grow and can maintain capacity to release reproductive spores.

Merimbula Bay is a large open embayment that periodically experiences large drifting biomass of a variety of macroalgal species (*i.e.* seaweeds) (Elgin, 2013). Since 2012, at least five (5) algal taxa have been reported as large drifting biomass in Merimbula Bay often washing up on Merimbula and Pambula beaches (Elgin, 2013). The local news and print media typically refer to these events as 'nuisance blooms' and subsequently generate considerable community concern.

For these events, dominant algae identified includes:

- filamentous brown algae of the Order Ectocarpales;
- calcareous red alga *Jania micrarthrodia;*
- brown alga *Phyllospora comosa;*
- brown alga *Sargassum* sp.; and
- filamentous brown alga *Hincksia* sp.

The origin of some of these drift algae could be attributed to sources near to Merimbula Bay. The coralline alga *Jania micrarthrodia* is commonly found in the Merimbula Lake and Pambula River estuaries as an epiphyte on the seagrass *Posidonia australis*, while the large brown algae *Phyllospora comosa* and *Sargassum* sp. are common taxa of macroalgal assemblages on nearby rocky reefs at Long Point and Haycock Point. The presence of these once-attached algal taxa in drifting rafts is due to having been inadvertently detached from their substrate typically during large swell events and storm conditions. While these taxa may survive for a short period unattached, they typically become senescent (as is the case for most marine macroalgae when unattached) and would not be increasing biomass (once detached) typical of an 'algal bloom'. However, the brown algal group known as the Ectocarpales, and in particular the member genus *Hincksia,* consists of a number of opportunistic, fast-growing species known to form large biomass in protected waters and is capable of growing unattached as a mass of self-supporting filaments.

Over the four-year period 2008 to 2012, large accumulations of drift algae observed in Merimbula Bay were largely mono-specific, comprised primarily of the single species *Hincksia sordida* (Elgin, 2013). A number of other alga taxa were found in minor proportions including fragments of *Colpomenia sinuosa,* the superficially similar *Ectocarpus fasiculatus,* and an unidentified red alga belonging to Family Ceramiaceae. However, *H. sordida* was the recurring dominant species comprising the drift algal biomass in Merimbula Bay during the time period 2008 to 2012 and was the target alga for the *Merimbula Bay Algal Bloom Study* (Elgin, 2013).

10.3 Nuisance Algal Blooms

Nuisance algal blooms have been a historical issue for the communities of Merimbula and Pambula, with at least 27 articles discussing the issue appearing in local news media over the 2004 to 2012 period (Elgin, 2012). The *Merimbula Bay Algal Bloom Study* (Elgin, 2013) was undertaken to investigate the occurrence of nuisance algal blooms and used nitrogen stable isotopes (δ^{15}N: δ^{13}N ratio) to examine whether the nitrogen present in drift algae was derived from treated wastewater from Merimbula STP.

The study was unable to unequivocally conclude that the bloom alga *Hinksia* was isotopically enriched with nitrogen derived from treated wastewater. The main reason being that the alga was sampled opportunistically when present in the near-shore zone. Consequently variation in the δ^{15}N signal of algae due to spatial and temporal factors could not be controlled or accounted for and therefore limited interpretation of the available data. Being a drift algae with high turnover of tissue nitrogen presents a potential case in which *H. sordida* may utilise treated wastewater derived nutrients where available and then drift away to areas of the bay where the influence of treated wastewater derived nutrients is diminished. After a few weeks have elapsed, the isotopically enriched δ^{15}N signal of wastewater in the algae may be replaced with a depleted δ^{15}N signal thereby confounding any assessment regarding the influence of wastewater on the algae.

Anecdotal accounts from several long-term Merimbula residents indicate macroalgal blooms have been a regular occurrence in the bay environment as early as the 1950's. This is prior to the commissioning of the Merimbula STP in 1971 and before the discharge of wastewater to the bay commenced. These historical accounts demonstrate that macroalgal blooms have been a regular natural occurrence in Merimbula Bay and it is likely that large aggregations of drift algal biomass and blooms may continue to occur even when strategies to reduce nutrient concentrations in wastewater and advances in STP management are implemented (Elgin, 2013).

Following the algal bloom study in 2012, the occurrence of nuisance algal blooms in Merimbula Bay have been rare and only a single news article (‘*Summer Scourge is Back’*, 27 January 2014, Merimbula News Weekly) has appeared in local media since that time.

10.4 Background Ocean Water Quality Data (2014 to 2017)

The *Merimbula Bay Algal Bloom Study* (Elgin, 2013) concluded that algae in the Bay, including *H. sordida,* would utilise wastewater derived nutrients where available in the marine waters of the Bay. However, wastewater represents just one source of available nutrients with diffuse source inputs from the catchments (via flood events), periodic upwelling of slope water, groundwater discharge and the release of nutrients from the bay sediments all contributing to the pool of bioavailable nitrogen in Merimbula Bay (**Table 10-1**). Assessing the relative contribution of nutrients from these diffuse sources is difficult due to their episodic nature.

Monitoring of background water quality data for the marine waters of Merimbula Bay was undertaken by Elgin over 24 months in 2014-15 and 2016-17. The monitoring program included sampling of surface, mid-water and bottom waters at three locations in the central region of the Bay and at sites south of Haycock Point to characterise background levels of nutrients and a range of metals in ocean waters.

Results showed that median levels of nitrate in Merimbula Bay ranged between 14 and 40 µg/L (median 17 ug/L), often exceeding the ANZECC guideline of 25 µg/L for the protection of aquatic marine ecosystems. However, during upwelling events where intrusions of slope water bring cooler nutrient-rich waters to the coastal zone, nitrate levels have been measured in Merimbula Bay at 126 to 138 µg/L (21 March 2017). These levels are within the range (>70 - 250 µg/L) previously reported for slope waters in other NSW regions (Pritchard *et al.* 2003, Suthers *et al.* 2011). As upwellings operate over large spatial scales of hundreds of kilometres, these nutrient concentrations represent a significant contribution of nutrients to the coastal zone. Pritchard *et al.* (2003) considered the various sources of nutrients to the coastal zone of the Sydney region and found slope water to be the dominant source of nutrients during upwelling events with daily nutrient loads exceeding STP wastewater and riverine discharges by orders of magnitude.

Table 10-1 Sources of nutrients to Merimbula Bay and their documented loads and/or concentrations (from Elgin, 2013)

Nutrient Source	TN load (kg/yr)	TP load (kg/yr)	Nitrate NO_3^- (mg/L)	Ammonium NH_4^+ (mg/L)	Phosphate PO_4^{3-} (mg/L)
STP wastewater discharging from ocean outfall (existing conditions)	1,664 [a]	3,090 [a]	5 [b]	<1 [b]	8.5 [b]
Pambula catchment [c]	*34,532* [c]	*3,037* [c]	0.1 – 0.27 [d]	0.05 [d]	0.06 – 0.07 [d]
Merimbula catchment [c]	*6,128* [c]	*798* [c]	0.09 – 0.21 [d]	0.01 [d]	0.03 – 0.05 [d]
Upwellings of slope water	-	-	~0.25 [e] >0.07-0.14 [f]	-	0.022 [g]
Groundwater - influenced by dunal exfiltration ponds [h]	367	711	0.34 [h]	0.82 [h]	2.26 [h]
Groundwater - natural [i]	-	-	0.42[i]	0.03 [i]	0.06 [i]
Merimbula Bay sediments	-	-	-	-	-
Atmosphere	-	-	-	-	-

Note

[a] Mean annual loads based on 2007-2011 Load Based Licensing data (POEO register - OEH 2012).

[b] Typical nutrient concentration values of STP wastewater – information supplied by BVSC.

[c] Modelled catchment nutrient loads delivered to estuary (DECCW 2009). Note - nutrient load exported from the estuary to Merimbula Bay is considered to be a minor proportion of this total load.

[d] Surface water concentrations measured during catchment rainfall events >100mm in 24hrs period (Elgin Assoc. *unpubl.)*

[e] From Suthers *et al.* (2011) – NO_3^- concentration of slope water reported as 4 µM (equivalent to 0.25 mg/L).

[f] From Tranter *et al.* 1986 and noted in Pritchard *et al.* (2003)

[G] From Cresswell 1994

[h] Groundwater influenced loads from an estimation of natural and wastewater induced groundwater flow to ocean in the vicinity of the exfiltration ponds and water quality data obtained from the coastal "influenced" bores (Data from BVSC)

[i]. Groundwater quality representative of natural background conditions obtained from the coastal "natural" bores. Groundwater natural loads for TN and TP for entire dune system are unknown. (Data from BVSC).

- dash indicates no data available

10.5 Visual surveillance monitoring of the nearshore beach zone

Visual surveillance monitoring for accumulations of drift algal biomass was conducted opportunistically during marine ecology field investigations between 2017 and 2020. Visual inspections were carried out from a slow-moving vessel zig-zagging within the nearshore zone between Pambula and Merimbula. Water clarity was typically very high and confirmation of drift algae on the seabed was possible to depths of 10 m.

Variable quantities of drift algae biomass was present on the seabed in Merimbula Bay though not always present in the nearshore zone. However, accumulations of drift algae biomass were noted in the nearshore zone on the following two occasions:

- minor scale accumulation - 9 January 2018
- major scale accumulation – 11 October 2019.

10.5.1 Minor scale accumulation of drift algae – 9 January 2018

On 9 January 2018, drift algal biomass was detected in the nearshore zone in approximately 4m of water just north of the existing beach-face outfall. The accumulation was relatively sparse and considered a minor scale event. Biomass washed up onto the beach was not observed. A drop camera was used to verify the species as fragments of the bullate brown alga *Colpomenia sinuosa* (**Figure 10-1**). The origin of this algal biomass was inferred to likely be from Merimbula Lake as it is one of two macroalgal taxa known to undergo prolific growth in the estuary during winter-spring period each year (Elgin, 2013).

The alga grows attached to the leaf blades of *Posidonia* seagrass until it reaches a size that cannot resist the drag forces of tidal flows and is torn from its seagrass substrate. Thalli of *Colpomenia* wash up along the shoreline of the estuary in early summer and are further washed out to Merimbula Bay where it accumulates on the seafloor and begins to decompose forming fragments (Elgin, 2013) as observed on 9 January 2018.

This is an example of drift algae biomass that occurs in Merimbula Bay every year on a seasonal basis, sometimes forming large accumulations on the seafloor and as surface rafts, that follows the winter-spring bloom of the species development in the estuarine environment.

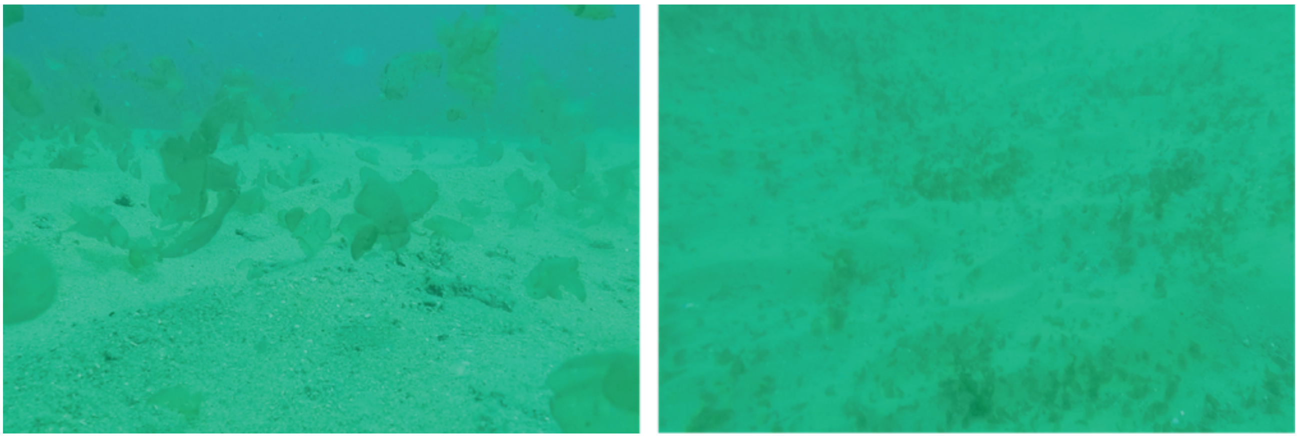


Figure 10-1 Small quantity of drift algae, fragments of *Colpomenia sinuosa*, observed over the seabed in January 2018

10.5.2 Major scale accumulation of drift algae – 11 October 2019

On 11 October 2019, a major scale aggregation event of drift algae biomass was observed in the shallow nearshore waters (5 – 10 m depth) extending from Merimbula beach to Pambula beach. The event comprised of floating surface rafts with majority of algal biomass on the seabed. Drift algal biomass was found to be extensive across the nearshore zone from Pambula Rivermouth to Merimbula beach (**Figure 10-2**).

The algal biomass was comprised primarily of two species, *Hincksia sordida* and fragments of *Colpomenia sinuosa*, that are both known to occur within Merimbula Bay and previously reported in large scale accumulation events. Still images taken from underwater video of the event off Pambula Rivermouth are provided in **Figure 10-3**. The drift algal biomass was visible as dark patches from the surface and extended from the 5 m depth contour out to 10 m.

Drift algal biomass of similar taxa were also observed in deeper waters between 20 m to 40 m depth in the central bay region on the following Monday 14/10/19. The quantity of algae suspended in the water column affected the water clarity. It was evident that drift algal biomass was a significant presence within the Merimbula Bay environment at that time, although not present on the beaches.

Dependent on local hydrodynamic factors, the likelihood that the drift algal biomass would eventually wash up on Merimbula and Pambula beaches in the short-term (days to weeks) was considered high. However, that was not observed, and only minor scale accumulations of drift algae were noted in the beach zone at Merimbula and Pambula over the following summer months of 2019-2020.

Seasonal factors considered to increase the likelihood and frequency of drift algal biomass moving into the beach zone and washing ashore include the spring and summer period when easterly and north-easterly winds are most prevalent. Sustained north to north-easterly winds invoke Ekman transport where the sea surface currents move away from the coast with this net movement of surface water acting to draw up bottom waters towards the near-shore zone. It is these bottom currents that resuspend *Hincksia* thalli in the water column and play a large role in shifting the biomass of *Hincksia* towards the nearshore zone in the first instance. Persistence of blooms in the nearshore zone is then influenced by wave action and prevailing wind direction (Elgin, 2013).

This is an example of a drift algae biomass event on a major scale that did not wash up on the beaches in a significant way and was largely un-noticed by the community. Previous such events in Merimbula Bay where the biomass has washed up on the beaches has resulted in reduced recreational amenity, community complaints and media coverage.

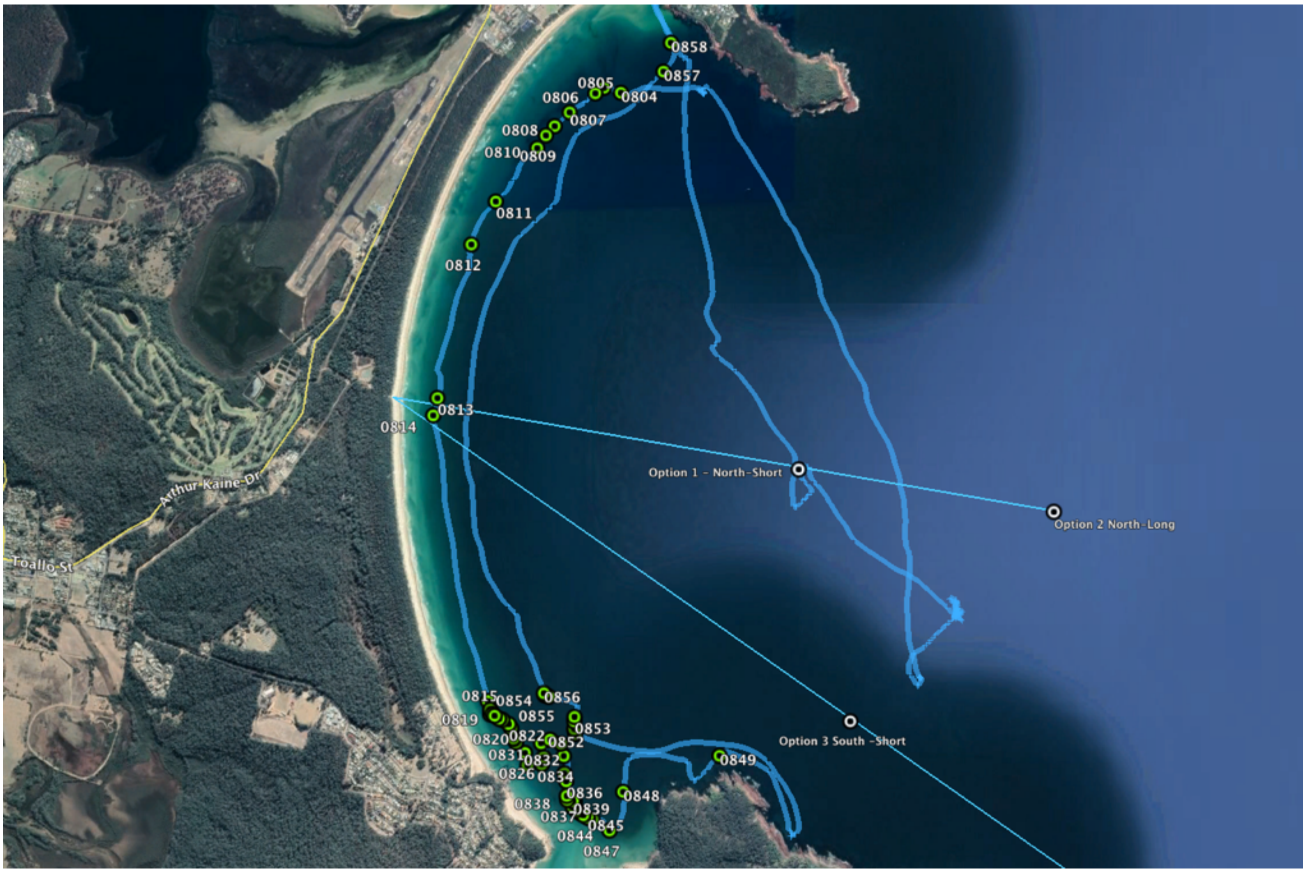


Figure 10-2 Locations where rafts of drift algae were observed either on water surface or on the seabed or both, 11 October 2019

Figure 10-3 Still images extracted from video of drift algal biomass (taxa included *Hinksia sordida* and fragments of *Colpomenia sinuosa*) observed over seabed 500m from shoreline at Pambula Beach in 5m depth, 11 October 2019

10.6 Key Findings

Key findings regarding the occurrence of drift algal biomass in Merimbula Bay based on previous studies and observations collected during marine ecology investigations include:

- Major scale aggregations of drift algal biomass, often referred to as nuisance algal blooms, have been a historical issue for the Merimbula and Pambula communities, and has prompted studies to investigate their occurrence. Anecdotal accounts of major aggregation events occurring within the embayment date back to the 1950s and prior to the commissioning of the Merimbula STP and discharge of treated wastewater to the marine environment in 1971.
- Drift algal biomass can include a variety of species but two species that are regularly observed in Merimbula Bay and constitute a dominant component of major scale aggregations includes the brown algae *Colpomenia sinuosa* and *Hincksia sordida*.
- A study on the nuisance algal blooms in 2012 investigated the alga *Hinksia* using nitrogen stable isotope analysis. Whilst this study was unable to unequivocally conclude that *Hinksia* was isotopically enriched with nitrogen derived from treated wastewater from Merimbula STP, it did conclude that drift algae in Merimbula Bay, including *Hinksia,* would utilise wastewater derived nutrients where available. This was along with a range of other potential nutrient sources including catchment inputs, slope water, groundwater discharge and release from benthic sediments. Assessing the relative contribution of nutrients from these diffuse sources is difficult due to their episodic nature.
- Ocean water quality monitoring in Merimbula Bay between 2014-2016 provides a dataset of ambient background levels of nutrients and a range of metals in ocean waters. Median levels of nitrate in Merimbula Bay often exceeded the ANZECC guideline (25 µg/L) for the protection of aquatic marine ecosystems. However, during upwelling events and intrusions of slope water to the coastal zone, nitrate levels have been measured well above this guideline in Merimbula Bay (126 to 138 µg/L), and

in the range (>70 - 250 µg/L) previously reported for slope waters in other NSW regions. Upwelling events trigger blooms of phytoplankton and provide stimulus for increased primary productivity generally.

- Drift algal biomass was detected in the nearshore zone during marine ecology investigations between 2017 and 2020 including a minor scale accumulation in January 2018 and a major scale accumulation in October 2019. The minor scale accumulation comprised of decomposing fragments of the estuarine brown alga *Colpomenia sinuosa* and no other species were observed. The major scale accumulation comprised primarily of *Hincksia* with *Colpomenia* also involved with drift algal biomass extensive over the seabed in the nearshore zone from Pambula Rivermouth to Merimbula.
- The accumulation of drift algal biomass on a major scale as observed on the seabed in October 2019 was largely un-noticed on the beaches by recreational users and indicates that these events likely occur more frequently than what is often reported.

10.7 Potential Impacts of the Project on Drift Algae

10.7.1 Construction Phase Impacts

Construction phase activities are unlikely to have a positive or negative impact on the occurrence of drift algae in Merimbula Bay.

10.7.2 Operational Phase Impacts

Potential operational phase inpacts of the Project on the occurrence of drift algae considers the following factors:

- The physical pipeline infrastructure may act as a barrier and interrupt the natural movement of drift algae biomass; and
- The addition of PAC dosing to the treatment process at the STP to reduce phosphorus in the treated wastewater.
- The discharge of treated wastewater containing nutrients to the mixing zone from the proposed ocean outfall.

Once constructed, the proposed ocean outfall pipeline with its cover of concrete blanket and or rock armour would effectively create a narrow, 2.7 km long, low-profile artificial reef oriented in a south-easterly direction to the North-Short diffuser. The sandy seabed of Merimbula Bay is relatively flat characterised by sand ripples and sand waves that currently provides for free unimpeded movement of drift algae around the embayment. The pipeline would introduce a low-profile structure into this otherwise flat environment and may act somewhat as a barrier to the natural movement of drift algae in Merimbula Bay although some proportion of drift algal biomass would be transported over the structure. Drift algae may accumulate along the pipeline and depending on prevailing hydrodynamic conditions, the pipeline may funnel the biomass in a seaward or shoreward direction. The latter scenario increasing the likelihood that drift algae biomass may wash onto the beach zone. It is possible that the physical structure of the pipeline may influence the accumulation of drift algal biomass when present in Merimbula Bay, potentially trapping algal biomass on one side of the pipeline for longer periods than what would occur naturally in the absence of the pipeline structure.

The discharge of treated wastewater to the North-Short diffuser at 30 m depth would include levels of nutrients that exceed MWQOs including oxides of nitrogen (NOx), ammonia, total phosphorus, and orthophosphate. Dispersion modelling shows that under most conditions, nutrient levels would dilute rapidly and meet MWQOs or natural background conditions within a 25 m mixing zone. As the treated wastewater would be buoyant and rise upwards in the water column, it is likely that the majority of this nutrient load would be assimilated by phytoplankton within the mixing zone with only a minor proportion available to other marine flora in the mixing zone that includes benthic microalgae and may include drift algae on occasion when present within Merimbula

Bay.

The inclusion of PAC dosing in the upgrade of the STP for increased removal of phosphorus from the treated wastewater, would reduce the total phosphorus load discharged to the Bay. Whilst primary productivity in marine waters is largely limited by nitrogen nutrients, phosphorus is also an essential nutrient for algal growth. Whilst there are a number of nutrient sources for drift algae in the Bay, a reduction in phosphorus load in the treated wastewater discharge is a mitigation measure to reduce the contribution of nutrients available for algal growth in the Bay.

It is considered unlikely that the Project would cause an increased occurrence of drift algae in Merimbula Bay. However, the frequency with which drift algal accumulations continue to occur and persist in Merimbula Bay is unpredictable due to a wide range of environmental factors that include storm activity, regional scale nutrient supply, and local hydrodynamic conditions. To most people, the occurrence of drift algae is a nuisance and viewed as a problem. For Merimbula Bay, the drift algal biomass represents an important component of the local ecology as they are a source of recycled nutrients and particulate carbon that is vital to detrital-based food webs that include benthic infauna (i.e. polychaete worms, crustacea, cnidaria) that then benefit the fishes and higher order predators in the food chain.

10.8 Conclusion

Construction phase activities are unlikely to have a positive or negative effect on the occurrence of drift algae in Merimbula Bay.

For the operational phase, it is considered unlikely that the discharge of treated wastewater would cause an increased occurrence of drift algae, in scale or frequency, in Merimbula Bay above that which currently occurs on an episodic basis. However, the physical pipeline infrastructure may act as a barrier and interrupt the natural movement of drift algae biomass resulting in accumulations along the pipeline. Depending on prevailing hydrodynamic conditions, the pipeline may funnel the biomass in a seaward or shoreward direction. The latter scenario increasing the likelihood that drift algae biomass may wash onto the beach zone. It is possible that the physical structure of the pipeline may influence the accumulation of drift algal biomass when present in Merimbula Bay, potentially trapping algal biomass on one side of the pipeline for longer periods than what would occur naturally in the absence of the pipeline structure. In terms of marine ecology, the occurrence of drift algae is not viewed as negative impact.

11 Estuarine Community

The potential impact of the Project, both from construction and operational phases, on estuarine communities and estuary health of Pambula Lake and Merimbula Lake is assessed in this section. Estuary health is based upon a number of key indicators that include macrophyte (seagrass, mangrove, saltmarsh) extent, water quality, occurrence of algal blooms, and fish assemblage data. The assessment also includes an analysis of the potential risks or benefits of the Project to recreational fishing in Merimbula and Pambula Lakes.

Studies conducted in Merimbula and Pambula Lakes include Pambula River estuary processes study (Cardno, 2012), Merimbula Lake flood study (Cardno, 2016), potential ecological impacts of dunal ex-filtration of wastewater (AECOM and Elgin, 2013), water quality and estuary health monitoring (Elgin, 2014) and estuarine macrophyte mapping (Creese *et al*., 2009; Cardno, 2012). Information from these studies combined with historical biodiversity data (Day and Hutchings, 1983) and estuary health assessments (Elgin, 2014) have been used to describe existing conditions.

For the EIS, estuarine habitats and communities potentially impacted by the project are identified and their risk of impact examined. This includes initial review of the current setting of the beach-face outfall and its relative location to the estuary entrances of both Merimbula and Pambula Lakes, and that there has been potential for exposure of wastewater from the beach-face outfall since operation commenced in 1971. Assessment of potential impacts from the Project includes the proposed upgrades to the STP and discharge of wastewater from the 'North-Short' outfall.

11.1 Merimbula Lake

Merimbula Lake has significant natural and physical values and is listed as a nationally important wetland (Environment Australia, 2017) with the following attributes:

- *Subtidal aquatic beds; includes kelp beds, seagrasses, tropical marine meadows (A2)*
- *Estuarine waters; permanent waters of estuaries and estuarine systems of deltas (A6)*
- *Intertidal mud, sand or salt flats (A7)*
- *Intertidal marshes; includes salt-marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes (A8)*
- *Intertidal forested wetlands; includes mangrove swamps, nipa swamps, tidal freshwater swamp forests (A9)*

The criteria for determining nationally important wetlands in Australia, and hence inclusion in the Directory, are those agreed to by the ANZECC Wetlands Network in 1994. Merimbula Lake meets the following criteria for inclusion:

- *It is a good example of a wetland type occurring within a biogeographic region in Australia* (Criteria 1).

A brief description of the natural and physical values of Merimbula Lake is provided in the sections below.

11.1.1 General Description

Merimbula Lake is a wave-dominated, barrier estuary that is permanently open to the ocean and is considered to be at an intermediate stage of evolution with regard to sediment infilling (Roy *et al.* 2001). The estuary has exceptionally good tidal flushing due to its wide, deep entrance and it has been estimated that weekly tidal flows through the entrance are equivalent to approximately twice the total volume of the lake (Webb, McKeown and Associates 1997). Merimbula Lake is central to Merimbula Township with boat access via the ramp located off Arthur-Kaine Drive on the southern side of the causeway. Merimbula Township and urban residential development largely surround the marine tidal-delta zone of the estuary and extend around the northern shoreline of the basin. Other catchment land uses include low-density residential, light agricultural grazing and forestry to the west and south, and recreational uses such as the Pambula-Merimbula Golf Club that is located adjacent to the Golf Course lake backwater (refer **Figure 11-1**). The Merimbula Airport and the Merimbula STP are located southeast of the estuary.

The estuary is characterised by a deep basin locally referred to as 'Top Lake' that connects to the ocean via an expansive marine tidal-delta and permanently open inlet. The marine tidal-delta zone is typically shallow, characterised by intertidal sand-flats, widespread seagrass meadows and a meandering main channel that forms a permanently open connection between the estuary and Merimbula Bay (ocean) via the inlet that is naturally trained along the rocky southern shoreline of Long Point. The estuary is one of the largest in the BVSC region covering an area of 5.6 km^2 (this includes the areas containing saltmarsh and mangrove vegetation communities) with a catchment area of 37.9 km^2 (OEH, 2017). Average water depth of the estuary is 2.6 m (OEH, 2017) with depths of up to 9.6 m recorded in the basin. The marine-tidal delta that extends from the basin to the entrance covers an estimated area of 2.0 km^2 (NLWRA, 2001), equivalent to 35% of the estuary area. The central basin covers approximately 40% of the estuary area.

The majority of the catchment area is intact comprising native woody vegetation (75%) with approximately 21.5% cleared for agriculture and 5.4% urban area (NLWRA, 2001). A small portion of the catchment in the southeast is part of Ben Boyd National Park, while the western-most forested area of the catchment is part of Yurammie State Forest. The primary inflows of freshwater and fluvial sediment to the estuary are from Boggy and Bald Hills Creeks that discharge to the northwestern and southwestern shorelines of the basin respectively.

A simplified geomorphological model of the estuary is shown in **Figure 11-1** below

Figure 11-1 Simplified geomorphological model of Merimbula Lake. Aerial image provides a south-westerly view over the estuary (photo from Ozcoasts website, dated 22 April 2000)

11.1.2 Estuarine Habitats

Merimbula Lake supports a range of estuarine habitats including seagrass meadows, mangroves, saltmarsh and intertidal sand/mud flats. Being permanently open to ocean and dominated by marine conditions, Merimbula Lake provides the ideal environment for the seagrass *Posidonia australis* and mangroves *Avicennia australis* and *Aegiceras corniculatum*.

It is one of only three BVSC estuaries that support large meadows of the seagrass *Posidonia australis*, commonly called 'strapweed' (it also occurs in Bermagui River and Pambula Lake). Other seagrasses present in the lake include *Zostera muelleri* (eelgrass) and *Halophila ovalis* (paddleweed). Collectively seagrasses cover an estimated 1.693 km^2 (~30%) of the estuary area (Creese *et al.,* 2009).

Discrete areas of saltmarsh community are present around the estuary, collectively estimated to cover 0.592 km^2 (~10%) of the estuary area (Creese *et al.,* 2009). The largest contiguous saltmarsh community is located adjacent to the Merimbula Airport and surrounds the Golf Course lake backwater. The community includes samphire (*Sarcocornia quinqueflora*), coastal speargrass (*Austrostipa stipoides*), sea rush (*Juncus krausii*) and a good population of shrubby samphire (*Tecticornia arbuscula*).

Mangroves include the grey and river mangrove and are present around the estuary margins and estimated to cover 0.592 km^2 (~11%) of the estuary area (Creese *et al.,* 2009). Merimbula Lake represents the southern limit for the River mangrove (*Aegiceras corniculatum).*

Sand flats, seagrass meadows, shell beds and oyster lease infrastructure (ropes, posts and baskets) provide habitats for the colonisation of macro- and microalgal assemblages. Prolific seasonal growth of macroalgae, predominantly as epiphytes on *Posidonia* seagrass have been observed in summer and winter (Elgin 2014). Epiphytic taxa recorded on seagrass included four species of red algae (*Laurenica majuscula* var. *elegans*, *Centroceras clavulatum, Spyrida filamentosa* and *Polysiphonia infestans*) and four species of brown algae (*Dictyota alternifida, Dictyota dichotoma, Colpomenia sinuosa,* and *Asperococcus bullosus*).

The approximate distribution of seagrasses, saltmarsh and mangrove communities are shown in **Figure 11-2.** below.

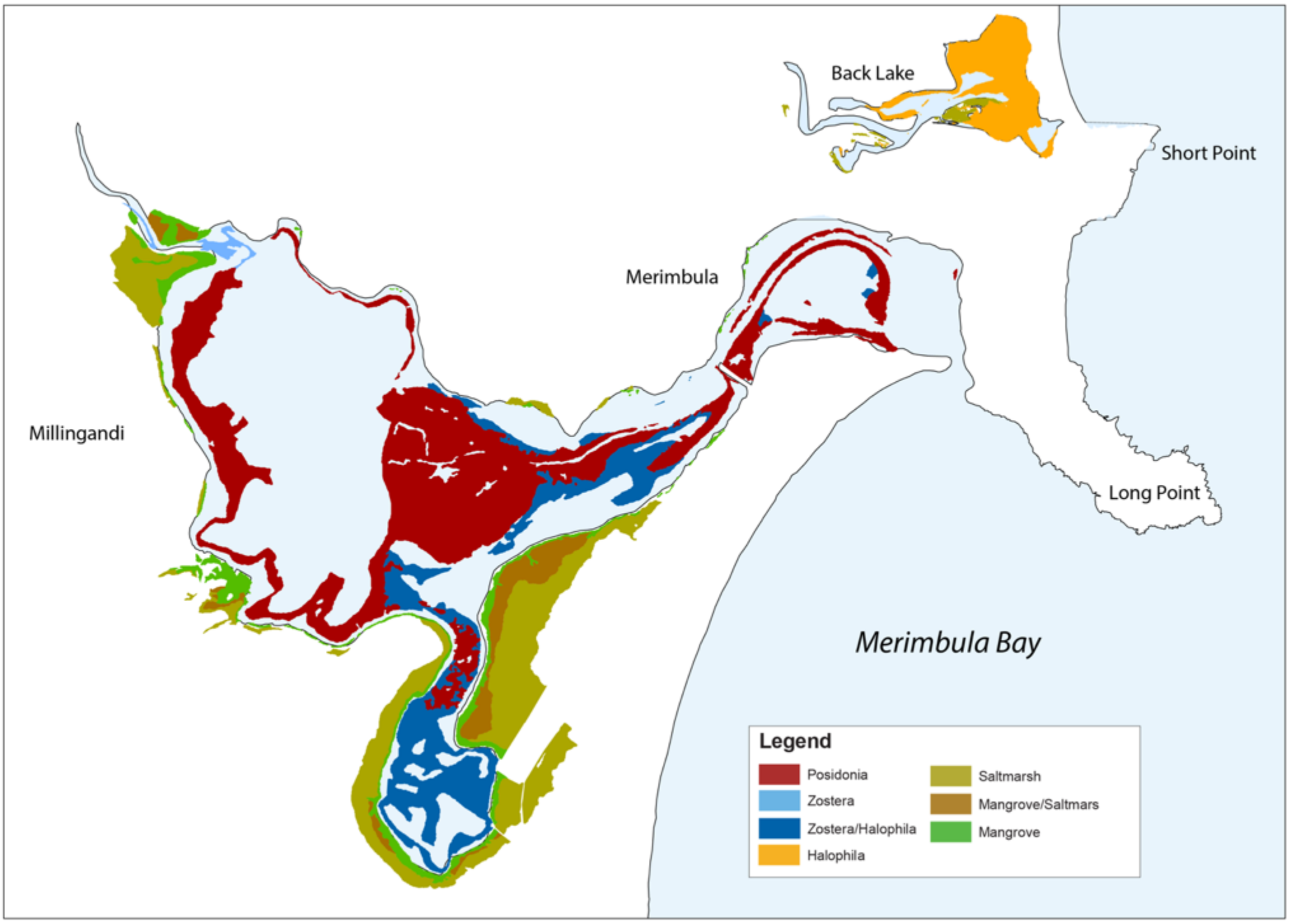


Figure 11-2 Estimated spatial extent of estuarine habitats of Merimbula Lake (vegetation mapping from Creese et al., 2009 - based on aerial imagery from 1994 & 2001 and field survey August 2002)

Estuarine macrophytes are a key indicator of estuary health in NSW and classified as key fish habitat under the *Fisheries NSW Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013). Seagrass and saltmarsh are *Type 1 – highly sensitive key fish habitat*, while mangrove and macroalgae are *Type 2 – moderately sensitive key fish habitat*.

Trends in macrophyte habitat change have been estimated by previous mapping studies (Meehan, 1997; Creese *et al.,* 2009). Meehan (1997) estimated that mangrove habitat in Merimbula Lake increased by 120% between 1948 and 1994 at the expense of saltmarsh habitat that is estimated to have contracted by approximately 30% in areal extent during the same time period. Meehan (1997) also estimated that 23.5% of seagrass habitat in Merimbula Lake was lost between 1977 and 1994. However, the most recent vegetation mapping of Creese *et al.* (2009) estimates that *Posidonia* seagrass habitat in Merimbula Lake has increased from 0.789 km^2 in area (West *et al.,* 1985) to 1.157 km^2, an approximate 145% increase in habitat for this particular seagrass species. The mapped distribution and extent of estuarine macrophytes in Merimbula Lake is more than 15 years old and a current understanding of temporal change and whether areas of habitat are increasing or contracting is not known.

11.1.3 State Environmental Planning Policy (SEPP) Coastal Management 2018 – Coastal Wetland

Merimbula Lake supports significant areas of Coastal Wetland identified under the SEPP (Coastal Management) 2018 as shown in **Figure 11-3**.

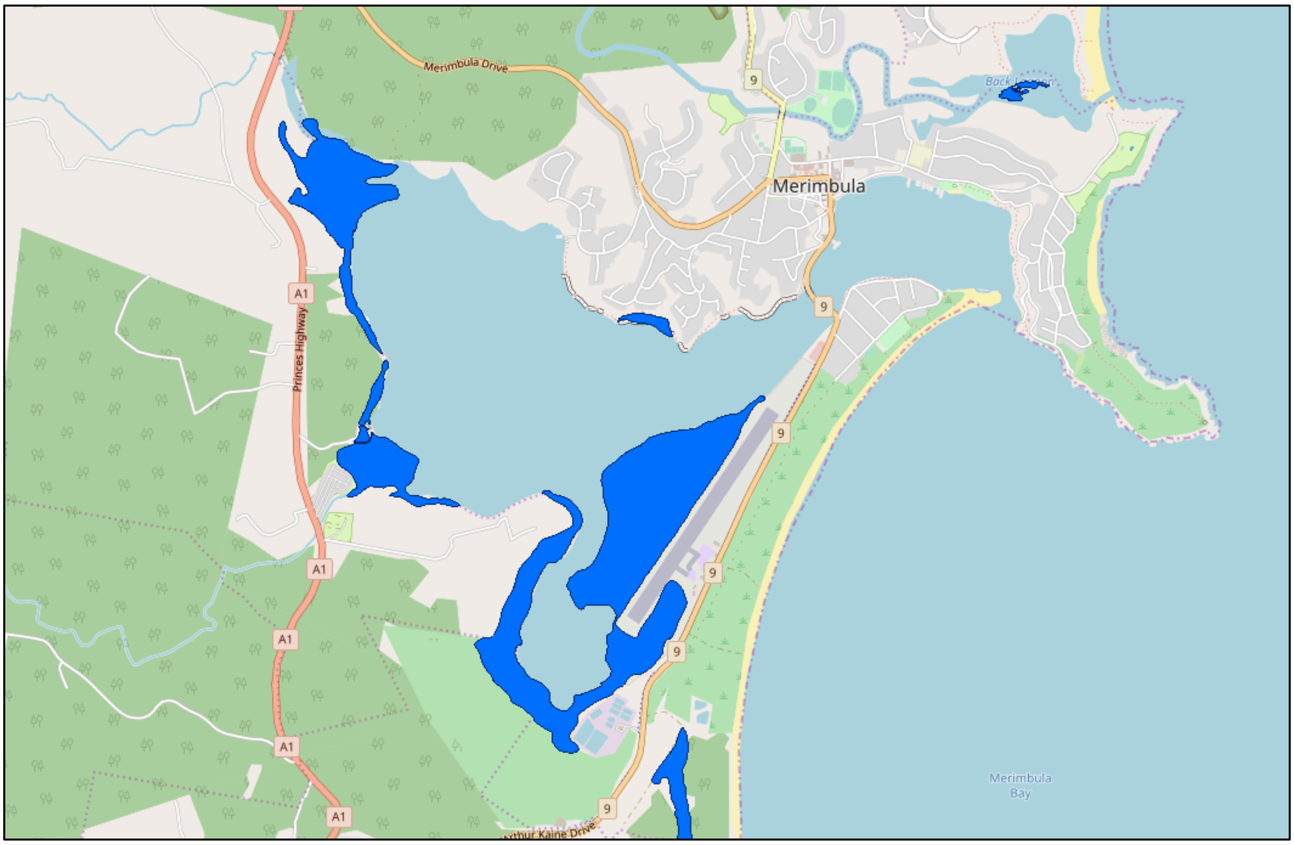


Figure 11-3 Occurrence of Coastal Wetland at Merimbula Lake identified under SEPP (Coastal Management) 2018 (areas coloured dark blue)

11.1.4 Faunal Assemblage

Merimbula Lake has a rich and diverse estuarine fauna with many species common to areas further north in New South Wales as well as species typically found in more southern regions (Day and Hutchings, 1984). With the exception of a study by Day and Hutchings (1984), few accounts of the fauna of Merimbula Lake have been published. Species sightings information is available on the Atlas of Living Australia (2017), which collates species record data from a range of government agencies, museums and citizen science groups such as Atlas of Life in Coastal Wilderness who are active in the Far South Coast region of NSW.

A search of the ALA (2017) of major faunal groups that are aquatic or rely on aquatic habitats such as birds, fish, molluscs and crustaceans that have been recorded from Merimbula Lake returned 293 bird species, 57 fish species, 232 molluscs and 60 crustaceans. This data has not been validated and it is noted that not all of these species may be estuarine or rely on estuarine habitats for foraging.

Avifauna

The fringing forest, mangrove and saltmarsh community in addition to the intertidal sand flats provide habitats important for foraging, resting and breeding for a variety of birds. A number of migratory waders / shorebirds that are listed under international agreements JAMBA and CAMBA have been recorded and include:

- Latham's Snipe (*Gallinago hardwickii*)
- Bar-tailed Godwit (*Limosa lapponica)*
- Eastern Curlew (*Numenius madagascariensis*)
- Whimbrel (*Numenius phaeopus)*

Bird species which are listed as threatened at state level and which have been recorded within the lake area include:

Hooded Plover (*Thinornis rubricollis*) (Endangered)

Australasian Bittern (*Botaurus poiciloptilus*) (Endangered)

Pied Oystercatcher (*Haematopus longirostris)* (Endangered)

Sooty Oystercatcher (*Haematopus fuliginosus*) (Vulnerable)

Glossy Black-Cockatoo (*Calyptorhynchus lathami*) (Vulnerable)

Barking Owl (*Ninox connivens*) (Vulnerable)

Masked Owl (*Tyto novaehollandiae*) (Vulnerable)

Great Egret (*Ardea alba*)

White-bellied Sea-Eagle (*Haliaeetus leucogaster*).

Fish

The fish assemblage of Merimbula Lake was surveyed by West and Jones (2001) and documented 61 species. The most specious families collected were the Gobiidae (10 species), the Monacanthidae (9 species) and the Syngnathidae (6 species). In terms of abundance, small mouth hardyhead (*Atherina microstoma*) and glassy perchlet (*Ambassis jacksoniensis*) dominated the assemblage. The highest numbers of commercial finfish were luderick (*Girella tricuspidata*), bridled leatherjacket (*Acanthaluteres spilomelanures*), yellow-finned leatherjacket (*Meuschenia trachylepis*) and sand mullet (*Myxus elongatus*). A list of fish species recorded from Merimbula Lake by West and Jones (2001) is provided in **Appendix H-1.**

No fish species listed as threatened under the FM Act or EPBC Act are known to occur in Merimbula Lake. However, six species belonging to the Syngnathiformes (seahorse, pipefish, pipehorses) and protected under the FM Act are known to occur. These include *Syngnathoides biaculeatus, Vanacampus poecilolaemus, Urocampus carinirostris, Vanacampus phillipi, Stigmatophora nigra, Stigmatophora argus.*

Marine Invertebrates

A study by Day and Hutchings (1984) surveyed the diversity of marine invertebrates at Merimbula Lake by sampling soft sediment, rocky reef, artificial substrates (*i.e.* oyster infrastructure), seagrass, mangrove and saltmarsh habitats. The study lists 247 taxa representing 20 taxonomic groups. The six most species-rich groups (in order of abundance) were the polychaete worms with 75 taxa, 43 gastropods, 32 amphipods, 29 bivalves, 28 crabs, and 13 isopods. Fourteen other invertebrate groups had six or less species.

11.1.5 Commercial Aquaculture

Commercial waterway uses in the estuary include oyster aquaculture primarily of Sydney rock oyster (*Saccostrea glomerata*) with smaller quantities of southern mud oyster (*Ostrea angasi*) also cultivated. Approximately 125.8 hectares of Merimbula Lake is designated as priority oyster aquaculture area. In 2005/2006, Merimbula Lake produced over 3% of the total NSW production of Sydney rock oyster worth in excess of $1 million (OISAS, 2006). As of 2016, the 10-year moving average for oyster production in Merimbula Lake was 134.8 tonnes (OISAS, 2016).

Potential impact to estuary aquaculture from the Project is evaluated in further detail in **Section 12 - Aquaculture** below.

11.1.6 Recreational Use and Amenity

The natural amenity and significant ecological values of the estuary including its clear waters and high tidal flows, extensive saltmarsh, mangrove and seagrass communities are an important asset to the coastal township, with the estuary representing a key attraction for local residents and tourists that visit Merimbula annually. It is among the most popular estuaries within the Bega Valley for recreational use with swimming, boating, kayaking, paddle-boarding and snorkelling popular activities.

The estuary is also a popular location for recreational fishing, targeting a range of angling species identified in **Section 11.1.4** and in **Appendix H-1**.

11.1.7 Water Quality

Water quality of Merimbula Lake is described in the *Water Quality Technical Report* (Elgin, 2021) and summarised below for normal and post-event flow conditions.

Under normal conditions the estuary has a high level of water quality with marine tidal flows a key process in maintaining water quality conditions. The estuary basin is well-mixed by tidal flushing and characterised by high water clarity and very low turbidity. There is low microalgal abundance and median nutrient levels are typically below estuary water quality objectives (WQOs). Exceptions include oxides of nitrogen and total nitrogen, with estuary monitoring indicating nutrient levels can remain elevated for some parameters for some time after catchment inflow events.

Post-event water quality of Merimbula Lake has been assessed from data collected after three separate rainfall events corresponding to an average recurrent interval (ARI) of less than 1 year (9/4/2015), 2 to 5-year event (6/6/2016), and 10 to 20-year event (31/1/2016). After significant rainfall, estuary water quality is poor with elevated levels of turbidity, nutrients and biological parameters all exceeding estuary WQOs. Water clarity is typically poor with elevated turbidity, although clarity quickly improves following an event due to exceptional tidal flushing. Mean levels of nutrient parameters increase by a factor of 2 to 7 compared to normal conditions. Microbiological parameters faecal coliforms and enterococci exceed the MWQOs and are often orders of magnitude higher than normal conditions, with highly elevated results indicative of possible failure of sewer network infrastructure.

A summary of Merimbula Lake water quality is provided in **Table 11-1**, below.

Table 11-1 Summary of Merimbula Lake ambient water quality 2012 – 2016 (from Elgin, 2021)

Parameter	Units	Adopted MWQO Trigger Value *	Normal Conditions - BASIN [a]					Post Event - LOWER ESTUARY [b]			
			Sample n	**Min**	**Max**	**Median**	**Mean**	***Sample n***	**Min**	**Max**	**Mean**
PHYS-CHEM											
Dissolved Oxygen (DO)	% sat.	80-110 [1]	0	0	0	0	0	4	80	108	89.8
Dissolved Oxygen (DO)	mg/L	>5 [2]	10	5.8	8.3	6.5	6.7	4	6.8	7.9	7.2
Turbidity	ntu	6 [3]	34	0.1	2.6	0.3	0.5	6	0.1	**34.0**	**10.7**
Salinity	ppt	-	33	26.3	37.8	35.4	34.8	6	18.3	33.8	25.9
Conductivity (EC)	uS/cm	-	34	41034	55612	53490	52574	6	29548	51469	40338
Temperature	°C	-	34	12.1	24.6	18.8	19.3	6	16.0	25.6	19.3
pH	pH	7.0-8.5 [1]	34	8.0	9.1	8.1	8.2	6	7.4	8.0	7.8
Suspended Solids (SS)	mg/L	10 [5]	0					6	4	**36**	**17**
NUTRIENTS											
Ammonia	mg/L	0.01 [4]	15	0	0.090	0.005	0.015	6	0.011	**0.040**	**0.024**
Ammonium (NH4+)	mg/L	0.015 [1]	10	0.003	0.010	0.007	0.006	6	0.011	**0.039**	**0.024**
Nitrate	mg/L	0.7 [5]	-	-	-	-	-	6	0.009	0.207	0.067
Oxides of Nitrogen (NOx)	mg/L	0.015 [1]	16	0.000	**0.056**	0.003	0.009	6	0.009	**0.207**	**0.067**
TKN	mg/L		16	0.100	0.240	0.200	0.183				
Total Nitrogen (TN)	mg/L	0.3 [1]	22	0.070	**0.360**	0.196	0.202	6	0.220	**0.680**	**0.422**
Total Phosphorus (TP)	mg/L	0.03 [1]	22	0.004	0.022	0.012	0.011	6	0.002	**0.050**	0.023
Orthophosphate	mg/L	0.005 [1]	12	0.000	0.003	0.002	0.002	4	0.003	**0.016**	**0.008**
BIOLOGICAL											
Chlorophyll a (Lab)	ug/L	5 [3]	20	0.6	**10.6**	2.0	2.9	1	1.6	1.6	1.6
Chlorophyll a (probe)	ug/L	5 [3]	34	0.1	**7.5**	0.9	1.6	2	0.6	1.1	0.8
Faecal Coliforms	cfu/100 mL	150 [4]	-	-	-	-	-	6	8	**3900**	**974**
Enterococci	cfu/100 mL	35 [4]	-	-	-	-	-	6	**62**	**24600**	**4864**

NOTE

Values in bold text and shaded exceed MWQOs

* Adopted MWQO trigger value relevant to estuarine waters from *Table 2-2 in this report*

[a] Data collected for the NSW estuary MER program for years 2012-2013 (Elgin 2014), 2014-2015 (DPIE unpubl.)

[b] Post event data collected following a range of significant rainfall events in 2015 and 2016 (Task 2) as part of Merimbula Ocean Outfall Ambient WQ Monitoring

[1] ANZECC (2000) Stressor guidelines for estuaries aquatic ecosystems, SE Australia – Tables 3.3.2 and 3.3.3. Also draft guideline values (DGVs) in ANZG (2018).

[2] ANZECC (2000) Physico-chemical stressors and toxicant guidelines for saltwater aquaculture species – Tables 4.4.2 and 4

[3] Chlorophyll a and turbidity trigger levels adopted by the NSW estuary MER program for estuary class Lake – applicable to Merimbula Lake (OEH 2016)

[4] ANZECC (2000) Water quality guidelines for recreational purposes – Tables 5.2.2 and 5.2.3

[5] ANZECC (2000) Interim working level, Section 8.3.7.2 of Volume 2

11.1.8 Estuarine Health

A State of the Catchments (SOC) 2010 report (DECCW, 2011) found Merimbula Lake had an overall condition index of 3.3 (out of 5), rated as being fair based on four of seven estuarine health indicators applicable to Merimbula Lake. Levels of chlorophyll a were rated as good, extent of seagrass and fish assemblages rated as fair, and extent of saltmarsh rated as poor. The overall assessment was provided with medium confidence as some of the data was greater than three years old and data regarding turbidity and macroalgae was not available. A trend for improving, declining or no change in overall condition was unknown (DECCW, 2011).

The SOC assessment also provided Merimbula Lake with an overall pressure index of 3.0 (out of 5), rated as having moderate pressure in terms of pressure indicators – cleared land, population, sediment and nutrient inputs, extractive fishing, freshwater flows, disturbed habitat and tidal flows. Among the indicators considered, nutrient inputs, disturbed habitat and tidal flows were rated as moderate pressures while cleared land, population and sediment inputs were deemed to be exerting the highest pressure on the condition of the estuary.

A more recent health report card (Elgin, 2014) for the estuary based on eutrophication risk indicators chlorophyll a and turbidity indicated the estuary basin to be rated very good 'A+' (**Figure 11-4**). This rating would likely also extend to the flood-ebb tidal delta that has the highest flushing rates but may not necessarily apply to the backwater known as Golf Course lake backwater where tidal flushing may be less efficient.

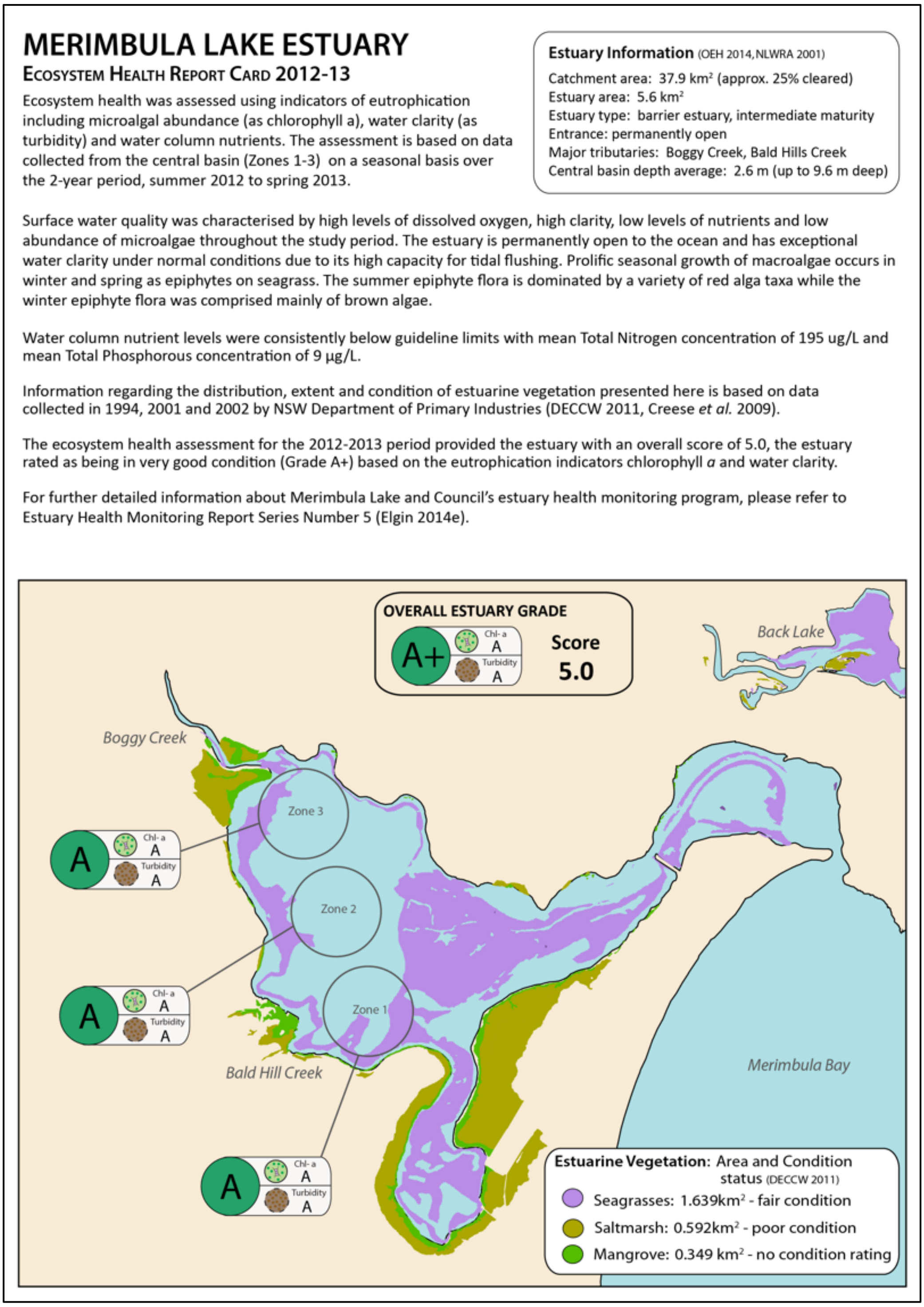


Figure 11-4 Estuary health report card for Merimbula Lake 2012-13 (based on eutrophication indicators)

11.2 Pambula River estuary

Pambula River estuary has significant natural and physical values with a significant area of estuarine wetland listed as a nationally important wetland (Environment Australia, 2017) with the following attributes:

- *Estuarine waters; permanent waters of estuaries and estuarine systems of deltas (A6)*

The criteria for determining nationally important wetlands in Australia, and hence inclusion in the Directory, are those agreed to by the ANZECC Wetlands Network in 1994. Pambula estuarine wetlands meet the following criteria for inclusion:

- It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex (Criteria 2)
- It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail (Criteria 3).
- The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level (Criteria 5)
- The wetland is of outstanding historical or cultural significance. (Criteria 6)

A brief description of the natural and physical values of Pambula River estuary is provided in the sections below.

11.2.1 General Description

Pambula River estuary is located approximately 5 km south of Pambula township accessible via Landing Road from the Princes Hwy on its western shoreline. Surrounding land uses include agricultural grazing, forestry, residential and recreational uses while waterway uses include oyster aquaculture, commercial fishing and recreational boating. The estuary is permanently open to the ocean and is characterised by a wide and relatively deep inlet that opens to the ocean alongside the Haycock Point headland and exhibits an extensive marine tidal delta. The inlet is approximately 4 km long and connects to the estuary at its northern side where it opens into a central sand-mud basin locally referred to as 'the Broadwater'. Water depths of the central basin range between 4 – 6 m, the shallower inshore areas surrounding the central basin and extending into the inlet are where the majority of seagrasses are distributed and also typically where oyster leases are located. The estuary is considered to be generally shallow, with average water depths reported to be 2.2 m (OEH, 2017), though deep sections of the inlet attain depths of up to 12 m (*i.e.* Shark Hole). The lake is one of the largest estuaries in the BVSC region with an estuary area of 4.7 km^2 and catchment area of 297 km^2 (OEH, 2017) which includes the sub-catchment areas of both the Yowaka and Pambula Rivers and the forested slopes surrounding the lake itself.

The majority of the catchment is intact with approximately 14.4% (43 km^2) of catchment area cleared for agriculture (NLWRA, 2001). Large areas of the Pambula River catchment form part of National Parks reserves with Ben Boyd National Park to the north and east of the estuary and headwaters of the Pambula River and its tributaries originating in the South East Forests National Park. Large areas of the catchment also form part of Nullica and Yurammie State Forests. The Yowaka and Pambula Rivers are the primary inflows of freshwater and fluvial sediments to the lake. Tidal influences extend approximately 10 to 11 km upstream from the ocean entrance located at Greigs Flat and the Princes Hwy bridge for the Yowaka River and Pambula River respectively. The confluence of these two rivers is located in the lower estuarine reaches (*i.e.* salinity ≥ 25 ppt) and together discharge at the western shoreline of the lake adjacent to Tea Tree Point where a fluvial delta extends into the central basin.

A simplified geomorphological model of Pambula River estuary is presented in **Figure 11-5** below.

Figure 11-5 Simplified geomorphic model of Pambula River estuary. Aerial image provides a south-easterly view over the lake (*photo from Ozcoasts website, dated 22 April 2000*)

11.2.2 Estuary Habitats

Pambula River estuary supports a range of estuarine habitats including seagrass meadows, mangroves and saltmarsh. Being permanently open to the ocean with a tidal response and exhibiting largely marine conditions, the lake also supports intertidal flats and is one of only three BVSC estuaries that support large meadows of the seagrass *Posidonia australis*, commonly called 'Strapweed' (it also occurs in Bermagui River and Merimbula Lake). The lake also supports the smaller seagrasses *Zostera muelleri* (eelgrass) and *Halophila ovalis* (paddle-weed). Previous habitat mapping undertaken in 2009 indicate that seagrasses collectively cover an estimated 0.706 km^2 (15%) of the estuary area (Creese et al., 2009). Discrete areas of saltmarsh community are also present fringing the estuary edge and estimated to cover 0.366 km^2 (7%) in area with mangrove community estimated to cover 0.580 km^2 (12%) in area (Creese *et al.,* 2009). The estuary also supports a variety of macroalgae and phytoplankton though no formal surveys have published on the species assemblages present. The mapped distribution and extent of estuarine macrophytes in Pambula River estuary is more than 15 years old and a current understanding of temporal change and whether areas of habitat are increasing or contracting is not known.

The approximate distribution of seagrasses, saltmarsh and mangrove communities are shown in **Figure 11-6** below.

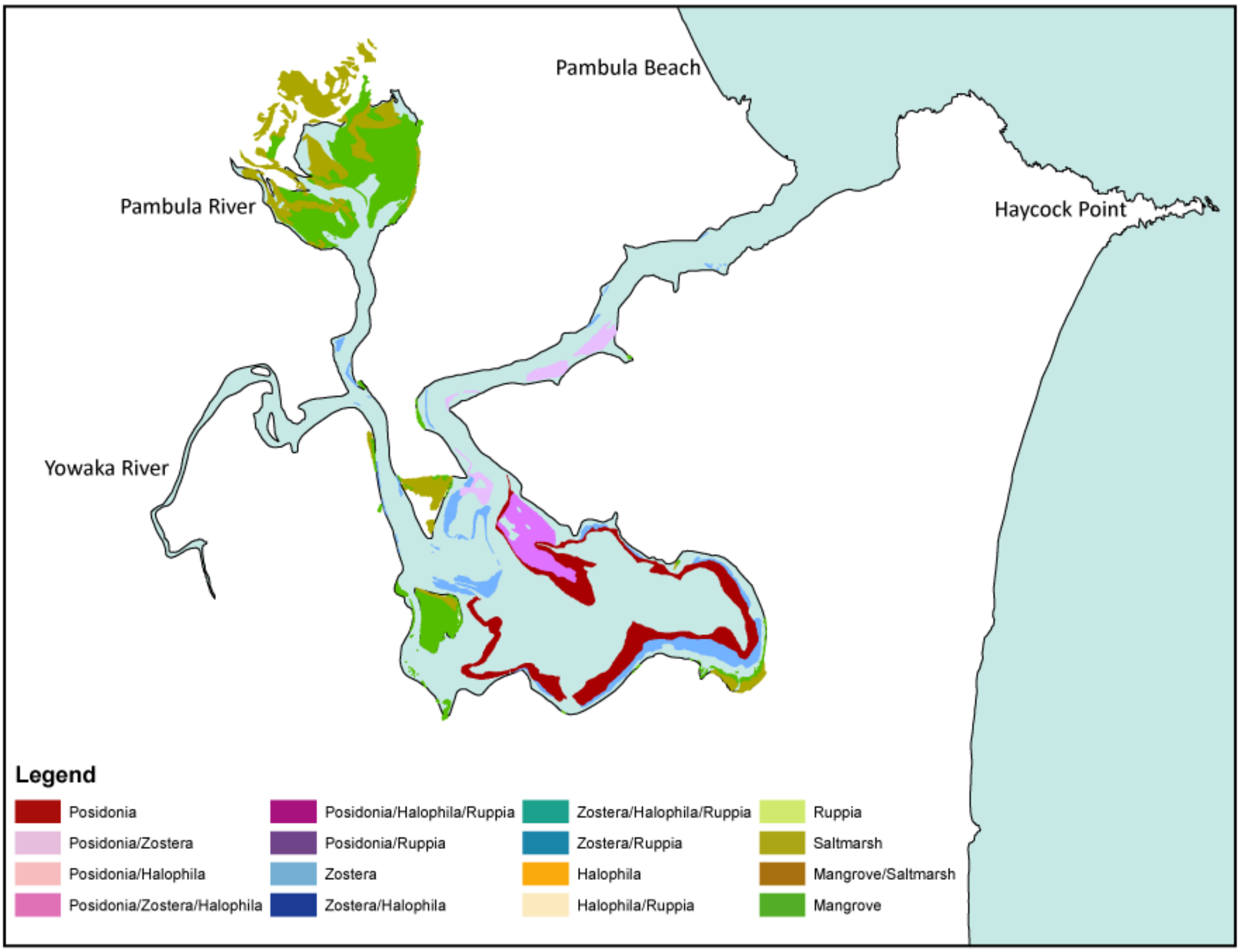


Figure 11-6 Estimated spatial extent of estuarine habitats of Pambula River estuary (vegetation mapping from Creese *et al.* 2009 - based on aerial imagery from 1994 and field survey August 2002)

11.2.3 State Environmental Planning Policy (SEPP) Coastal Management 2018 – Coastal Wetland

Pambula River estuary supports significant areas of Coastal Wetland identified under the SEPP (Coastal Management) 2018 as shown in **Figure 11-7**.

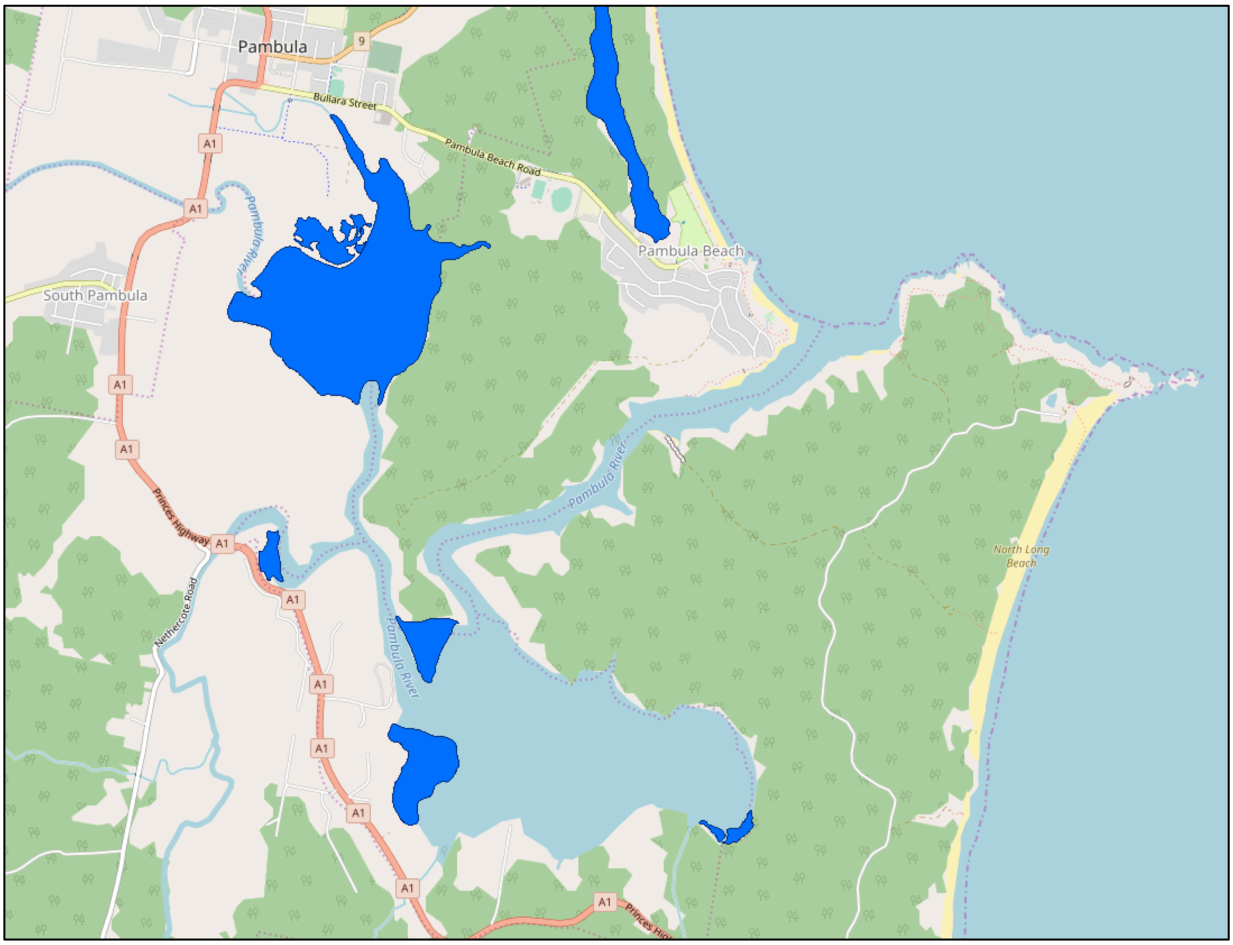


Figure 11-7 Occurrence of Coastal Wetland at Pambula River estuary identified under SEPP (Coastal Management) 2018 (areas coloured dark blue)

11.2.4 Faunal Assemblage

Pambula River estuary and its surrounding saline wetlands has a rich and diverse fauna. Species sightings information is available on the Atlas of Living Australia (2017), which collates species record data from a range of government agencies, museums and citizen science groups such as Atlas of Life in Coastal Wilderness who are active in the Far South Coast region of NSW.

A search of the ALA (2017) of major faunal groups that are aquatic or rely on aquatic habitats such as birds, fish, molluscs and crustaceans that have been recorded within 5km of Pambula River estuary (**Figure 11-8**) returned 230 bird species, 18 fish species, 94 molluscs and 10 crustaceans. This data has not been validated and it is noted that not all of these species may be estuarine or rely on estuarine habitats for foraging.

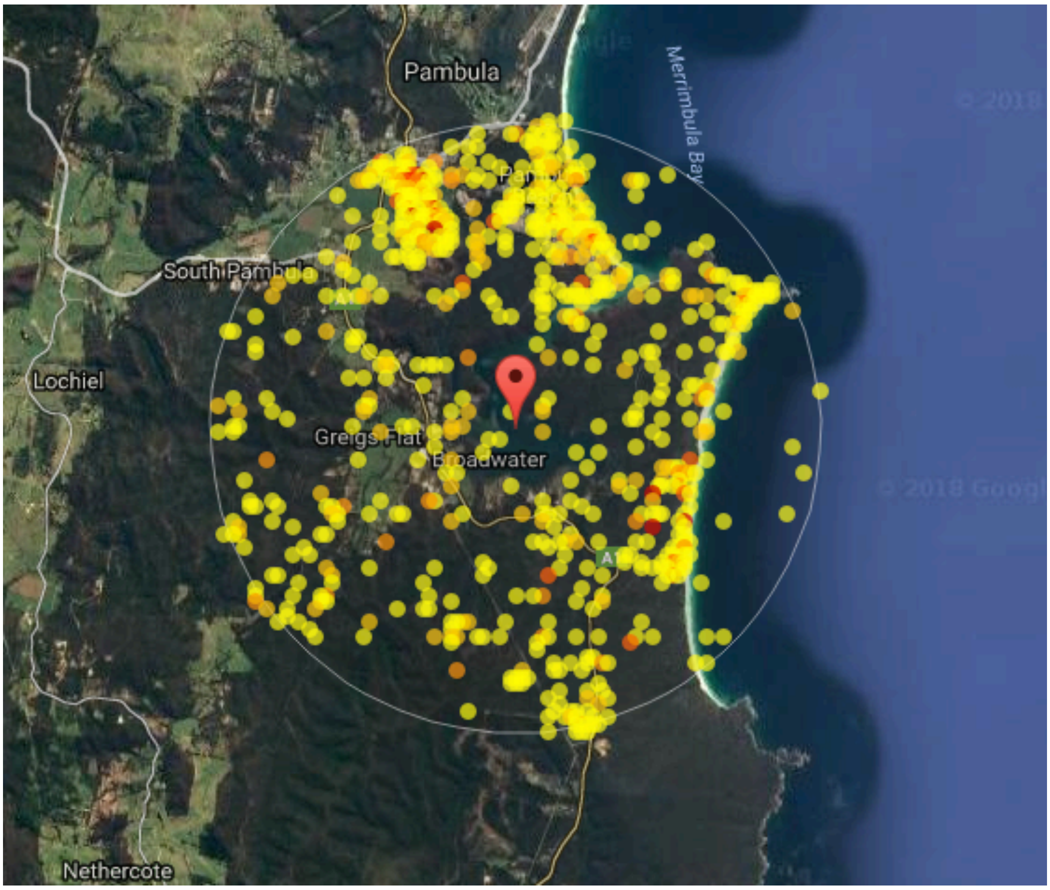


Figure 11-8 Fauna and flora records within 5km of Pambula River estuary (ALA, 2020)

Avifauna

The fringing forest, mangrove and saltmarsh community in addition to the intertidal sand flats near the entrance provide habitats important for foraging, resting and breeding for a variety of birds. At least 26 threatened bird species listed under the EPBC and or BC Act have been recorded in the Pambula River estuary catchment (Cardno, 2012). Bird species which are listed as threatened at state level and which have been recorded within the lake area include:

- Hooded Plover (*Thinornis rubricollis*) (Endangered)
- Swift parrot (*Lathamus discolour*) (Endangered)
- Regent honeyeater (*Anthochaera phrygia*) (Endangered)
- Gibson's albatross (*Diomedea gibsoni*) (Vulnerable)
- Black-browed albatross (*Thalassarche melanophris*) (Vulnerable).

An additional 50 other threatened bird species are modelled to occur within the catchment area (Cardno, 2012).

Fish

The fish assemblage of Pambula River estuary was surveyed by West and Jones (2001) and documented 23 species of which eight species are of value to commercial and recreational fisheries. The most speciose families collected were the Monacanthidae (4 species) and the Syngnathidae (4 species). In terms of abundance, the glassy perchlet (*Ambassis jacksoniensis*) and luderick (*Girella tricuspidata*) dominated the assemblage. Other economically important fish species caught were silver trevally (*Pseudocaranx dentex*) and Monacanthids, namely the Chinaman leatherjacket (*Nelusetta ayraudi*) and six-spined leatherjacket (*Meuschenia freycinetti*). A list of fish species recorded from Pambula River estuary by West and Jones (2001) is provided in **Appendix H-2.**

No fish species listed as threatened under the FM Act or EPBC Act are known to naturally reside in Pambula River estuary. In January 2018, a solitary Southern Bluefin tuna listed as vulnerable under the FM Act was observed in the Pambula broadwater likely having followed baitfish up the river (Merimbula News Weekly, 16 January 2018). However, four species belonging to the Syngnathiformes (seahorse, pipefish, pipehorses) and protected under the FM Act are known to occur. These include *Vanacampus poecilolaemus, Urocampus carinirostris, Stigmatophora nigra and Stigmatophora argus.*

11.2.5 Commercial Aquaculture

Commercial waterway uses in the estuary include oyster aquaculture. Oyster aquaculture is an important local industry with approximately 97.3 hectares of the lake designated as priority oyster aquaculture area (OISAS 2016). As of 2016, the 10-year moving average for oyster production in Pambula estuary was 59.8 tonnes (OISAS, 2016).

Potential impact to estuary aquaculture from the Project is evaluated in further detail in **Section 12 - Aquaculture**, below.

11.2.6 Recreational Use and Amenity

The natural amenity and significant ecological values of the estuary including its extensive saltmarsh wetlands, mangrove and seagrass communities are an important asset to Pambula, with the estuary representing a key attraction for local residents and tourists. The lower estuary is most popular for swimming while the upper estuary is primarily used for boating and kayaking.

The estuary is also a popular location for recreational fishing, targeting a range of angling species identified in **Section 11.2.4** and in **Appendix H-2**.

11.2.7 Water Quality

Water quality of Pambula River estuary is described in the *Water Quality Technical Report* (Elgin, 2021) and summarised below for normal and post-rainfall event flow conditions.

Under normal conditions, estuary waters are predominantly marine with a high level of water quality characterised by high dissolved oxygen, high water clarity, low turbidity and low microalgal abundance. Physico-chemical and nutrient parameters generally meet estuary WQOs. Depth profiling indicates that mixing processes in the basin including tidal flushing and surface wind advection, are effective with water quality conditions generally uniform throughout the water column. However, following significant rainfall events inflows of freshwater from the catchment can result in short-term density gradients with differences in water temperature and salinity between surface and bottom waters and impacts to water quality.

Post-rainfall event water quality for Pambula River estuary has been assessed from data collected after four separate rainfall events (23/4/2012, 9/4/2015, 31/1/2016, 6/6/2016), the three most recent events correspond to those same events described for Merimbula Lake above. After significant rainfall, impact to estuarine water quality from stormwater runoff and catchment inflows is apparent with brown coloured waters, poor clarity, high suspended load, and reduced salinity. Water quality is poor with elevated levels of turbidity, nutrients and biological parameters all reported at concentrations above estuary WQOs. Mean levels of nutrient parameters increase by a factor of 2 to 7 compared to normal conditions. Microbiological parameters faecal coliforms and enterococci exceed the MWQOs and are often orders of magnitude higher than normal conditions. Large inflows of freshwater can also dramatically lower salinity levels. Post-event water quality is subsequently improved by tidal flushing through the estuary.

A summary of Pambula River estuary water quality is provided in **Table 11-2**, below.

Table 11-2 Summary of Pambula River estuary ambient water quality 2012-12016 (from Elgin, 2021)

Parameter	Units	Adopted MWQO Trigger Value *	Normal Conditions - BASIN [a]					Post Event - LOWER ESTUARY [b]			
			Sample n	**Min**	**Max**	**Median**	**Mean**	***Sample n***	**Min**	**Max**	**Mean**
PHYS-CHEM											
Dissolved Oxygen (DO)	% sat.	80-110 [1]	51	78.8	106.0	98.0	97.1	10	67.0	100.8	86.3
Dissolved Oxygen (DO)	mg/L	>5 [2]	12	5.9	7.7	6.9	6.9	6	7.3	9.0	8.0
Turbidity	ntu	2.8 [3]	66	0	**5**	1.3	1.4	14	**4**	**72**	**32**
Salinity	ppt	-	54	30.9	37.5	35.3	35.1	14	0.1	27.5	8.4
Conductivity (EC)	uS/cm	-	66	45330	55273	53059	52749	14	140	42719	13750
Temperature	°C	-	66	11.9	25.9	20.5	19.4	14	14.7	21.5	17.5
pH	pH	7.0-8.5 [1]	51	7.8	8.2	8.1	8.0	14	**6.4**	8.2	7.4
Suspended Solids (SS)	mg/L	10 [5]						10	8	**70**	**39**
NUTRIENTS											
Ammonia	mg/L	0.01 [4]	16	0.003	**0.090**	0.007	**0.017**	12	**0.016**	**0.047**	**0.028**
Ammonium (NH4+)	mg/L	0.015 [1]	14	0.003	**0.087**	0.007	**0.018**	12	**0.015**	**0.046**	**0.028**
Nitrite	mg/L							5	0.003	0.006	0.005
Nitrate	mg/L	0.7 [5]						10	0.064	0.539	0.209
Oxides of Nitrogen (NOx)	mg/L	0.015 [1]	20	0.000	**0.110**	**0.021**	**0.025**	12	**0.064**	**0.544**	**0.197**
TKN	mg/L		22	0.080	0.200	0.160	0.153	2	0.300	0.400	0.350
Total Nitrogen (TN)	mg/L	0.3 [1]	24	0.060	**0.560**	0.175	0.181	12	0.270	**1.190**	**0.724**
Total Phosphorus (TP)	mg/L	0.03 [1]	24	0.004	0.027	0.011	0.013	12	0.013	**0.078**	**0.044**
Orthophosphate	mg/L	0.005 [1]	20	0.003	**0.015**	**0.006**	**0.007**	12	**0.005**	**0.012**	**0.008**
BIOLOGICAL											
Chlorophyll a (Lab)	ug/L	2.3 [3]	38	0.7	3.8	1.6	1.8	2	0.8	1.7	1.2
Chlorophyll a (probe)	ug/L	2.3 [3]	51	0.5	4.6	1.6	1.7	6	0.8	2.0	1.1
Faecal Coliforms	cfu/100 mL	150 [4]						10	**340**	**6000**	**1897**
Enterococci	cfu/100 mL	35 [4]						10	**527**	**9700**	**4697**

NOTE

Values in bold text and shaded exceed MWQOs

* Adopted MWQO trigger value relevant to estuarine waters from *Table 2-2 in this report*

[a] Data collected for the NSW estuary MER program for years 2010-2013 (Elgin 2014), 2008-2009 and 2017-2018 (DPIE unpubl.)

[b] Post event data collected following a range of significant rainfall events in 2015 and 2016 (Task 2) as part of Merimbula Ocean Outfall Ambient WQ Monitoring

[1] ANZECC (2000) Stressor guidelines for estuaries aquatic ecosystems, SE Australia – Tables 3.3.2 and 3.3.3. Also draft guideline values (DGVs) in ANZG (2018).

[2] ANZECC (2000) Physico-chemical stressors and toxicant guidelines for saltwater aquaculture species – Tables 4.4.2 and 4

[3] Chlorophyll a and turbidity trigger levels adopted by the NSW estuary MER program for estuary class Riverine Lower – applicable to Pambula River estuary (OEH 2016)

[4] ANZECC (2000) Water quality guidelines for recreational purposes – Tables 5.2.2 and 5.2.3

[5] ANZECC (2000) Interim working level, Section 8.3.7.2 of Volume 2

11.2.8 Estuarine Health

The SOC 2010 report (DECCW, 2011) found Pambula River estuary had an overall condition index of 4.0 (out of 5), rated as being good to very good based on the estuarine health indicators - chlorophyll a, turbidity, extent of seagrass, extent of saltmarsh and fish. Majority of the indicators were assessed as 'good', with turbidity rated as 'very good' and extent of saltmarsh assessed as 'fair'.

The SOC assessment also provided Pambula River estuary with a pressure index of 4.3 (out of 5), rated as having low to very low pressure in terms of pressure indicators – cleared land, population, sediment and nutrient inputs, extractive fishing, freshwater flows and tidal flows. The lake was rated as having moderate pressure in terms of disturbed habitat which includes jetties, moorings, reclamation walls and oyster lease infrastructure. Detailed information regarding the calculation and rules for the estuarine condition and pressure indices is provided in Roper *et. al.* (2011).

A more recent health report card (Elgin 2014) for the estuary based on eutrophication risk indicators chlorophyll a and turbidity indicated the estuary basin to be rated very good ‘A+’ (**Figure 11-7**).

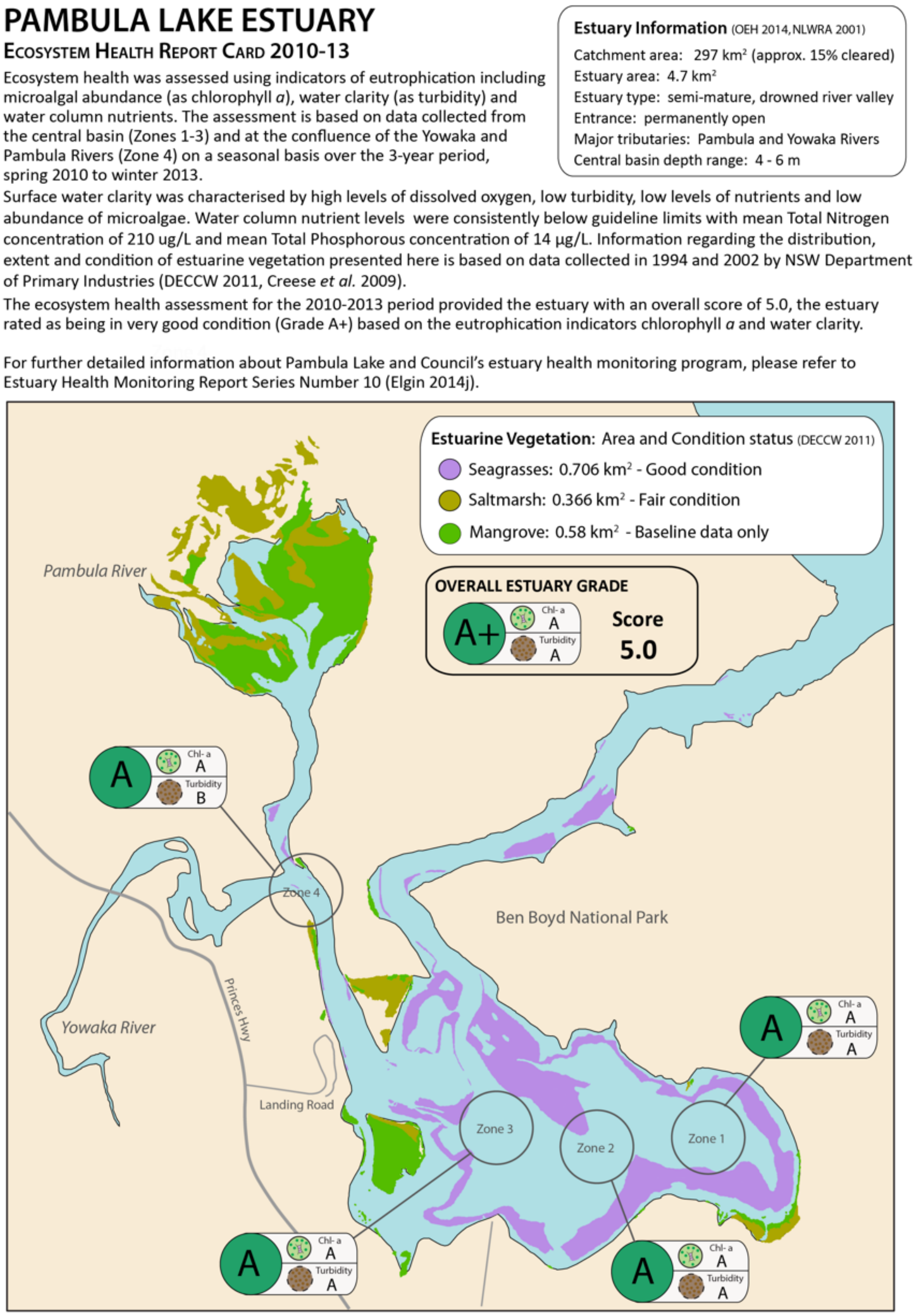


Figure 11-9 **Estuary health report card for Pambula River estuary 2010-13 (based on eutrophication indicators)**

11.3 Key Findings

Key findings of the assessment of estuarine communities of Merimbula and Pambula River estuary include:

- Both estuaries are listed as wetlands of national importance based on their significant ecological and cultural values and have significant areas of coastal wetland identified under the SEPP (Coastal Management) 2018. A range of habitats are supported including seagrass meadows, mangroves, saltmarsh and intertidal sand/mud flats.
- Both estuaries are characterised by good water quality and high level of tidal flushing. In 2014, the health of both estuaries was rated 'very good' in terms of eutrophication indicators turbidity and chlorophyll a. Water quality assessments in both estuaries have also found that they are occasionally subject to high levels of nutrients, suspended solids and microbiological parameters (*i.e.* Faecal coliforms, *Enterococci*) from diffuse sources (i.e. catchment runoff and urban stormwater) during high rainfall events. Water quality improves quickly after rainfall events due to efficient tidal flushing.
- A range of threatened wader and shorebirds have been recorded from both estuaries.
- No fish species listed as threatened under the FM Act or EPBC Act are known to occur in the estuaries. However, at least six species belonging to the Syngnathiformes (seahorse, pipefish, pipehorses) and protected under the FM Act are known to occur. These include *Syngnathoides biaculeatus, Vanacampus poecilolaemus, Urocampus carinirostris, Vanacampus phillipi, Stigmatophora nigra, Stigmatophora argus.*
- Both estuaries support a valuable oyster aquaculture industry primarily cultivating the Sydney Rock oyster (*Saccostrea glomerata*) but also southern mud oyster (*Ostrea angasi*). The potential risk of impact to oyster aquaculture in the estuaries is assessed in **Section 12 - Aquaculture** below.
- The natural amenity and significant ecological values of the estuaries are important assets to the coastal townships of Merimbula and Pambula, with the estuarine environment representing a key attraction for local residents and tourists that visit the coastal towns annually. They are among the most popular estuaries within the Bega Valley for recreational use with swimming, boating, fishing, kayaking, paddle-boarding and snorkelling popular activities.

11.4 Potential Impact of the Project to Estuary Health and Values

The potential risk of impact to estuary health and values of Merimbula Lake and Pambula River estuary from the Project was assessed in context of the existing condition of ecological communities described above and the water quality of both lakes which is characterised by a high level of water quality under normal tidal and baseflow conditions with episodes of poor water quality following significant catchment rainfall events. Post-rainfall event estuary inputs from diffuse sources (*i.e.* catchment runoff, urban stormwater, OSMs) include elevated levels of suspended sediment, nutrients and microbiological parameters that exceed estuary WQOs. Post-rainfall event water quality impacts are short-term with water quality conditions improving quickly from efficient tidal flushing.

Potential risks to commercial aquaculture in the estuaries is assessed separately in **Section 12 - Aquaculture** below.

11.4.1 Construction Phase Impacts

Potential impacts from the construction phase of the Project would only apply to Merimbula Lake with its proximity to the STP site. Pambula River estuary is too distant from the location of the construction works to be impacted.

Construction works proposed on the STP as part of its upgrade include installation of additional treatment infrastructure for PAC dosing, tertiary filtration, UV treatment and chlorine dosing. A range of ancillary infrastructure is also proposed that includes pump stations, storage tanks, pits, pipes, power supply, retaining wall and access roads, with utilities also relocated and upgraded. The existing 17 ML wastewater storage pond is to be decommissioned, including dewatering and sediment/sludge removal.

All of these activities are proposed within the STP site and are considered routine for STP upgrades, with potential risks to the values of Merimbula Lake able to be managed at low levels through a Construction Environmental Management Plan (CEMP) with elements that would typically include:

- Construction laydown areas with sediment and erosion runoff controls.
- Fuels and other chemicals stored in designated areas that are bunded and have available spill kits.
- Excavated soils, sediments and/or sludges stockpiled in bunded areas with runoff controls. Onsite or offsite reuse and/or offsite disposal to be informed by contamination testing and classification.
- Decommissioned infrastructure sorted and temporarily stockpiled onsite in designated areas with subsequent transport offsite for recycling or disposal.
- Meeting relevant conditions in a Development Application (DA) for the Project.

Construction works also proposed on or nearby offsite from the STP includes decommissioning of the dunal ex-filtration ponds and horizontal drilling of the outfall pipeline from the STP to the nearshore beach zone to the east. It is expected that these works would also be undertaken under a CEMP which would include similar risk mitigation measures to those outlined above along with:

- Management of drilling muds.
- Stockpiling of drilling spoil, with similar measures as above for managing excavated soils.

The laydown area for this component of the construction works is proposed for an area in the eastern part of the STP site and away from the Merimbula Lake backwater. The drilling and decommissioning works are proposed to the east of the STP site and also away from the backwater.

The factors above were carried forward in assessing potential risk of impact to ecological values of Merimbula Lake (i.e. water quality, macrophyte communities, fish assemblage, oyster aquaculture) which is included in the analysis in **Section 14 – Impact Assessment** below. The outcome of this analysis is that the risk to Merimbula lake from the proposed construction activities is considered low to minimal with works to be implemented under a CEMP that describes measures to mitigate risks.

11.4.2 Operational Phase Impacts

Potential impacts from operational phase activities of the project were assessed for Merimbula Lake and Pambula River estuary, with the key risk considered to be dilute treated wastewater entering either estuary from the proposed North-Short outfall discharge point in Merimbula Bay. This is also considered in context of other water quality risks to the estuaries, namely stormwater inputs which is identified as the highest priority threat to estuarine ecosystems in NSW (BMT-WBM, 2017). The operational phase of the Project was also considered in context of current discharge via the beach-face outfall and dunal ex-filtration which includes:

- The beach-face outfall has discharged treated wastewater since 1971 and is approximately 3km to the entrances of Merimbula Lake and Pambula River estuary, located almost equidistant from each entrance along the adjoining beach. Modelling of treated wastewater discharge at the beach-face outfall indicates that it is entrained in the nearshore beach zone and rapidly achieves 1,000 times dilution and gradually disperses to the north and south along the beach zone, and to offshore deeper waters of the central bay region where it dilutes further.

- The modelling of the beach-face outfall also indicated that wastewater may enter Merimbula Lake, the latter trend becoming more evident under stronger southward flowing boundary current conditions. Whilst the modelling indicates this potential entry into Merimbula Lake, it is noted the level of dilution is modelled between 10,000 to 100,000 times, would meet estuary WQOs and would be unlikely to be detected in water laboratory analysis,

- The potential for treated wastewater from the beach-face outfall to enter Merimbula Lake or Pambula River estuary is likely to be higher during storm events of strong onshore winds and rainfall (i.e. an East Coast Low) with higher likelihood of wet weather flows in the STP, entrapment of wastewater from an more active surf zone and dispersion to the north and south potentially enhanced by storm currents or surge. This potential would be offset by other fluvial and stormwater inputs into both Lakes at the same time which have been shown in post-event water quality datasets to reduce water quality in both Lakes.
- The dunal ex-filtration ponds are located approximately 600 m east of Merimbula Lake, with groundwater assessment (AECOM, 2020) reporting that groundwater receives infiltrated wastewater and that there is a component of groundwater flow to the west towards Merimbula Lake where groundwater is expected to discharge.

Key factors in assessing the risk to Merimbula and Pambula River estuaries from the Project include:

- STP upgrade with PAC dosing to enhance the removal of phosphorus, with consideration for the addition of tertiary filtration to further reduce metals from the wastewater stream.
- Ceasing the beach-face outfall and discharging treated wastewater instead to the proposed ocean outfall would improve wastewater dispersion, with modelling indicating MWQOs would be met within a 25 m mixing zone of the discharge point for the majority of the time. Under worse-case conditions that may occur a small proportion of time (*i.e.* wet weather flows coinciding with stagnant ocean currents), MWQOs would be met within 200 m of the discharge point. The estuary entrances are located 2700-3000 m away from the proposed ocean outfall location. Moving the discharge point from the beach out into the Bay would also eliminate the risk of treated wastewater being entrained in the surf zone where it has more potential to disperse parallel to the beach and towards the estuary entrances.
- Ceasing wastewater disposal to the dunal ex-filtration ponds would be expected to improve groundwater quality beneath the ponds over time, including the component of groundwater that flows westwards and discharges to Merimbula Lake.

The factors above were carried forward in assessing potential risk of impact to Merimbula Lake and Pambula River estuary from the operational phase of the project which is included in the risk analysis in **Section 14 – Impact Assessment** below. The outcome of this analysis is that the risk to both estuaries from the operational phase is assessed as minimal.

In terms of relative risk, the analysis indicates that there is a reduction in risk to Merimbula Lake and Pambula River estuary by the Project when compared to current conditions. This reduction in risk is largely due to ceasing disposal of treated wastewater to the beach-face outfall and dunal ex-filtration ponds and replacing it with the proposed ocean outfall out in the Bay, along with the improved wastewater quality from the STP upgrade. This reduction in risk means there are potential benefits to the health and values of both estuaries, including recreational fishing, from the Project.

11.5 Conclusion

The potential for impacts to Merimbula Lake from the construction phase of the project was assessed as low to minimal, with mitigation of environmental risks controlled through implementation of CEMP (**Section 15 – Evironmental Management**). Due to its distance from the STP, there is no potential for Pambula River estuary to be impacted by the construction phase of the Project.

The potential for impacts to Merimbula Lake and Pambula Lake from the operational phase of the project was assessed as low to minimal, with key factors including the improved wastewater quality from the STP upgrade, cessation of the beach-face outfall and ex-dunal infiltration ponds, and replacement with an outfall out into the

Bay beyond the surf zone that has improved dispersion. In terms of relative risk, there is considered to be a reduction in risk to Merimbula Lake and Pambula River estuary by the Project when compared to current conditions, which should also mean there are potential benefits to the health and values of both Lakes, including recreational fishing.

12 Aquaculture

12.1 Introduction

A requirement of DPI in its submission to the SEARs (letter dated 30/5/2016) is for the Project to:

- *Provide analysis of potential impacts upon, and risks from both the construction and operational phases to potential future marine waters aquaculture including risk of promotion of toxic algal blooms.*
- *An analysis of potential benefits of the Project to the oyster industry in Merimbula and Pambula estuaries.*

This report section provides an overview of existing aquaculture operations within the study area, describes the opportunity for future marine waters aquaculture in Merimbula Bay under the *Marine Water Sustainable Aquaculture Strategy* (MWSAS – DPI, 2018), and evaluates the risk of potential impact and constraints from construction and operational phases of the Project.

Oyster aquaculture is currently the only existing aquaculture within the study area.

12.2 Oyster Aquaculture

The oyster aquaculture industry is the largest aquaculture industry in NSW by production value and accounts for approximately 32% of the State's total commercial fisheries production (OISAS, 2016). It is one of the State's most valuable per hectare agricultural enterprises with long-term gross average production of $8,000/ha across the state and as high as $35,000/ha in some estuaries (White, 2001).

Oyster aquaculture is an important local industry in the estuaries of Merimbula Lake and Pambula River estuary. The local industry is based primarily of Sydney rock oyster (*Saccostrea glomerata*) with smaller quantities of southern mud oyster (*Ostrea angasi*) also cultivated. Approximately 125.8 hectares of Merimbula Lake is designated as priority oyster aquaculture area (**Figure 12-1**). In 2005/2006, Merimbula Lake produced over 3% of the total NSW production of Sydney rock oyster worth in excess of $1 million (OISAS, 2006). As of 2016, the 10-year moving average for oyster production in Merimbula Lake was 134.8 tonnes (OISAS, 2016).

For the Pambula River estuary, approximately 97.3 hectares of the estuary is designated as priority oyster aquaculture area (**Figure 12-2**). As of 2016, the 10-year moving average for oyster production in Pambula estuary was 59.8 tonnes (OISAS, 2016).

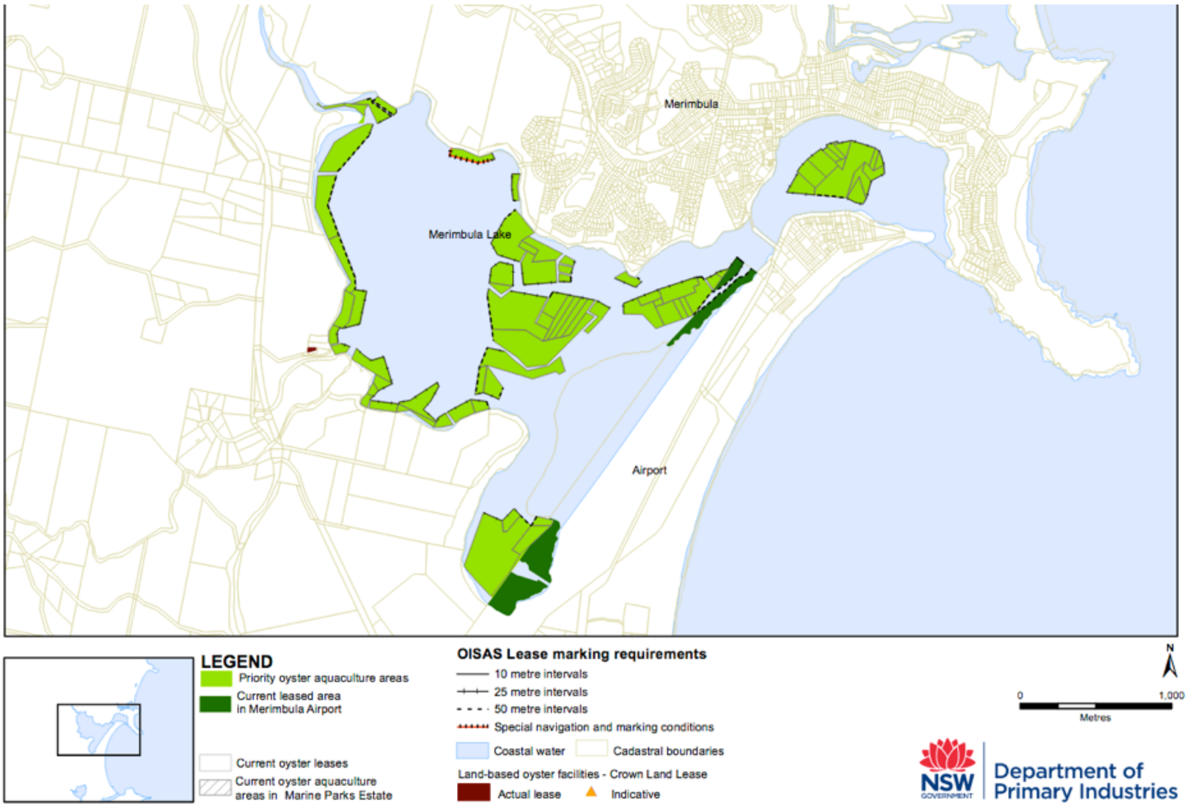


Figure 12-1 Priority oyster aquaculture areas in Merimbula Lake (OISAS, 2016)

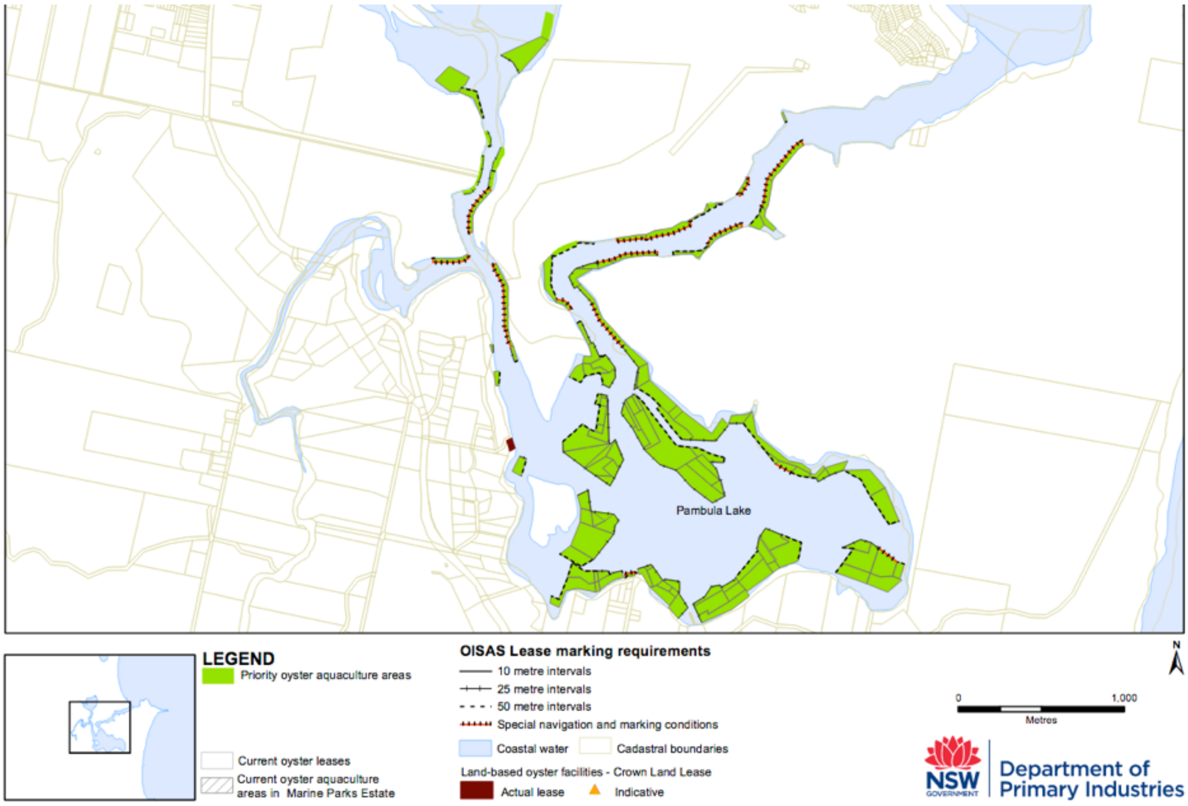


Figure 12-2 Priority oyster aquaculture areas in Pambula River estuary (OISAS, 2016)

12.3 Threats to Oyster Aquaculture

Protection and maintenance of water quality is vital to estuary health and the ongoing viability of sustainable oyster aquaculture. Poor water quality resulting from point source (*i.e.* sewage overflows from STP pump stations, poorly managed septic systems) and diffuse source water pollution (*i.e.* catchment and urban stormwater runoff) is an ongoing challenge for the industry. Poor water quality can lead to eutrophication and increased risk of algae bloom and in particular blooms of harmful microalgae that can form biotoxins. Other threats related to poor water quality include the risk of viruses and disease.

12.3.1 Water Quality Objectives for Oyster Aquaculture

NSW water quality objectives relevant to oyster aquaculture are based on the ANZECC (2000) and ANZG (2018) draft guideline values (DGVs) for Aquatic Foods (**Table 12-1**).

Table 12-1 Water quality guidelines for oyster aquaculture (*from Table 4 in* OISAS, 2016)

Parameter	Guideline	Source
Faecal (thermotolerant) coliforms	90th percentile of randomly collected Faecal coliform samples do not exceed 43MPN or 21 MF/100mL	ASQAP Operations Manual 2002 and the NSW Shellfish Program Operations Manual 2001.
pH	6.75 – 8.75	Shumway (1996).
Salinity	20.0 – 35.0 g/L	Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000).
Suspended solids	<75 mg/l	
Aluminium	<10µg/L	
Iron	<10µg/L	
Other parameters	For other parameters please refer to Section 4.4 and Section 9.4 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)	

Note: MPN – mean probable number, MF – membrane filtration

Merimbula and Pambula estuaries are characterised by good water quality with high dissolved oxygen, high water clarity, low turbidity and low microalgal abundance primarily due to efficient tidal flushing. Physico-chemical, nutrient and microbiological parameters typically meet estuary WQOs and the health of both estuaries was rated 'very good' in terms of eutrophication indicators turbidity and chlorophyll a (Elgin, 2014). However, following significant rainfall events inflows of freshwater from the catchment can result in poor water quality with high levels of nutrients, suspended solids and microbiological parameters (*i.e.* Faecal coliforms, *Enterococci*) that exceed regulatory guidelines and can result in short-term closures of oyster harvest areas.

12.3.2 Sewerage Network and Sewer Overflows

Occasionally a sewer overflow may cause localised impact to estuarine water quality that can threaten aquaculture operations. Sewer overflows can occur in dry and wet weather. Dry weather overflows are usually caused by chokes (i.e. tree roots) in the pipework restricting or blocking flow and are usually small in scale. Wet weather overflows are caused by inflow and infiltration of stormwater exceeding the hydraulic capacity of the system or pump station failure. Wet weather overflows are more likely to be larger in volume and scale, although typically occur during times when catchment pollution inputs from broader diffuse sources are also significant. The most recent sewer overflow reported for Merimbula Lake occurred on 5 August 2020 (https://begavalley.nsw.gov.au/cp_themes/default/page.asp?p=DOC-PYO-64-26-08), and resulted in a minor amount of untreated sewage overflowing to the lower estuary at Spencer Park.

Capital maintenance programs, such as CCTV inspection, pipebursting and relining, are undertaken by Council to renew and upgrade the sewer network with aim of reducing chokes, inflows and infiltration by stormwater and risk of overflows impacting waterways. The threat likelihood is greater for Merimbula due to the urban development surrounding the estuary. For Pambula River estuary, the majority of the rural residential homes surrounding the estuary are on septic systems, with a minor area of residential located near the ocean entrance on the sewer network with pump station. Overall, the potential threat is infrequent and short-lived, with incidents of overflow only reported occasionally and which are managed by the council maintenance program.

12.3.3 Harmful microalgal blooms

Potential blooms of harmful microalgae (*i.e.* phytoplankton) is an ongoing threat for all estuaries where oyster or other shellfish cultivation is an important local industry. In Australia, there is a select group of biotoxin-producing marine and estuarine microalgal species that have been documented to cause impacts in terms of seafood poisonings, the deaths of fish or other marine life, and direct human impacts due to skin exposure or respiratory complaints. The maintenance of good water quality is important to minimise the risk of microalgal blooms and in particular those of harmful species.

Under the NSW Shellfish QA Program coordinated by NSW Food Authority, fortnightly water samples are collected from oyster harvest areas and screened for harmful phytoplankton taxa to provide early detection of potential biotoxin events. The three main algal toxin groups found in NSW coastal waters are amnesic shellfish toxin (AST), paralytic shellfish toxins (PSTs) and diarrhetic shellfish toxins (DSTs). Neurotoxic shellfish toxins (NSTs) and azaspiracid shellfish toxins (AZTs) have not previously been detected in NSW (NSW Food Authority, 2017).

Like most estuaries in NSW, potentially harmful algal taxa have been recorded from both Pambula and Merimbula estuaries, but these taxa are typically recorded at low to very low levels and have not been a cause for concern. Phytoplankton action limits (PALs) for potentially harmful phytoplankton taxa are set out in the *Marine Biotoxin Management Plan* (NSW Food Authority, 2015) and provided in **Appendix G-3**.

A description of the phytoplankton community of Merimbula and Pambula estuary was provided in **Section 9 - Phytoplankton** with a summary of the key points relevant to harmful algal blooms summarised below.

- For Merimbula Lake over the monitoring period 2005 to 2016, phytoplankton counts of potentially harmful taxa exceeding the NSW Food Authority's phytoplankton action limits (PALs) include diatoms - *Pseudo-nitzschia delicatissima* group, *Pseudo-nitzschia fraudulenta/australis*, *Pseudo-nitzschia subpacifica/heimii, Pseudo-nitzschia pungens/multiseries, and Dinoflagellates - Dinophysis acuminata, Dinophysis caudata, and Alexandrium catenella/fundyense.*
- For Pambula River estuary over the monitoring period 2005 to 2016, phytoplankton counts of potentially harmful taxa exceeding the NSW Food Authority's PALs include diatoms - *Pseudo-nitzschia fraudulenta/australis* and dinoflagellates - *Alexandrium catenella/fundyense, Dinophysis caudata.*

For both estuaries, exceedances of PALs have been an occasional occurrence and not all PAL exceedances resulted in a positive toxin detection. A summary of positive toxin detections in shellfish at both Merimbula and Pambula lakes over the monitoring period 2005 to 2016 is provided in **Table 9-1**. Species associated with ASTs in Merimbula were *Pseudo-nitzschia delicatissima* group, *Pseudo-nitzschia fraudulenta/australis, Pseudo-nitzschia pungens/multiseries,* whilst in Pambula they were *Pseudo-nitzschia pungens/multiseries.* Species associated with PST in Merimbula were unconfirmed whilst in Pambula Lake it was *Alexandrium catenella/fundyense.*

12.4 NSW Marine Waters Sustainable Aquaculture Strategy

The NSW Marine Waters Sustainable Aquaculture Strategy (MWSAS – DPI, 2018) has been adopted as an aquaculture industry development plan under the *FM Act*. The vision for the marine aquaculture industry in NSW is for a thriving, economically and environmentally sustainable industry that meets future demands for high quality seafood supply for the state and creates economic opportunities in regional NSW. The MWSAS provides a regulatory and industry best practice framework for the future expansion of the NSW marine waters aquaculture industry in an ecologically sustainable and socially responsible manner. In summary, the MWSAS:

- provides a platform for the NSW Government to:
    - identify suitable marine aquaculture investigation areas
    - undertake appropriate environmental impact assessment and obtain relevant approvals for marine aquaculture
    - invite commercial interest by tender, to investigate and make application for leases within the investigation area
- defines the development approval and assessment processes;
- provides guidance to industry and consent authorities to prepare and assess applications for aquaculture development;
- provides the community and stakeholders with relevant advice to inform them about sustainable marine waters aquaculture; and
- avoid ad hoc aquaculture industry development in NSW waters which may be at unsuitable locations or using technologies and approaches that are not optimal for a specific location.

The scope of the MWSAS applies to coastal waters to the jurisdictional limit of three nautical miles offshore (state waters) but excludes estuarine waters.

12.4.1 Potential types of marine waters aquaculture in Merimbula Bay

The types of marine waters aquaculture covered by the MWSAS include floating and submerged infrastructure:

Floating infrastructure

- Sea pen aquaculture approximately on the 20-50 m depth contour, floating or partly submerged (i.e. finfish such as kingfish)
- Longline aquaculture on approximately the 10 m depth or greater contour, floating infrastructure principally supported by buoys (i.e. algae or shellfish such as mussels/oysters)

Submerged infrastructure

- Longline aquaculture on approximately the 20 m depth or greater contour, submerged below the surface but supported by subsurface buoys to maintain the culture infrastructure off the sea floor (i.e. algae or shellfish such as mussels/oysters)
- Extensive artificial reef aquaculture on about the 15-20 m depth contour, submerged infrastructure on the sea floor (i.e. abalone)
- Extensive ranching at varying depths – no infrastructure (i.e. shellfish seeded on ocean floor)

If the eastern limit of Merimbula Bay is taken as the Ocean Trawl fishery closure boundary (a straight line drawn from Long Point to Haycock Point), then water depths of the embayment are primarily within the 0-20 m depth range with some deeper waters between 20-30 m.

Based on the types of aquaculture described above, water depths of Merimbula Bay would be considered suitable for most forms of marine waters aquaculture excluding sea pen aquaculture.

12.4.2 Assessment, Approvals and Constraints for marine waters aquaculture

The planning controls for marine aquaculture are set by the Environment Planning and Assessment Act 1979 (*EP&A Act)* with the key regulatory framework provided by the *State Environmental Planning Policy (Primary Production and Rural Development) 2019* which includes provisions of the former SEPP 62 – Sustainable Aquaculture (now repealed).

A key component of the MWSAS is a recommended list of 12 criteria and constraints where marine waters aquaculture operations would not be permissible (refer Table 1 in DPI, 2018). It is proposed that constraint mapping would be incorporated into Part 1 of Schedule 2 of the SEPP (Primary Production and Rural Development) 2019 to identify areas excluded for marine waters aquaculture. As of 29 September 2020, no areas are as yet listed under Part 1 of Schedule 2.

Criteria and constraints relevant to Merimbula Bay include those identified in **Table 12-2.**

Table 12-2 Criteria and constraints relevant to marine waters aquaculture in Merimbula Bay (from MWSAS – DPI, 2018)

Criteria	Constraint
3. Pipelines and cables	Must not be within 1km of sewage outfall pipelines or protection zones for submarine cables
6. Substrate type	Must not be located over rocky reefs
10. Marine infrastructure and monitoring equipment	Must not be with 1 km of marine infrastructure (i.e. moorings, boat ramps, marinas) and monitoring equipment (i.e. wave rider buoys, acoustic listening stations, IMOS buoys)

For Merimbula Bay, the pipeline and cables criterion is triggered by the proposed North-Short outfall, extensive areas of rocky reef are present at the northern and southern extent of the embayment, with the marine infrastructure and monitoring equipment criterion triggered by the DPI SharkSmart VR4G acoustic listening station situated off Merimbula Beach.

Based on these criteria, constraint mapping provided in **Figure 12-3** shows the effective area that would be considered available (taking into account constraint buffers) for future marine waters aquaculture under the MWSAS (DPI, 2018) pending update to the SEPP (Primary Production and Rural Development) 2019.

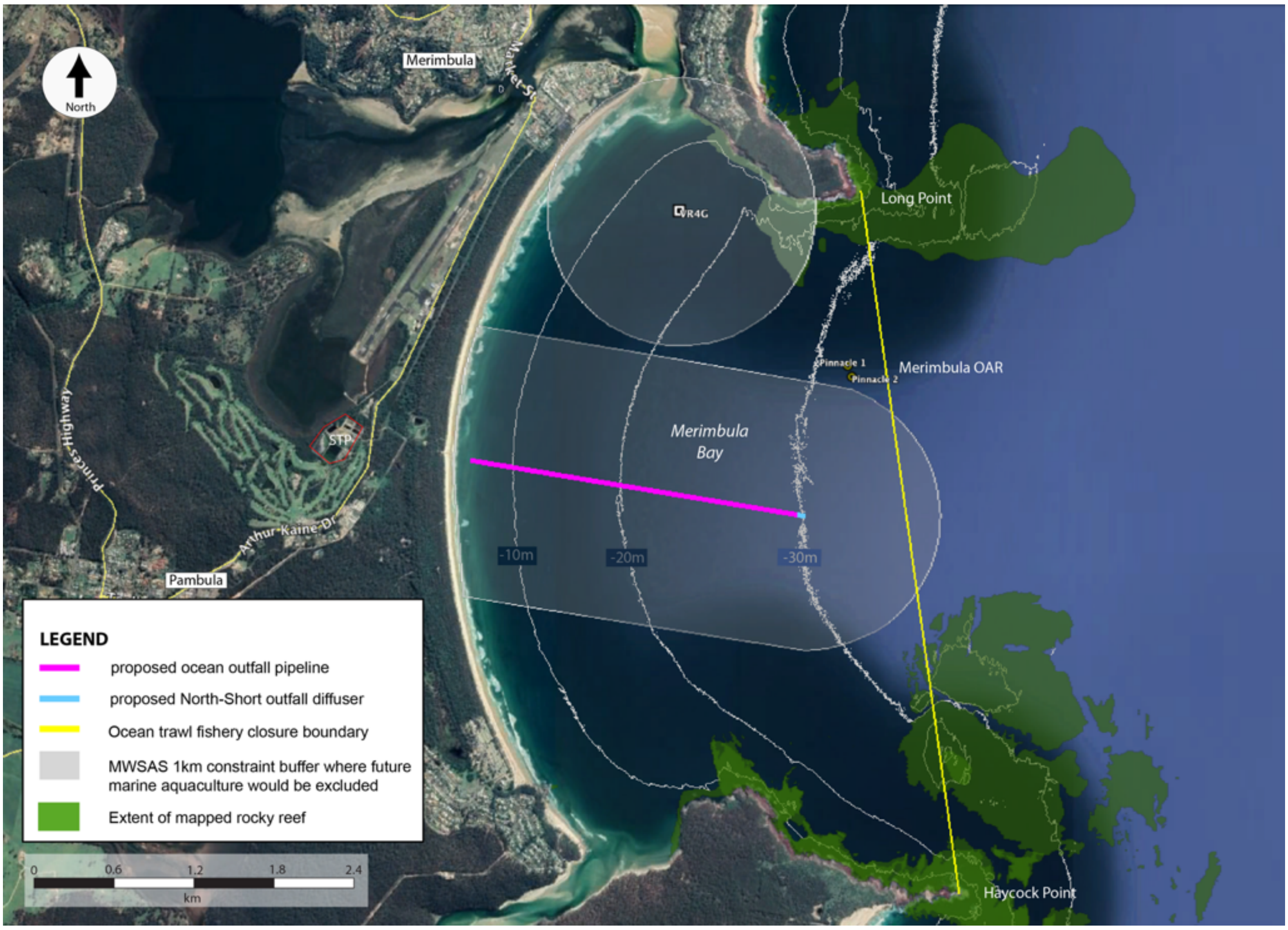


Figure 12-3 Project impact on future opportunities for marine aquaculture in Merimbula Bay under the MWSAS (DPI, 2018)

12.4.3 Risk of toxic algal bloom in Merimbula Bay

As discussed in **Section 9 - Phytoplankton**, blooms of phytoplankton can be stimulated by upwelling events that bring intrusions of nutrient-rich slope water to the coastal zone. These upwelling events can occur at any time but are typical in spring and summer and are a natural part of oceanic primary productivity and the basis of the marine food web. Occasionally these blooms may include high abundances of potentially harmful taxa.

For Merimbula Bay, OEH records contain four documented reports of algal bloom events over the past 20-year period (*pers. comm*., T. Ingleton, OEH). Of these, three were macroalgae washed up on the beach. In February 2003 a large red tide was reported in Merimbula Lake and was identified as the large and harmless dinoflagellate *Noctiluca scintillans.* While blooms of drift macroalgae are a common occurrence in Merimbula Bay, no records of toxic algal blooms have been reported, although that may partly be due to an absence of monitoring.

For the Twofold Shelf Bioregion, blooms of harmful algae that can pose a threat to marine waters aquaculture have been reported from Twofold Bay in 2005, 2011, 2012, and most recently 2016. The 2016 event was attributed to the dinoflagellate *Alexandrium fundyense* and resulted in the closure of mussel aquaculture in Twofold Bay for an 8-week period, until toxin levels decreased to below the regulatory limit for two consecutive samples one week apart. The closure was also expanded by the NSW Food Authority to include the commercial lobster, abalone and sea urchin fisheries. While the highest cell concentrations of *Alexandrium fundyense* were reported from Twofold Bay, evidence of the bloom was detected in other south coast shellfish harvest areas including Pambula Lake and elevated concentrations (1,200-15,000 cells^{-l}) of *Alexandrium fundyense* were detected along the coastal shelf up to 13 km north and 21 km south of Twofold Bay around this time.

12.5 Key Findings

Key findings of the assessment of aquaculture include:

- Oyster aquaculture is currently the only existing aquaculture within the study area, representing an important local industry in Merimbula Lake and Pambula River estuaries. The local industry is based primarily of Sydney rock oyster (*Saccostrea glomerata*) with smaller quantities of southern mud oyster (*Ostrea angasi*) also cultivated.
- The primary threat to sustainable oyster aquaculture is protection and maintenance of water quality. Poor water quality resulting from point source (*i.e.* sewage overflows from STP pump stations, poorly managed septic systems) and diffuse source water pollution (*i.e.* catchment and urban stormwater runoff) is an ongoing challenge for the industry. Poor water quality can lead to eutrophication and increased risk of algae bloom and in particular blooms of harmful microalgae that can form biotoxins. Other threats related to poor water quality include the risk of viruses and disease.
- Under normal ambient conditions, water quality of both estuaries is very good. Poor water quality typically occurs following significant rainfall events with high levels of nutrients, suspended solids and microbiological parameters (*i.e.* Faecal coliforms, *Enterococci*) exceeding regulatory guidelines that can result in short-term closures of oyster harvest areas.
- Risk of harmful microalgal blooms to oyster aquaculture and marine waters aquaculture is managed through the NSW Shellfish Quality Assurance Program coordinated by NSW Food Authority.
- Merimbula and Pambula estuaries are characterised by a diverse assemblage of phytoplankton including the presence of potentially harmful taxa (diatoms and dinoflagellates) at low levels. For the monitoring period 2005 to 2016, occasionally elevated abundance of a potentially harmful taxon that also exceeded the NSW Food Authority phytoplankton action limit (PALs) was reported from both estuaries. However, only few PAL exceedances resulted in a positive biotoxin detection.
- Blooms of phytoplankton in nearshore marine waters are a natural occurrence that can be stimulated by oceanic upwelling events that bring intrusions of nutrient-rich slope water to the coastal zone. These upwelling events can occur at any time but are typical in spring and summer. Occasionally these blooms may include high abundances of potentially harmful taxa such has occurred in Twofold Bay. No records of toxic algal blooms have as yet been reported for Merimbula Bay though that would be partly due to absence of monitoring.
- Future opportunities for marine waters aquaculture under NSW *Marine Waters Sustainable Aquaculture Strategy* (MWSAS – DPI, 2018) include the nearshore waters of Merimbula Bay. Merimbula Bay would be considered suitable for most forms of marine waters aquaculture excluding sea pen aquaculture due to the generally shallow depths.

12.6 Construction Phase Impacts

Construction phase impacts to aquaculture considers the risk of construction activities to existing estuarine aquaculture and future opportunities for marine waters aquaculture in Merimbula Bay.

- As discussed in **Section 11 – Estuarine communities**, potential impacts from the construction phase of the Project would only apply to Merimbula Lake with its proximity to the STP site. Pambula River estuary is too distant from the location of the construction works to be impacted. The risk of construction impacts to ecological values of Merimbula Lake was assessed as minimal with works to be implemented under a CEMP that describes measures to mitigate risks. Therefore, risk of impact to oyster aquaculture from construction phase activities is also low to minimal.
- Construction of the North-Short pipeline and outfall diffuser would reduce the area of Merimbula Bay available for future marine aquaculture by approximately 50% according to the MWSAS. It should be noted that this finding is provisional pending further update to the SEPP (Primary Production and Rural Development) 2019 that adopts the recommendations of the MWSAS (DPI, 2018).

12.7 Operational Phase Impacts

Potential operational phase impacts, to existing estuarine aquaculture and future opportunities for marine waters aquaculture from the project, were assessed in terms of whether the Project may increase the risk of toxic algal bloom via discharge of treated wastewater at the proposed ocean outfall.

This is also considered in context of other water quality risks to the estuaries, namely stormwater inputs which is identified as the highest priority threat to estuarine ecosystems in NSW (BMT-WBM, 2017), and episodic regional-scale nutrient input events such as oceanic upwellings that deliver significant concentrations of nutrients to the coastal zone and trigger algal blooms.

Key factors considered in assessing the risk include:

- Entrances to Merimbula Lake and Pambula River estuary are situated 2,700 m and 3,000 m away from the mixing zone respectively and dispersion modelling indicates these would not be affected by the plume of diluted treated wastewater.
- Under existing conditions, the beach-face outfall has discharged treated wastewater to Merimbula Bay since 1971. Modelling of treated wastewater discharge at the beach-face outfall indicates that it is entrained in the nearshore beach zone and rapidly achieves 1,000 times dilution and gradually disperses to the north and south along the beach zone, and to offshore deeper waters of the central bay region where it dilutes further. Under certain current conditions, modelling indicates potential for highly dilute treated wastewater to enter Merimbula Lake. It is noted the level of dilution is modelled between 10,000 to 100,000 times, would meet estuary WQOs and therefore would be unlikely to be detected in water laboratory analysis.
- Significant catchment rainfall events deliver high levels of suspended solids and nutrients to the estuarine environment with some proportion of that load then discharged to Merimbula Bay.
- Episodic upwellings of slope water deliver high levels of nitrate to coastal waters that typically provides the stimulus for phytoplankton blooms in the nearshore zone.
- STP upgrades of PAC dosing and tertiary filtration would improve wastewater quality by enhancing removal of phosphorus and metals from the wastewater stream

12.7.1 Risk of toxic algal bloom to estuarine aquaculture

Ceasing the beach-face outfall and discharging wastewater instead via the proposed ocean outfall would improve wastewater dispersion, with modelling indicating MWQOs would be met within a 25 m mixing zone of the discharge point for the majority of the time. Under worse-case conditions that may occur a small proportion of time (*i.e.* wet weather flows coinciding with stagnant ocean currents), MWQOs would be met within 200 m of the discharge point. Given the estuary entrances are located 2,700 - 3,000 m away from the proposed North-Short outfall location, there is low to minimal risk that diluted treated wastewater would enter the estuaries at concentrations sufficient to trigger an algal bloom above what already occurs on an intermittent basis due to stormwater and catchment inputs.

The following are potential benefits to estuarine aquaculture as a result of the Project:

- Moving the discharge point from the current beach-face location out into the Bay eliminates the risk of wastewater being entrained in the surf zone where it has more potential to disperse parallel to the beach and towards the estuary entrances.
- Ceasing wastewater disposal to the dunal ex-filtration ponds would be expected to improve groundwater quality beneath the ponds over time, including the component of groundwater that flows westwards and discharges to Merimbula Lake.

In terms of relative risk, the analysis indicates that there is a reduction in risk to the estuaries and estuarine aquaculture when compared to current conditions.

Considering the factors above, the risk of impact to estuarine aquaculture from the operational phase of the project is considered low to minimal which is included in the risk analysis in **Section 14 – Impact Assessment.**

12.7.2 Risk of toxic algal bloom to marine waters aquaculture

The marine environment is generally considered to be oligotrophic (*i.e.* contain low available nutrients) and it is widely understood that among all the possible limiting elements, nitrogen most frequently limits primary productivity (Lobban and Harrison, 1994).

The discharge of treated wastewater via the ocean outfall would include levels of nutrients that exceed the MWQOs and in particular, high levels of bioavailable forms of nitrogen, nitrate and ammonium, that would provide a localised stimulus for increased primary productivity. For majority of conditions, nutrient concentrations would dilute rapidly and meet MWQOs within a 25 m mixing zone. It is expected that majority of this nutrient load would be assimilated by phytoplankton with only a minor proportion available to other marine flora within the mixing zone that includes drift algae. Under worse-case conditions where MWQOs would be met within 200 m of the discharge point, the stimulus for increased primary productivity may extend in scale. However, for both typical and worse-case conditions, the scale of nutrient availability would be considered minor when compared to the concentrations of nutrients supplied to coastal waters during regional-scale upwelling events or following catchment flood flow events.

As discussed in **Section 9 - Phytoplankton** and **Section 12.5.3** above, phytoplankton blooms occur on a large geographic scale and the seasonal influence of the East Australian Current (EAC) is an important factor controlling phytoplankton dynamics in south-eastern Australia. Occasionally these blooms may include high abundances of a potentially harmful taxa that can pose a threat to marine waters aquaculture as has occurred in Twofold Bay. While the Project may provide stimulus for increased primary productivity, it would be localised and unlikely to generate a bloom at a scale that would cause adverse impact to marine aquaculture beyond what may already occur under existing environmental conditions and wastewater disposal at the beach-face outfall.

Overall, the risk from the Project to increasing the likelihood of a toxic algal bloom on a scale that would have an adverse effect on marine waters aquaculture is considered low which is included in the risk analysis in **Section 14 – Impact Assessment.**

12.8 Conclusion

The potential impact to existing estuarine aquaculture from an increased risk of toxic algal bloom is considered minimal. The Project, by ceasing disposal of wastewater at the current beach-face outfall and dunal ex-filtration ponds, would be beneficial to estuarine aquaculture as the water quality risks associated with those methods of disposal are eliminated.

The potential impact to future opportunities for marine waters aquaculture in Merimbula Bay from increased risk of toxic algal bloom beyond ambient conditions is considered low to minimal. However, the Project would impact future opportunities for marine waters aquaculture by reducing the the area of Merimbula Bay available for consideration under the MWSAS.

13 Threatened and Protected Marine Species

13.1 NSW and Commonwealth Legislation

In NSW, threatened marine species and ecological communities are provided protection by the *Fisheries Management Act 1994* (FM Act) that includes fish and marine vegetation. Other threatened marine fauna such as whales, dolphins, turtles and birds are provided protection by the *Biodiversity Conservation Act 2016* (BC Act).

Threatened marine species of National Environmental Significance are provided protection by the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) that covers:

- Nationally threatened species and ecological communities and threatening processes;
- Migratory species protected under international treaties; and
- Commonwealth marine areas.

13.2 Preliminary Identification of Threatened Species

A preliminary list of threatened species, populations, ecological communities, and critical habitat that have been reported or modelled to occur within 5km radius of the study area was obtained from searches of the following databases:

- DPIE BioNet threatened species database.
- DPI Fisheries records of threatened and protected species and key threatening processes (KTPs) listed under Schedules 4 to 6 of the FM Act were reviewed to satisfy the requirements of the Fisheries NSW Policy and Guidelines for Fish Habitat Conservation and Management (NSW DPI 2013) and the NSW *Environmental Planning and Assessment Act 1979*.
- EPBC protected matters search tool.

In summary:

- A search of DPIE BioNet database found 313 species recorded within a 5km radius of the study area. Excluding the terrestrial species, 47 of those species are marine including: one turtle, dugong, three seals, eight cetaceans (whale and dolphins) and 34 birds.
- Five (5) fish taxa listed as either threatened or protected under the FM Act are known or predicted to occur in the project area. These include the Grey nurse shark, Great white shark, Black Cod, Southern bluefin tuna and Syngnathiformes (all seahorses, pipefish, pipehorses, sea moths). In addition, one Key Threatening Process (KTP) listed under FM Act that is considered relevant to the project is also identified.
- The EPBC protected matters search tool identified 73 species listed as threatened, 47 migratory species and 85 marine species with potential to occur within 5km radius of the project area. Excluding terrestrial species, a total list of 99 species was considered relevant to the 'marine' study area that included 14 cetaceans, one dugong, three seals, five turtles, five fish, 28 members of Syngnathiformes, and 48 marine birds.

A complete list of database search results is provided in **Appendix I-1**. Further evaluation of each species likelihood of occurrence within the study area was undertaken based on the qualitative criteria in Section 13.4 below.

13.3 Species Likelihood of Occurrence

An assessment as to whether each of the threatened species, populations and ecological communities recorded and or modelled to occur within a 5km radius are likely to occur in the study area was undertaken using the following sources:

- ALA (2017). Atlas of Living Australia, URL: https://www.ala.org.au/
- RLS (2017). Reef Life Survey Data Portal, URL: http://reeflifesurvey.imas.utas.edu.au/portal/search
- Dorsal (2018). Shark Reporting URL: https://www.dorsalwatch.com/report/

Based on information concerning habitat requirements of each species and observations gathered during marine ecology field surveys, each species was assigned a score based on two criteria: (1) the likelihood of occurrence, and (2) when the species was last reported in the BVSC region. Scores were then multiplied together to generate a likelihood of occurrence score - high, moderate, low or unlikely to occur (**Table 13-1**).

Table 13-1 Qualitative assessment criteria for species likelihood of occurrence

Qualitative Assessment Criteria	
Likelihood of Occurrence Score	
5	Confirmed present - species identified within the project area during field surveys
4	Species known from the project area, and suitable habitat (such as foraging habitat) exists within the project site
3	Species known from the broader BVSC region though not recorded from the project area, and potential suitable habitat (such as foraging habitat) exists within the project site
2	Species not known from the broader BVSC region, though potential suitable habitat (such as foraging habitat) exists within the project site
1	No suitable habitat exists for the species within the project area
Last Reported in BVSC Region Score	
5	Last reported in the BVSC region less than 5 years ago
3	Last reported in the BVSC region between 5 to 10 years ago
1	Last reported in the BVSC region more than 10 years ago
0	Not reported in the BVSC region
Likelihood Score	
20 - 25	High likelihood of occurring within the project area
11 - 19	Moderate likelihood of occurring within the project area
6 - 10	Low likelihood of occurring within the project area
0 - 5	Unlikely to occur within the project area

Following an evaluation of likelihood of occurrence, a total of 33 species including five cetaceans, two seals, four fish, two syngnathids, and 20 birds were found to have moderate to high likelihood of occurrence within the study area (**Table 13-2**), including:

- Five EPBC listed threatened cetaceans: Humpback whale, Southern right whale, Orca, Common dolphin, and Bottlenose dolphin.
- Two EPBC listed seals are also listed as threatened in NSW under the BC Act: New Zealand fur seal

and Australian fur seal.

- Four fish species listed as threatened under the FM Act and or EPBC Act: Black cod, Southern Bluefin tuna, Grey nurse shark and Great white shark.
- Two syngnathids listed as protected under the FM Act: bigbelly seahorse and weedy seadragon.
- Twenty marine birds that includes eight EPBC listed species and 14 listed as protected under the BC Act, with two birds listed under both Acts (**Table 13-2**).

The complete likelihood of occurrence assessment for all identified threatened species (excluding terrestrial species) is provided in **Appendix I-2.**

Table 13-2. Threatened and protected marine species listed under the FM Act, BC Act and EPBC Act that have moderate to high likelihood of occurrence within the project area.

Species Name	Common Name	Legal Status			Source	Last Reported in BVSC region [1]	NOTES	Score	Likelihood of Occurrence [2]
		EPBC Act	BC Act	FM Act					
Cetaceans (Whales and Dolphins)									
Eubalaena australis	Southern right whale	E, M, W	E	-	ALA	2016	The species migrates to coastal region of southern Australia for calving during winter period (June to August). Species is occasionally observed in coastal waters and embayments of the BVSC region where mothers and calves may be observed resting in shallow waters close to the beach. There are several records of the species occuring within Merimbula Bay but no records specifically with the Project area.	20	High
Megaptera novaeangliae	Humpback whale	V, M, W	V	-	Elgin	2020 *	Observed annually in Merimbula Bay during spring southerly migration (August to November). Groups of individuals and mothers and their calves were observed passing through the project area during marine ecology investigations in 2017, 2019, and 2020.	25	High
Orcinus orca	Killer whale, Orca	M, W	P	-	ALA	2015	Inhabit all of worlds oceans with a total of nine records in the BVSC region since 1930, most recently reported in 2015 from Twofold Bay. Typically forages in offshore waters over the continental shelf.	15	Moderate
Delphinus delphis	Common dolphin	W	P	-	Elgin	2020 *	Regularly observed in waters offshore to the BVSC coastal region all year. Groups of individuals were observed in the Project area in October 2020.	25	High
Tursiops truncatus s. str.	Indo-Pacific Bottlenose dolphin	W	P	-	Elgin	2020 *	Broadly distributed around the Australian coast found in temperate and tropical waters. Regularly observed in waters offshore to the BVSC coastal region all year. Groups of individuals were observed in the Project area in 2020.	25	High
Pinnipeds (Seals)									
Arctocephalus forsteri	New Zealand fur-seal	L	V	-	ALA	2012	Colony of non-breeding New Zealand fur-seal exist at Montague Island 80 km to the north of the project area. New Zealand fur-seal are known to forage in waters offshore of Merimbula and Pambula including the project area.	25	High
Arctocephalus pusillus	Australian fur-seal	L	V	-	Elgin	2020 *	Colonies of non-breeding fur-seal exist at Montague Island 80 km to the north and Green Cape 40 km to the south of the project area respectively. Australian fur-seal are known to forage in waters offshore of Merimbula and Pambula with individuals sighted in 2017 during fieldwork including the project area.	25	High
Bony Fish									
Epinephelus daemelii	Black cod	V, L	-	V	ALA, pers. comm.	2005 / 2017	Found on coastal reefs, estuaries or in deep water offshore. The species has been reported from locations >10km to the south and north of Merimbula Bay with the last recorded sighting from Bermagui in 2005. Anectdotal reports from local spearfishers indicate individuals are regularly observed at Mowarry Point south of Eden. Suitable habitat exists within the project area.	15	Moderate
Thunnus maccoyii	Southern bluefin tuna	-	-	E	ALA	2017	Highly migratory species found in Australian oceanic waters from northwestern Australia, around southern Australia to NSW and the broader Pacific ocean. The southern bluefin tuna is targeted by fishers in waters offshore to the BVSC coast each year, typically during summer and autumn period coinciding with warmer currents. The species is usually observed in offshore waters but has been sighted within Merimbula Bay on occasion. Suitable foraging habitat exists within the project area.	20	High

Table 13-2. Threatened and protected marine species listed under the FM Act, BC Act and EPBC Act that have moderate to high likelihood of occurrence within the project area.

Species Name	Common Name	Legal Status			Source	Last Reported in BVSC region [1]	NOTES	Score	Likelihood of Occurrence [2]
		EPBC Act	BC Act	FM Act					
Syngnathiformes	Seahorses, pipefish, pipehorses, sea moths	L	-	P	ALA, RLS	2017	Majority of species are typically found in seagrass and macroalgal habitats of estuaries and protected embayments. EPBC Protected Matters Search Tool indicates 28 spp. may occur within 5km radius of the project area. A total of 31 spp are known from NSW waters. Of these, only 10 species are recorded within the BVSC region and mostly from estuarine and sheltered environments. Two species that may be observed in habitats of Merimbula Bay at Long Point and Haycock Point include the bigbelly seahorse and weedy seadragon.	15	Moderate
Sharks									
Carcharias taurus	Grey nurse shark	CE	-	CE	ALA, RLS, Dorsal	2018	Grey nurse shark have been observed in coastal waters within the BVSC region with the the most recent sighting at Long Pont, Merimbula Bay in 2018. The closest known aggregation site critical to the species is Montague Island (80 km north of Merimbula). Suitable habitat (i.e. sand gutters and rocky reef) exists at the project site.	15	Moderate
Carcharodon carcharias	Great white shark	V, M, W	-	V	ALA, RLS, Dorsal	2020	Found in Ausralian coastal waters over a broad range. White shark individuals are sighted along the BVSC coast each year, typically in spring and summer coinciding with the southerly migration of humpback whales. The Great white shark was reported within Merimbula Bay on at least eight different occasions over 12-month period between January 2017 to May 2020 (Dorsal 2020).	15	Moderate
Birds									
Ardenna grisea	Sooty Shearwater	-	P	-	ALA	2013	A migratory seabird that is known to nest on islands in NSW south of Port Stephens. Foraging habitat exists within the project area.	15	Moderate
Ardenna pacificus	Wedge-tailed Shearwater	-	P	-	Elgin	2020 *	A migratory seabird that nests on islands off coast of NSW. Foraging habitat exists within the project area with indiviudals observed foraging during fieldwork in November 2017 and October 2020.	25	High
Ardenna tenuirostris	Short-tailed Shearwater	-	P	-	Elgin	2020 *	A migratory seabird that nests along the eastern and southern coastlines of Australia. Foraging habitat exists within the project area with indiviudals observed foraging during fieldwork in November 2017 and October 2020.	25	High
Chroicocephalus novaehollandiae	Silver Gull	-	P	-	Elgin	2020 *	Coastal, offshore waters; beaches, mudflats, estuaries, larger rivers, reservoirs, lakes; some inland. Suitable habitat present within project area.	25	High
Diomedea exulans	Wandering Albatross	V, L	-	-	ALA		Regularly observed foraging in waters offshore from Merimbula Bay. Foraging habitat exists within the project area.		Moderate
Eudyptula minor	Little Penguin	-	P	-	Elgin	2020 *	Nearest breeding, nesting colonies are Montague Island and Gabo Island, approx 80km to the north and south of the project area respectively. Foraging habitat exists within the project area and individuals were observed foraging within Merimbula Bay during fieldwork in November 2017 and October 2020.	25	High
Haematopus longirostris	Pied Oystercatcher	-	E1,P	-	ALA	2017	Favours intertidal flats of inlets and bays, open beaches and sandbanks. Limited suitable habitat exists within the project area.	15	Moderate
Haliaeetus leucogaster	White-bellied Sea-Eagle	L	V, P	-	ALA	2017	Inhabits coastal areas, over islands, reefs, beaches, estuaries, lagoons and floodplains. Foraging habitat exists within the project area.	15	Moderate
Macronectes giganteus	Southern Giant-Petrel, Southern Giant Petrel	E, L	-	-	ALA	2013	The Southern Giant-Petrel is widespread throughout the Southern Ocean. Has been observed in waters ofshore from Merimbula Bay. Foraging habitat exists within the project area.	15	Moderate

Table 13-2. Threatened and protected marine species listed under the FM Act, BC Act and EPBC Act that have moderate to high likelihood of occurrence within the project area.

Species Name	Common Name	Legal Status			Source	Last Reported in BVSC region [1]	NOTES	Score	Likelihood of Occurrence [2]
		EPBC Act	BC Act	FM Act					
Macronectes halli	Northern Giant Petrel	V, L	-	-	ALA	2017	Immature and some adult birds are commonly seen in offshore and inshore waters from around Fremantle (WA) to around Sydney (NSW). Has been observed in waters ofshore from Merimbula Bay. Foraging habitat exists within the project area.	15	Moderate
Morus serrator	Australasian Gannet	-	P	-	Elgin	2019 *	Coastal bird usually breeding on islands or artificial structures. Foraging habitat exists within the project area with individuals observed within Merimbula Bay during fieldwork in November 2017 and October 2019.	25	High
Pandion haliaetus	Osprey	L	-	-	ALA	2017	Favours coastal areas, especially the mouths of large rivers, lagoons and lakes. Feed on fish over clear, open water. Observed within the Merimbula coastal region. Foraging habitat exists within the project area.	15	Moderate
Phalacrocorax carbo	Great Cormorant	-	P	-	ALA	2017	Prefers freshwater wetlands but also observed in coastal inlets and estuaries. Known from Merimbula and Pambula region. May forage in coastal habitats within the project area.	15	Moderate
Phalacrocorax fuscescens	Black-faced Cormorant	-	P	-	Elgin	2019 *	Found primarily around southern Australian coastline where it breeds on rocky headlands, islands and inlets building nests of seaweed and driftwood. Known from the Merimbula and Pambula region and observed foraging within the project area.	25	High
Phalacrocorax varius	Pied Cormorant	-	P	-	Elgin	2019 *	Found throughout Australia, in marine habitats including estuaries, harbours and bays. It is also found in mangroves and on large inland wetlands in eastern Australia. Known from the Merimbula and Pambula region and observed foraging within the project area.	25	High
Puffinus carneipes	Flesh-footed Shearwater, Fleshy-footed Shearwater	L	-	-	ALA		Ranges throughout the Pacific and Indian oceans, with main breeding areas Lord Howe Island, New Zealand and along coast of Western Australia. Occasionally observed foraging in waters offshore from Merimbula. Foraging habitat exists within the project area.	15	Moderate
Puffinus gavia	Fluttering Shearwater	-	P	-	ALA		Endemic to New Zealand and migrates to Australia and Solomon Islands. Occasionally observed foraging in waters offshore from Merimbula. Foraging habitat exists within the project area.	15	Moderate
Sternula albifrons	Little Tern	L	-	-	Elgin	2019 *	Almost exclusively coastal, preferring sheltered environments; however may occur several kilometres from the sea in harbours, inlets and rivers. Suitable foraging habitat exists within the project area.	25	High
Thalassarche cauta	Tasmanian Shy Albatross	V, L	V, P	-	ALA	2017	Shy Albatrosses appear to occur over all Australian coastal waters below 25° S. It is most commonly observed over the shelf waters around Tasmania and south eastern Australia. Foraging habitat exists within the project area.	15	Moderate
Thalasseus bergii	Crested Tern	-	P	-	ALA	2019 *	Widespread around the Australian coastline. Known from Merimbula Bay. Foraging habitat exists within the project area.	20	High

Notes

EPBC Act 1999 Status: L = listed marine species, V = vulnerable, E = endangered, CE = critically endangered, W = whales and other cetaceans, M = migratory.

NSW *Biodiversity Conservation Act 2016* Status: E = endangered, V = vulnerable, P = protected.

NSW *Fisheries Management Act 1994* Status: CE = critically endangered, V = vulnerable.

[1] Last reported occurrence in Bega Valley Shire Region according to ALA (2017), RLS (2017) and Dorsal (2018) databases, or confirmed by observations during marine ecology fieldwork*

[2] Likelihood of occurrence score: 20-25 = high, 11-19 = Moderate, 6-10 = Low, Unlikely = 1-5 (Refer scoring criteria Table 13-1)

13.4 SEARs

The Project SEARs specifically require that:

- *The Proponent must assess impacts on endangered ecological communities (EECs), threatened species and/or populations, and provide the information specified in s9.2 of the FBA.*
- *The Proponent must identify whether the project as a whole, or any component of the project, would be classified as a Key Threatening Process in accordance with the listings in the Biodiversity Conservation Act 2016 (replaced the Threatened Species Conservation Act 1995), Fisheries Management Act 1994 (FM Act) and Environment Protection and Biodiversity Conservation Act 2000 (EPBC Act).*
- *The proponent must undertake an assessment of significance as required by Part 7A of the FM Act for relevant threatened fish species according to NSW DPI Threatened Species Assessment Guidelines.*

In addressing the above SEARs, a general discussion of the potential impacts from Project construction and operational phase activities is provided below in **Section 13.5**.

13.5 Potential Project Impacts to Marine Fauna

Potential impacts from construction and operational phase activities on marine fauna can be summarised as:

Construction phase

- Construction noise
- Vessel or cable strike
- Water pollution from accidental spill of fuel, oils or other substance
- Translocation of an introduced marine pest (IMP) to local waters (Key Threatening Process)
- Disturbance and loss of Type 3 soft sediment habitat establishing the pipeline and diffuser infrastructure

Operational phase

- Discharge of treated wastewater

13.5.1 Construction noise

Hearing is the primary sense for many marine vertebrate species and is used for detecting signals from; prey, predators, conspecific social interactions, competitors and the environment. Marine fauna that are most likely to be affected by construction noise are marine mammals that include whales, dolphins and seals. Exposure to anthropogenic underwater noise can interfere with key life functions of marine mammals (*i.e.* foraging, mating, nursing, resting, migrating) by impairing hearing sensitivity, masking acoustic signals, eliciting behavioural responses, or in extreme cases (if the receptor is close enough to the noise source for long enough) possible physiological stress and / or injury.

Underwater noise generation is classified as either impulsive or non-impulsive noise sources. Impulsive noise is generated by activities such as pile driving, explosions, airgun shots and is defined as impulsive sounds of short duration and occur singly, irregularly, or as part of a repeating pattern. An explosion represents a single impulsive event whereas the periodic impacts from a piling rig or a geophysical survey result in a patterned impulsive sequence (Government of South Australia, 2012). Impulsive noises generate high peak pressure and rapid rise times and due to these physical characteristics are thought to be more damaging to marine fauna hearing (NOAA, 2018).

Non-impulsive noise sources (i.e. continuous, steady state noise) produce sounds that can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have high peak sound pressures with rapid rise / decay time that impulsive sounds, like pile driving do (ANSI 1995; NIOSH 1998 as cited in NOAA 2018).

Underwater noise generating activities as a result of the Project construction would comprise non-impulsive noise sources such as vessel movements and construction activities to establish the pipeline and diffuser infrastructure on the seabed and anchoring of the pipeline with protective concrete mattress or rock armour. No impulsive noise sources are anticipated.

The effects of underwater noise on marine fauna is complex and no definitive models are available to predict the precise nature of, and potential for, injury, due to a broad range of variables relating to bathymetric and environmental conditions and the varying sensitivity of the range of species potentially exposed.

Noise related impacts to marine fauna are based on temporary and or permanent hearing loss, referred to as either Temporary Threshold Shift (TTS) or Permanent Threshold Shift (PTS). TTS is a short-term reversible loss of hearing, whereas PTS is an irreversible loss of hearing.

Marine mammals do not hear equally well at all frequencies; therefore, the effects of noise frequency on hearing loss / damage are incorporated by using auditory weighting functions, to emphasise noise where a species is more sensitive to noise and de-emphasize noise at frequencies where susceptibility is low (Finneran, 2016). These frequency-weighting functions are commonly applied in assessing the potential for the detection of a sound at a specific frequency, and more commonly, for assessing potential noise impacts.

A number of listed threatened and protected marine mammals have a high likelihood of occurrence at the study area and are known to be sensitive to noise. These include southern right whales, humpback whales, orcas, bottlenose dolphins and seals. **Table 13-3** provides the TTS- and PTS-onset threshold levels for these species exposed to non-impulsive noise: SEL thresholds in dB re 1 μPa^{2}s as detailed in Southall *et al.* (2019).

Table 13-3 TTS- and PTS-onset threshold levels for marine mammals exposed to non-impulsive noise that may occur in the project area (derived from Table 6 in Southall *et al.,* 2019).

Marine Mammal Hearing Group	TTS onset: SEL (weighted) dB re 1 μPa^{2}s	PTS onset: SEL (weighted) dB re 1 μPa^{2}s
LF Cetaceans Southern right whale, Humpback whale	179	199
HF Cetaceans Orcas and bottlenose dolphins	178	198
OCW Pinnipeds in water	199	219

Note:
TTS = temporary threshold shift
PTS = permanent threshold shift
LF = low frequency
HF = high frequency
OCW = other marine carnivores in water

An underwater noise assessment of proposed Project activities was undertaken by AECOM (refer **Chapter 21 Noise (Underwater)** in the EIS). Given the source noise characteristics, a model was used to predict the propagation of sound away from the source, and the noise exposure criteria, and predict the zones within which impacts may be expected to occur. The resulting zones of potential noise impact are provided in **Figure**

13-1 which shows the distance radii modelled from source noise at the end of the diffuser structure. These distance radii apply to construction activities occurring along the entire 2.7 km pipeline, not just the end of diffuser.

Key points from the assessment include:

- **Zone of potential hearing injury** – potential for physiological impact such as PTS to low frequency cetaceans (humpback and southern right whales) within 170 m radius of the noise source, therefore a 170 m safety shut-down zone would be adopted by the Project if noise generating activities occur during key ecological migration windows that may result in LF cetaceans being present in Merimbula Bay (southern migration for humpback and southern right whales – June to November) with an observation zone of 2.3 km implemented. PTS thresholds for high frequency cetaceans and other marine carnivores are not anticipated to be exceeded as result of the Project. Therefore, for works undertaken outside of June to November each year, no shut down zone would be required.
- **Zone of potential responsiveness** – for LF cetaceans a watch zone of 2.3 km will be implemented to account for potential for TTS. Outside of LF cetacean key ecological migration windows, a conservative watch zone of 500 m would be adopted.

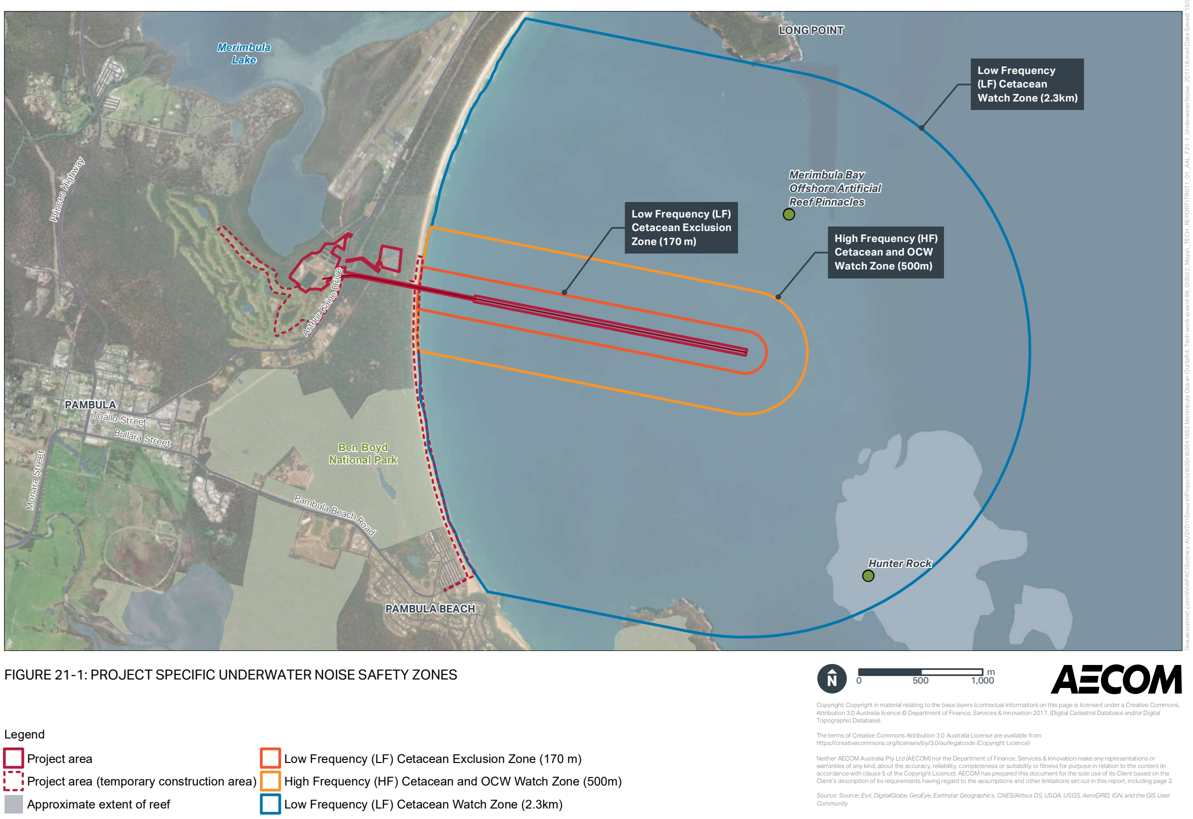


Figure 13-1 Noise impact zones for potential hearing injury for high frequency and low frequency marine mammals and other marine carnivores (from AECOM 2020)

Birds and fish are generally considered to be less likely affected by construction noise and would avoid or move away from the area as required. However, it is now understood that fish with swim bladders are sensitive to noise disturbance although the physiological effects from noise are not yet well understood (Hawkins and Popper, 2017; Popper and Hawkins, 2019). Noise levels from the majority of proposed construction activities would be similar to ambient noise already occurring in Merimbula Bay from recreational, charter and commercial vessels. Noise effects would be short-term, localised and fish within the vicinity of construction activities would avoid or move away from the area as required. The risk of noise disturbance to fish is considered minimal.

The potential impacts of non-impulsive underwater noise on marine fauna is considered a low risk with adoption of mitigation measures to minimise exposure to underwater noise during construction (**Section 15 – Enviromental Management**).

13.5.2 Vessel or cable strike

Construction works would require vessels and materials to mobilise from Twofold Bay to Merimbula Bay. Construction activities broadly may include towing the pipeline to site, anchoring vessels, laying pipeline into position, and anchoring pipeline with protective concrete mattress or rock armour.

Vessel strike to marine fauna is a world-wide problem (Marsh et al., 2003) and there is a clear relationship between the number of vessels within a given area and the incidence of vessel strike. The risk of vessel strike during mobilisation to or works at the study area is most likely to involve slower moving marine mammals such as whales, with seals or dolphins considered at lower risk of vessel strike as they can easily out manoeuvre approaching vessels. Vessel strike has the potential to cause injury and or death depending on vessel size, travel speed and species involved.

Cable strike is related to anchor cables that stretch and slacken in the water column. Cables or anchor lines may strike marine fauna, causing slashing injury. Risk of cable strike is considered higher for inquisitive young whales, dolphins and seals, compared to older individuals and potential risk of cable strike increases at night due to reduced visibility.

The potential risk of vessel or cable strike is related to the number of individuals in the area, which is also related to the species seasonal migration period. The risk of vessel or cable srike is considered low with the risk further reduced by adopting routine control measures during construction phase activities (**Section 15 – Enviromental Management**).

13.5.3 Water pollution from accidental spill

There is the potential for hazardous substances (*ie.* fuels, oils and other construction vessel related fluids) to accidently enter the water through spills or leaks from construction vessels and/or equipment. Water pollution has the potential to cause harm to a wide variety of marine fauna including sessile and mobile invertebrates, fish, reptiles, birds and marine mammals. Marine mammals may swim and feed in or near an oil spill and some fish may be attracted to oil because it appears similar to floating food. Birds can then be attracted to schools of fish and inadvertently become covered in or ingest fuels or oils. Impacts from water pollution on marine fauna can potentially occur via ingestion or substances such as oils smothering their bodies, fur or feathers.

Oil in the environment or oil that is ingested can cause the following effects:

- tainting of fish, crustacean, mollusc and algal food resources of higher order fauna
- poisoning of fauna in higher in food chain if consuming large amounts of oil-tainted prey
- physiological damage to organs and illness and weakened immune system leading to secondary infection
- irritation to eyes, mouth and naval cavity, and skin
- damage to fish eggs and larval phase of invertebrates
- stress causing behavioural change and interference with breeding

Oil smothering the bodies, fur or feathers of marine fauna can cause the following effects:

- hypothermia in fur seal pups as the insulation of their wooly fur (lanugo) is reduced. Adult fur seals have blubber and are not as susceptible to hypothermia if covered in oil.
- fur seals may drown or become susceptible to predation if covered in oil
- birds exposed to oils lose the waterproofing and insulative properties of their plumage. They become

susceptible to hypothermia or can drown in polluted waters
- birds may inadvertently ingest oils when preening feathers leading to poisoning and death

The potential impacts of water pollution on marine fauna can be harmful and is considered a medium risk. This risk can be reduced by implementing a range of control measures to protect water quality during construction.

13.5.4 Translocation of an introduced marine pest to local waters

Introduced marine pest (IMP) species pose a serious threat to biodiversity and marine primary production in NSW (DPI 2008). They can foul marine infrastructure, alter marine habitats, outcompete or prey on native species and put at risk Australia's fisheries and aquaculture industries. They may be introduced in various ways, including in ballast waters, attached to the hulls of domestic or international ships, or imported deliberately as aquarium or aquaculture species (DPI, 2008).

The *Introduction of non-indigenous fish and marine vegetation to the coastal waters of New South Wales* is listed as a KTP under the FM Act and is considered with regards to its potential impact to the marine fauna at the study area.

The potential risk exists for translocating an introduced marine pest (IMP) to Merimbula Bay from Twofold Bay via construction vessels. Three IMPs reported from the Port of Eden, 30 km to the south (Pollard *et al*. 2003) that are not yet reported from Merimbula Bay include the dinoflagellate *Alexandrium catenella*, European fan worm (*Sabella spallanzanii*) and the New Zealand Screwshell (*Maoricolpus roseus*). The latter is known to occur on the continental shelf off Merimbula but is not present within the study area of the embayment. Another two IMPs reported from Twofold Bay include the Pacific oyster and European green shore crab (*Carcinus maenus*). Both species are known to occur within the estuarine habitats of Merimbula and Pambula Lakes. Other IMPs not yet detected but considered possible high risk to Twofold Bay include the Yellowfin goby, Japanese goby, Northern Pacific seastar, *Caulerpa taxifolia* and Japanese kelp (*Undaria pinnatifida*). These IMPs could also pose a threat to habitats and species at the study area.

The risk of translocating an IMP during construction phase activities is considered a medium risk. It is expected that construction vessels would adopt standard environmental management practices and controls as recommended by the *National Marine Pest Plan 2018-2023* to mitigate the risk (**Section 15 – Environmental Management**)

13.5.5 Discharge of treated wastewater

The NSW marine estate threat risk assessment report (BMT-WBM 2017) found that the discharge of treated sewage wastewater to coastal marine waters was typically a low to moderate risk to marine ecosystems and fauna (including threatened species). This was based on the finding that potential impacts were likely to be localised around the outfall and of small scale when the entire marine estate is considered. In contrast, the report found that discharge of sewage wastewater to estuarine waters was a moderate to high risk to estuarine ecosystems and fauna due to the generally poorer dispersion and dilution processes compared to those of the open ocean.

The operational phase of the Project would result in the discharge of treated wastewater to an ocean outfall at 30 m depth over sandy sediments where it is expected to rapidly dilute and meet marine water quality objectives (MWQOs) within a 25 m mixing zone the majority of the time. It should be noted that treated sewage wastewater has been discharged to a beach-face outfall at Merimbula Bay since 1971. The Project would result in the improved management of treated wastewater providing a disposal option during peak wet weather events that currently can result in episodic sewage overflows to Merimbula estuary that poses a threat to estuarine values including oyster aquaculture. The Project also includes upgrades to the STP that would result in improved wastewater quality and disposal at the proposed ocean outfall would provide improved dispersion of the treated wastewater compared to the current beach-face outfall.

Overall, the Project is contributing to mitigating the potential impacts of water pollution on marine ecosystems and fauna in Merimbula Bay through STP upgrades and improved dispersion of treated wastewater.

13.6 Significance Assessments (*FM Act*)

Part 7A of the *FM Act* 1994 includes in Section 220ZZ, seven factors which are to be considered when determining if a proposed development action or activity '…*is likely to significantly affect threatened species, populations or ecological communities, or their habitats'.* These seven factors must be taken into account by consent or determining authorities when considering a development proposal or development application. This enables a decision to be made as to whether there is likely to be a significant effect on the species and hence if a Species Impact Statement (SIS) is required.

Table 13-2 found that five fish taxa listed as either threatened or protected under the FM Act had potential to occur within the study area based on the evaluation completed. These were the:

- Black cod
- Southern bluefin tuna
- Great white shark
- Grey nurse shark
- Two members of Syngnathiformes (big belly seahorse and weedy seadragon)

The significance assessments for these species are provided in **Appendix I**.

13.6.1 Conclusion

The Project is not likely to have an adverse effect on threatened or protected species listed under the FM Act and therefore, there is no requirement for an SIS.

The Project as a whole is not considered a KTP. However, in relation to the recognised KTP - *introduction of non-indigenous fish and marine vegetation to the coastal waters of New South Wales*, a potential risk exists for this KTP to occur during Project construction activities. The Project construction phase would require vessels and materials to mobilise from Twofold Bay where a number of IMPs are known to occur. The risk of translocating an IMP via construction vessels is considered a medium risk that can be reduced by implementing environmental management controls as discussed in **Section 15 – Environmental Management.**

13.7 Significance Assessments (BC Act)

Section 7.3 of the BC Act includes five factors which are to be considered when determining if a proposed development or activity '…*is likely to significantly affect threatened species, populations or ecological communities, or their habitats'*. These five factors must be taken into account by consent or determining authorities when considering a development proposal or development application.

From **Table 13-2** it was found that two seal species, and five cetaceans threatened or protected under the *BC Act* had potential to occur within the study area based on the evaluation completed. These were the:

- New Zealand fur seal
- Australian fur seal
- Southern right whale
- Humpback whale
- Orca
- Common dolphin
- Bottlenose dolphin

The test of significance for these species is provided in **Appendix I.**

13.7.1 Conclusion

Based on the current information available for both the diffuser location, dispersion modelling, and the species of significance identified, the Project is not likely to have an adverse effect on threatened or protected species listed under the *BC Act*.

13.8 Significance Assessments (*EPBC Act)*

The *EPBC Act* Significant Impact Guidelines (DEWHA 2013) for threatened species and for endangered ecological communities was reviewed and the proposed Project assessed in relation to –

An action is likely to have a significant impact on a critically endangered, endangered or vulnerable species if there is a real chance or possibility that it would trigger one or more of the following nine impact criteria.

Based on the information provided for FM Act in Section 2.6 and BC Act in Section 2.7, the following findings are made in relation to the Project impact:

Criteria 1) The Project would not lead to a long-term decrease in the size of a population

Criteria 2) The Project would not reduce the area of occupancy of the species

Criteria 3) The Project would not fragment an existing population into two or more populations

Criteria 4) The Project would not adversely affect habitat critical to the survival of a species

Criteria 5) The Project would not disrupt the breeding cycle of a population or of an important population (for vulnerable species)

Criteria 6) The Project would not modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

Criteria 7) Adopting environmental controls as recommended in **Section 15 – Environmental Management**, the Project is not likely to result in invasive species that are harmful to a critically endangered, endangered or vulnerable species becoming established in the species' habitat

Criteria 8) The Project is unlikely to introduce disease that may cause the species to decline

Criteria 9) The Project would not Interfere or interfere substantially (for vulnerable species) with the recovery of the species.

On this basis, it is determined that the Project would not have a significant impact on a matter of national environmental significance (MNES) and a referral under the EPBC Act is not required.

13.9 Key Findings

A total of 33 species listed as threatened or protected under FM Act*,* BC Act and/or the EPBC Act, are considered to have moderate to high likelihood of occurrence within the project area. These include:

- Five cetaceans (whales and dolphins): Humpback whale, Southern right whale, Orca, Common dolphin, and Indo-Pacific bottlenose dolphin.
- Two seals: New Zealand fur seal and Australian fur seal.
- Four fish species: Black cod, Southern Bluefin tuna, Grey nurse shark and Great white shark.
- Two syngnathids: big belly seahorse and weedy seadragon.
- Twenty marine or migratory birds that includes eight EPBC listed species and 14 listed as protected under the BC Act, with two birds listed under both Acts (refer **Table 13-2**)

Based on the findings of the significance assessments, it is concluded that the Project is not likely to have an adverse effect on the threatened or protected species listed under the FM Act, BC Act, or EPBC Act.

The Project as a whole is not considered a KTP. However, in relation to the recognised KTP - *introduction of non-indigenous fish and marine vegetation to the coastal waters of New South Wales*, a potential risk exists for this KTP to occur during Project construction activities. The risk of translocating an IMP during construction phase activities is considered a medium risk. It is expected that construction vessels would adopt standard environmental management practices and controls as recommended by the *National Marine Pest Plan 2018-2023* to mitigate the risk as discussed in **Section 15 – Environmental Management.**