Report to: Arup Australia & Port of Hastings Corporation

Port Facility Feasibility
North Arm Western Port

Marine Ecosystem Existing Conditions
Available Information

May 2023

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Chidgey S and N Goodwin (2023) :“Marine Ecosystem Existing Conditions. Available Information”. Report to Arup and the Port of Hastings Corporation. CEE Pty Ltd, Environmental Scientists and Engineers, Melbourne. May 2023

Port Facility Feasibility
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Marine Ecosystem Existing Conditions

1 Introduction

The Port of Hastings is proposing to construct the Victorian Renewable Energy Terminal (VRET) in Western Port, Victoria (Figure 1). The terminal would be located within the Long Island precinct on the Old Tyabb Reclamation Area between the existing BlueScope Steel Wharf and the Esso Long Island Point Jetty. The VRET is a proposal to develop a facility to serve as a base of operations for the assembly of Offshore Wind (OSW) along the coast of Victoria. In the longer term, the facility could be used to support other typical seaborn trades and export locally manufactured items. The VRET would include landside development, land reclamation, construction of a reinforced quay and dredging to allow for ship access.

Construction activities associated with the development will include clearing and levelling of the existing landside area and constructing shipping wharfage by infilling and dredging within the boundary of the development area. The dredging plan is yet to be decided, however dredged material likely be disposed of into the reclamation, with the remainder potentially disposed offshore to a dredge material ground (if necessary).

The development is consistent with environmental management regulations such as The Environment Protection Act (2017) Environment Reference Standard (2021), which lists “Navigation and Shipping” as an Environmental Value of the Entrances and North Arm Subsegment of the Western Port Segment of Victoria’s surface waters.

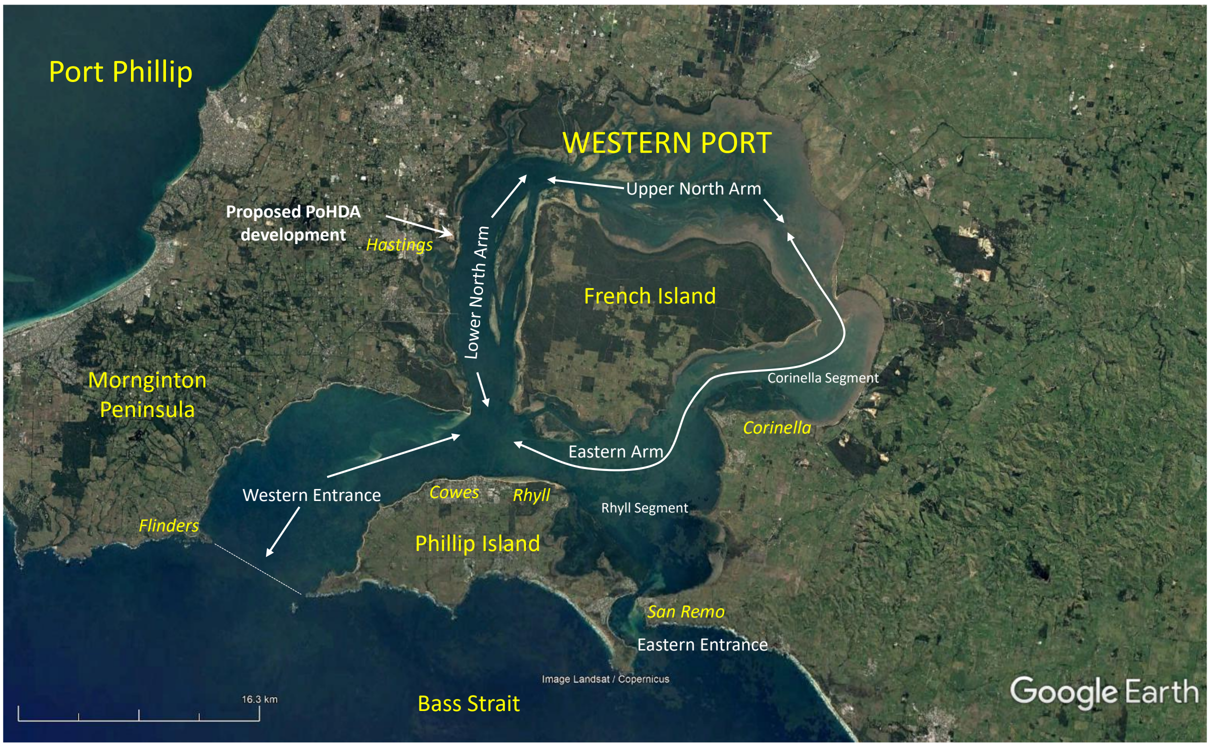


Figure 1. Western Port, Victoria

Figure 2. Port of Hastings proposed development in North Arm Western Port

1.1 Study Area

The site for the proposed Port of Hastings Corporation Renewable Energy Terminal is located on the western shore of Lower North Arm of Western Port, between the existing BlueScope Steel Wharf and the Esso Long Island Point Jetty (Figure 2)

The proposed site is within the Port of Hastings boundary and includes part of the Old Tyabb Reclamation Area. The site extends seaward into the existing declared shipping channels and anchorages which extend from close to the low tide mark to a kilometre offshore from the development area (Figure 3).

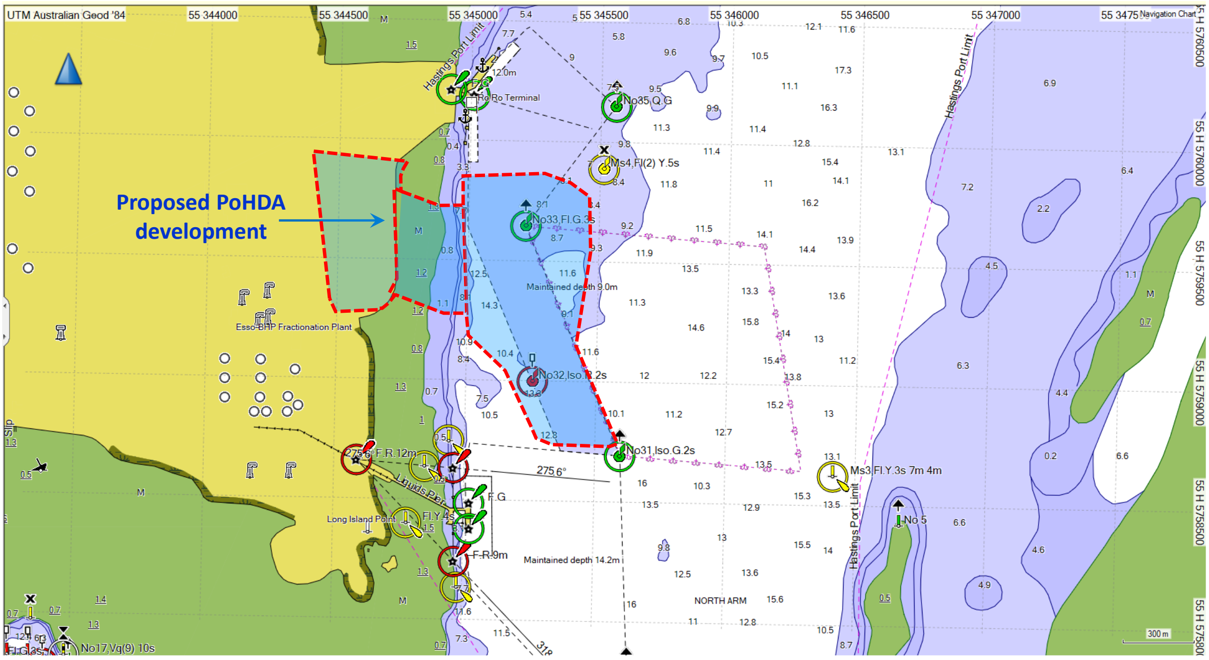


Figure 3. Project area showing existing shipping channels and anchorages

1.2 Scope of Review

This report is a review and summary of existing information that describes the marine ecological values that are relevant to the study area and the North Arm of Western Port. The review was undertaken to provide an initial characterisation of the marine environmental values within and adjacent to the study area and is not intended to be a comprehensive review of the ecological values of the whole of Western Port.

It is considered for the purposes of referral documentation that the intense impact pathways from the project development would be localised within the project area, with a gradient of effect radiating from project area (Royal Haskoning 2022). Preliminary assessment of sediment plumes and changes to hydrodynamics from the project development has confirmed that sediment plumes will be the dominant process for defining the extent of the zone of influence for the project (Royal Haskoning 2022). On this basis, marine ecosystem values beyond the Lower North Arm have been considered unlikely to be affected by impact pathways from the proposed development unless impacts on marine ecosystem values are predicted to be severe beyond the project area. Therefore, for the purposes of referral documentation, this report focusses on existing marine ecosystem conditions below mean sea level in the Lower North Arm of Western Port.

2 Marine Ecosystem

Western Port has an area of approximately 680 km², with approximately 270 km² of intertidal mudflats (Blake and Ball 2001). The marine ecosystem of Western Port is recognised as rich and diverse with a variety of marine habitats and biological assemblages that is shaped by the unusual combinations of physico-chemical factors, bathymetry It is a world heritage area, Ramsar listed wetland and contains three Marine National Parks (Figure 4).

2.1 Marine ecosystem values

The marine ecosystem components of Western Port have been described and discussed in varying detail in a large volume of scientific publications, research and government agency reports and project technical reports.

The Westernport Bay Environmental Study (Ministry for Conservation 1975) developed a baywide management overview for the bay based an integrated understanding of marine environmental conditions documented in coordinated specialist studies. The Study report presented initial outcomes from the various specialist studies to inform conclusions and recommendations.

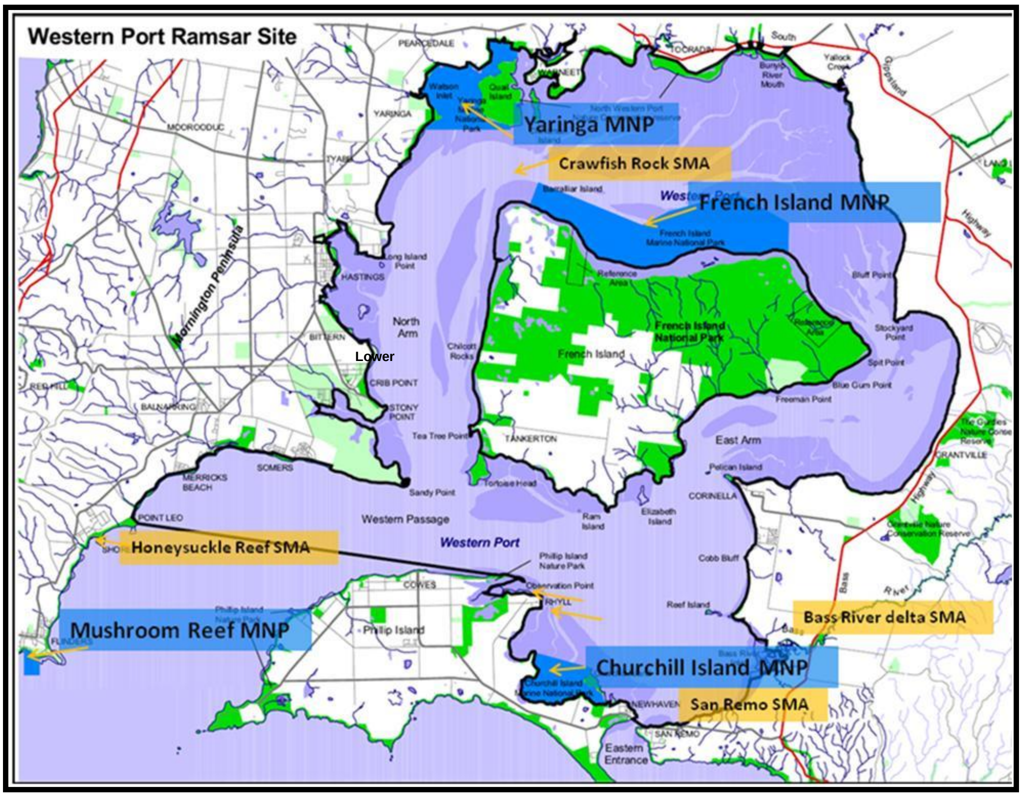


Figure 4. Western Port Ramsar Wetland and Marine National Parks (MNP)
Marine National Parks are blue areas. Special Management Areas are orange areas
National Parks are green areas. Ramsar area bordered in black.
(Source: "Western Port Ramsar site. Strategic management plan." DSE 2003)

Scientists working in northern Western Port in the late 1970s characterised the physical environment segments of Western Port (Figure 5, Marsden et al 1979), and raised concern that vast areas of seagrasses on the intertidal mudflats in the north of Western Port were observed to be declining in seabed cover and health. This initiated a series of mapping and experimental investigations and technical reports on seagrass distribution and characteristics by agency marine biologists (principally Dr D Bulthuis and colleagues at the State marine science laboratories Queenscliff). The present understanding of seagrass distribution in Western Port is discussed further in Section 3.

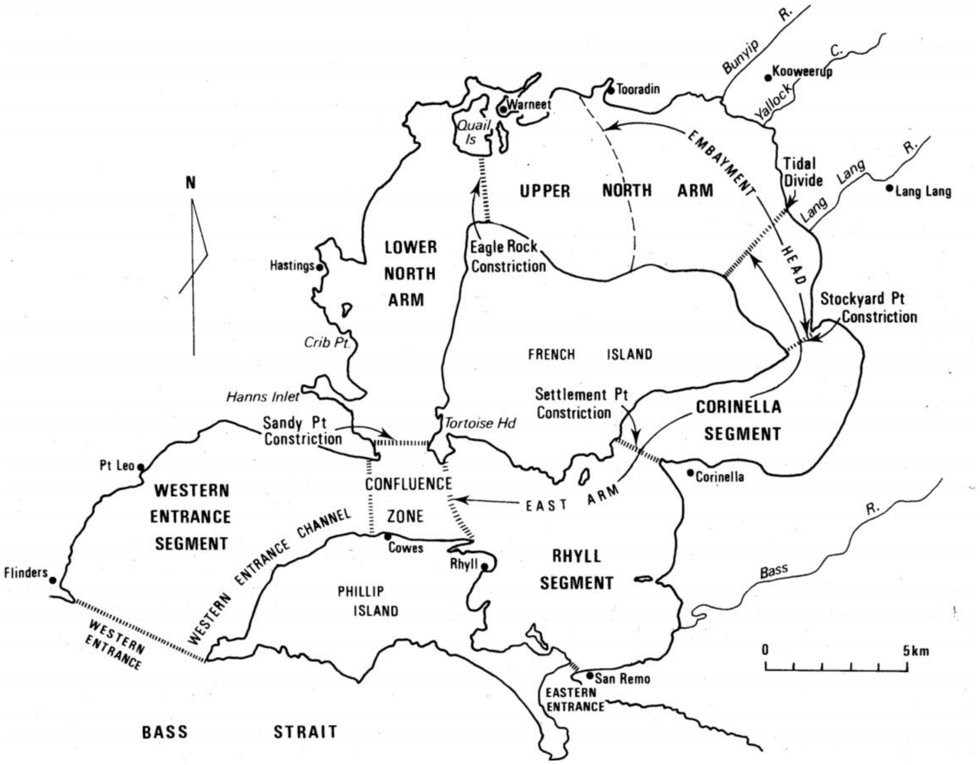


Figure 5. Physical environmental segments of Western Port
(Marsden et al 1979)

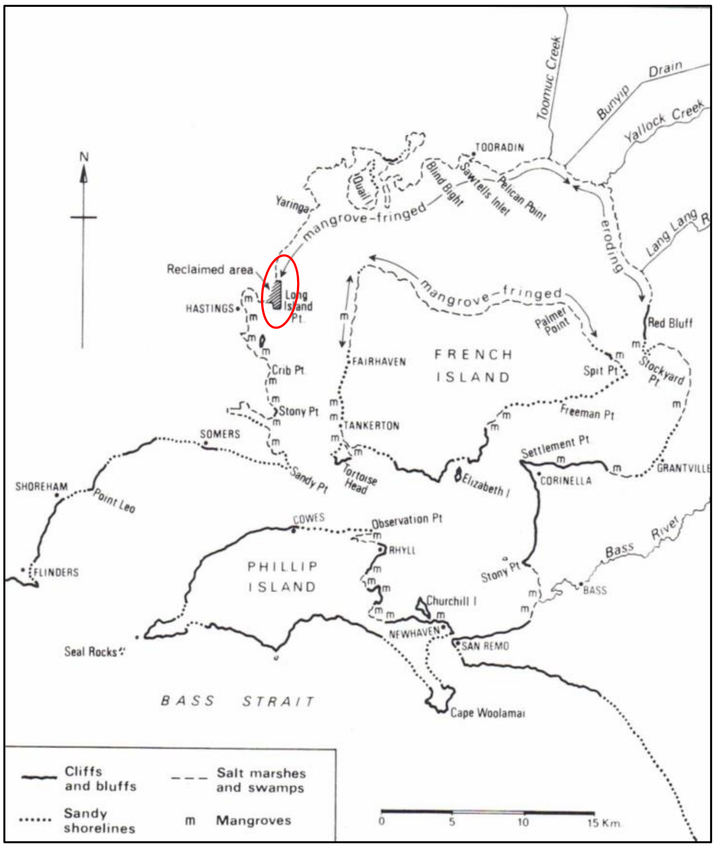


Figure 6. Interpreted original shoreline features of Western Port
(Bird 1993)

The original coastline of Western Port was interpreted over the 1960s to 1980s from early maps, charts and aerial photographs (Bird 1993). Figure 6 shows the distribution of mangroves and saltmarsh along the shoreline, areas of erosion shoreline and the area of coast infilled at Long Island Point in the 1960s. The distribution of coastal saltmarsh and mangroves along the entire Victorian coast, including Western Port, was subsequently mapped from aerial imagery and ground-based survey in 2010 (Boon et al 2011).

Potential development options for the infill area between Long Island Point and BlueScope the Port of Hastings and Port of Hastings Development Authority between 2008 and 2014 included a range of reviews of existing information, investigations and modelling. Marine ecosystem information was reviewed, and seagrass investigations were initiated (Chidgey et al 2009, Chidgey and Crocket 2014, Chidgey et al 2014).

Existing information on the Western Port marine environment for Melbourne Water was comprehensively reviewed by a team of expert scientists led by Head Scientist Prof M J Keough through the Victorian Centre for Aquatic Pollution Identification and Management (CAPIM) for nine Victorian government agencies led by Melbourne Water and the Department of Sustainability and Environment in 2011. The review was presented in “Understanding the Western Port Environment. A summary of current knowledge and priorities for future research.” (Melbourne Water 2011). Outcomes of the recommended research over the period 2011 to 2017 were published subsequently in 2018 (Melbourne Water 2018). Various agency, research and project development investigation programs have added individually to marine ecosystem information in Western Port since the 2011 review and 2018 research report.

This report draws on a range of available information from a variety of these sources to provide a description of existing marine ecosystem values in the proposed development area of Lower North Arm in the broader context of Western Port to inform approvals referral processes for the proposed development.

2.2 Marine habitats and communities

The marine habitats of the ecosystem in the north and east of the Bay have been mapped from available information by the Department of Energy Environment and Climate Action (DEECA) and is compiled onto the publicly accessible CoastKit coastal biodiversity decision-support tool for Victoria (Figure 7 and Figure 8). The data are available also on the national SeaMap Australia platform (https://seamapaustralia.org/). Figure 8 shows the proposed development area together with the CoastKit biotopes, bathymetry and hypsometric topographic shading.

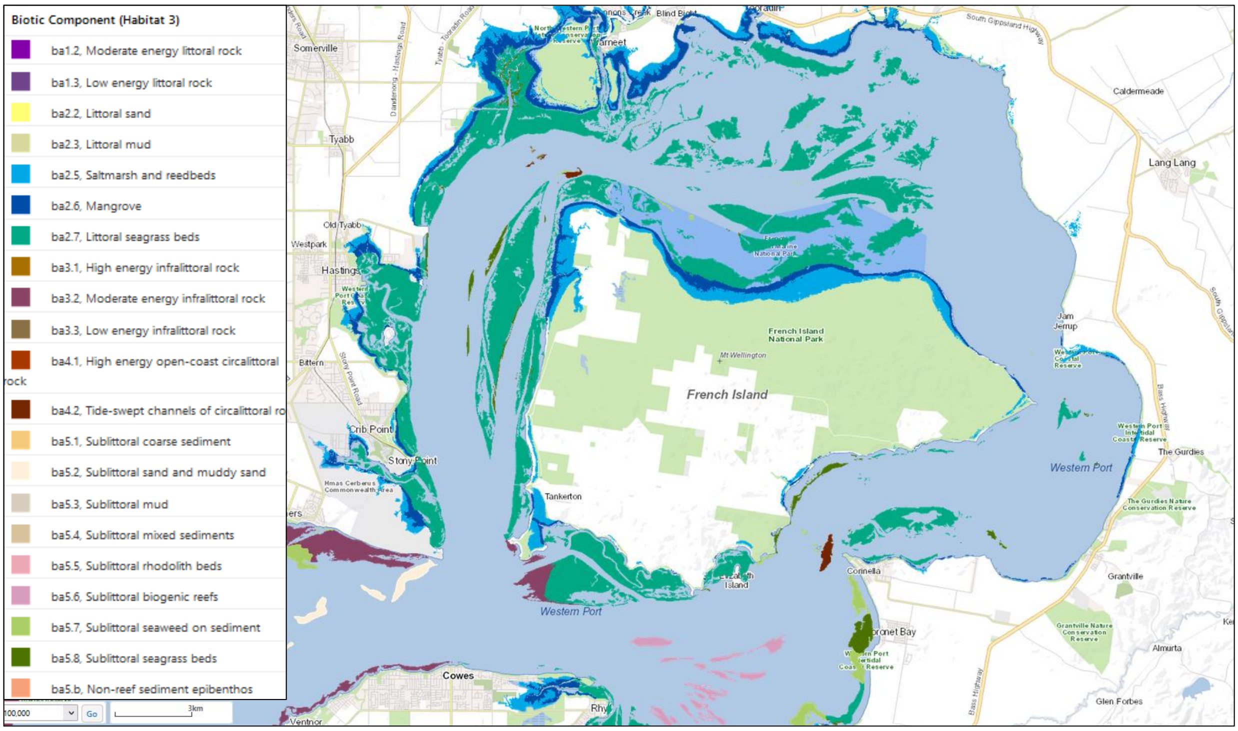


Figure 7. Marine habitats in northern Western Port (CoastKit Victoria, DELWP) https://mapshare.vic.gov.au/coastkit

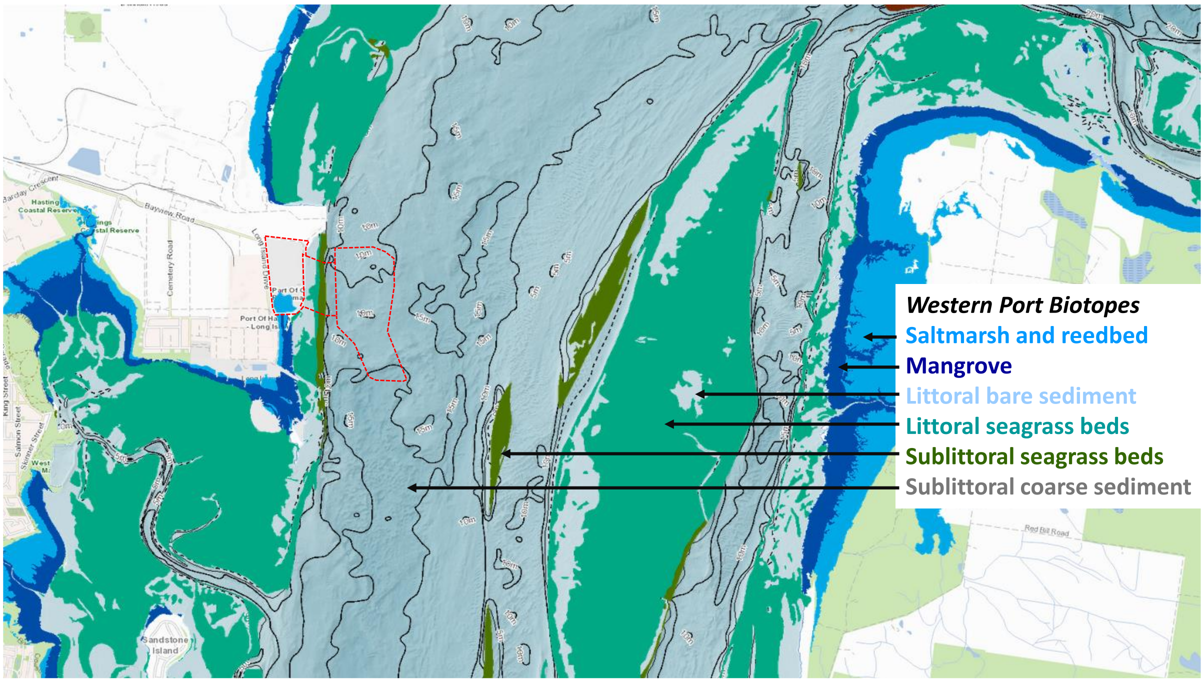


Figure 8. Marine biotopes in upper North Arm

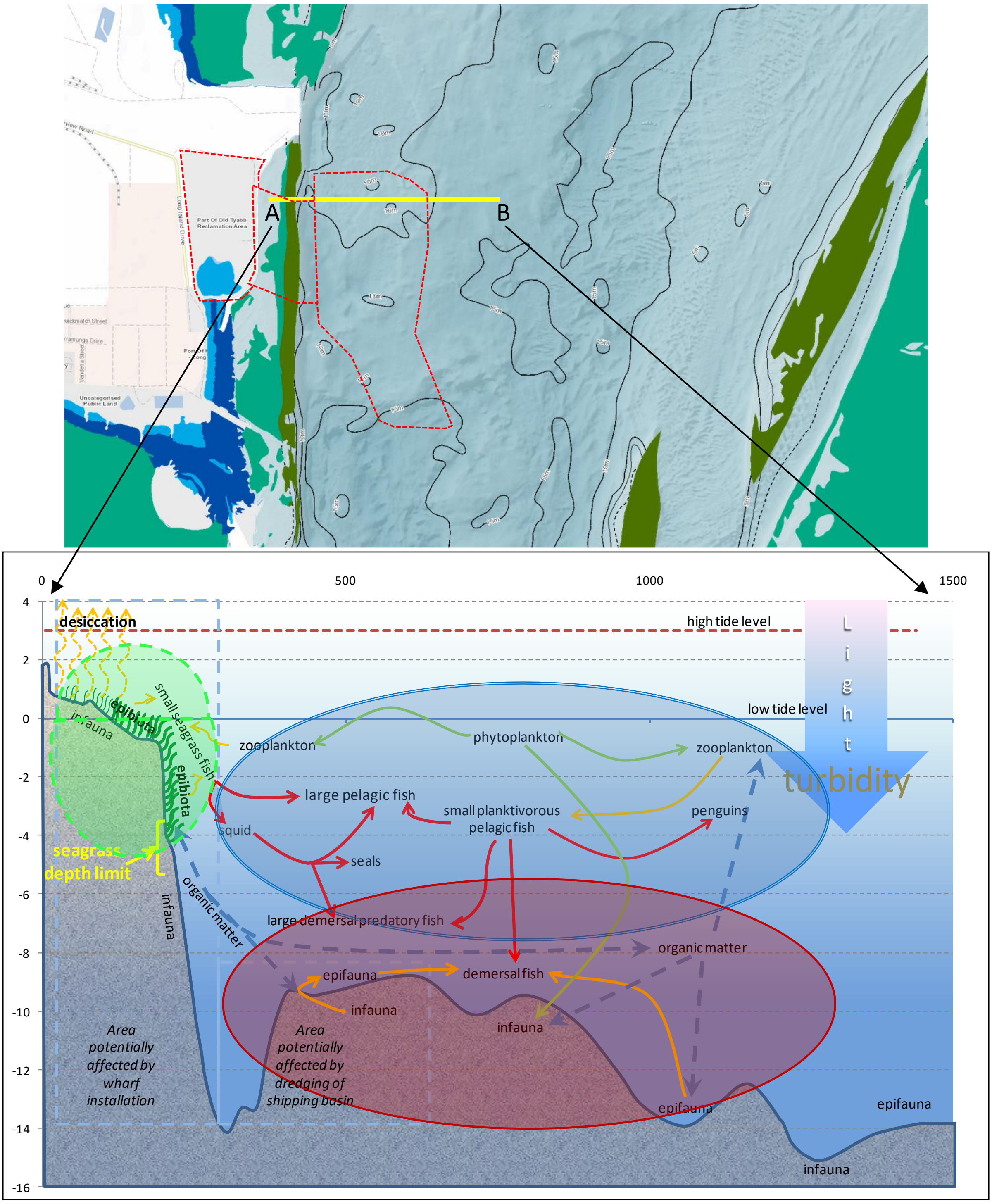


Figure 9. Conceptual profile of seabed in study area

Lower figure shows profile of 1.500 km Section AB from plan view of project area shown above

A conceptual profile of marine ecological characteristics of the intertidal and channel profile in this area was developed in earlier studies of the area (Figure 9, Chidgey et al 2009). The profile ecological characteristics are typical of North Arm.

The profile section in Figure 9 shows:

- A band of seagrass habitat extending across the lower, gently sloping intertidal area to around the low tide mark where the slope steepens into the channel.
- Seagrass extending down the steeply sloping channel bank to its depth limit. In North Arm of Western Port (Chidgey et al 2014), this point may be:
    - The seagrass light limit or compensation point, where average seagrass production by photosynthesis equals the average respiration breakdown of the organic material by the seagrass. or
    - A depth where the seabed slope is scoured or too steep and unstable for seagrass to grow.
- The seabed below the seagrass depth limit, comprises unconsolidated sediments of various coarseness and shell content. It is usually bare apart from some areas of the green alga *Caulerpa cactoides*, which may be found slightly deeper than the seagrass light limit, or tufts of red algae attached to shell or rubble in the unconsolidated sediments.

- The seabed beyond the slope is characterised by a patchwork of sediment size and bedforms. While the general perception of the North Arm channel is relatively uniform fine to medium sediments with areas of sand waves, towed underwater camera surveys (Chidgey et al 2019 b) and the hypsometric representation of high-definition sonar records in CoastKit (Figure 8) shows that the sediment forms of the North Arm channel bed seabed are quite diverse.

The conceptual profile of the study area and the broader marine environment in the Lower North Arm comprise:

- Intertidal saltmarsh and mangroves;
- Intertidal and subtidal seagrass habitat;
- Intertidal bare sediment habitat;
- Subtidal slope and channel seabed sediment habitat;
- Water column planktonic community, and;
- Fish communities associated with seabed and water column

These communities and habitats are discussed further in the following sections of this report except for waterbirds and seabirds which are addressed by other specialist in separate documents.

3 Seagrasses

Seagrass meadows are a critical habitat for a broad range of aquatic life within Western Port and play a vital role in coastal and estuarine ecosystem functions (Melbourne Water 2018). Seagrasses on mudflats, sandspits and on the banks of channel provide habitat for marine biota in an area that would otherwise offer little refuge for small fish and invertebrates, or permanent attachment for small marine algae, invertebrates and microscopic plants.

Seagrasses in Western Port have been the focus of many studies in the past, including spatial mapping (NSR 1974; Bulthuis 1981; Bulthuis 1981; Bulthuis 1984; Stephens 1997; Ball and Blake 2001; Ball et al. 2010,) and biomass and production studies ((NSR 1974), (Bulthuis 1981; Bulthuis 1983; Bulthuis and Woelkerling 1983; Bulthuis et al 1984, Campbell and Miller 2002; Walker 2003)). Most of these studies were limited to intertidal areas (0 to -1.8 m below MSL).

The seagrasses in Western Port create complex habitat for a wide variety of epibiota such as the invertebrates that live on or among their leaves and infauna that live within the sediments bound by the roots of the seagrasses (Edgar and Shaw 1995, Watson *et al* 1984). These invertebrates are food for small fish species and the juveniles of larger fish, which are the prey of a range of larger fish (Edgar and Shaw 1995, Hindell *et al* 2000, Robertson 1978, Smith 2009).

Four species of seagrass may be found in Western Port:

- *Amphibolis antarctica* usually grows in dense patches or meadows on sandy rock rubble in wave exposed areas.
- *Zostera muelleri,* commonly grows on muddy to sandy seabed in lower intertidal areas in low to moderate wave exposure;
- *Heterozostera nigricaulis* usually grows subtidally in dense to sparse meadows in relatively sheltered, muddy to sandy areas from the low tide mark to around 5 m depth, depending on water clarity. *H. nigricaulis* is listed on the Flora and Fauna Guarantee Act Threatened species list;
- *Halophila australis* grows subtidally in sparse meadows in relatively sheltered, muddy to sandy areas from the low tide mark to around 5 m depth among sparse *Z nigricaulis* beds or below the lower depth limit of *Z nigricaulis*.

A fifth species *Heterozostera tasmanica* (which is also a is listed on the Flora and Fauna Guarantee Act listed Threatened species) is common in suitable environments in the open waters of Bass Strait but is unlikely to occur in North Arm and Corinella Segments of Western Port.

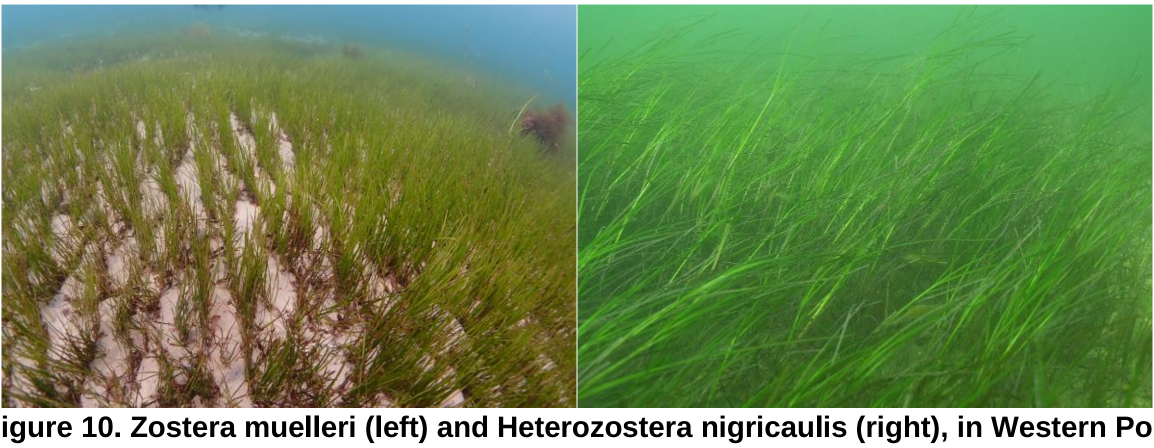


Figure 10. Zostera muelleri (left) and Heterozostera nigricaulis (right), in Western Port

Of the species mentioned, *Z. muelleri* is most likely be present intertidally and *H. nigricaulis* is most likely to be present subtidally within the study area (Figure 10). Patchy areas of *H. australis* may also be present subtidally as a mixed assemblage with *H. nigricaulis.*

The seagrasses in Western Port occupy a defined depth range determined by exposure to air, wave action, light intensity, seabed slope and seabed composition. It should be possible to map the extent of seagrass if these physical factors and the seagrass requirements are defined. The spatial extent of seagrass has been mapped from aerial imagery and ground-truthing surveys in 1973/74, 1984, 1995 and 1999, and most recently 2019.

The most recent mapping undertaken by Deakin University used 2019 Copernicus Sentinel-2 satellite image analysis, ground-truthing surveys (147 points) and previous mapping to model seagrass extent in Westernport as shown in Figure 11 (Dalby et al 2022). The difficulty in differentiating the three dominant species of seagrass and macroalgae from remote imaging was recognised, and the species were not differentiated for the purposes of this mapping exercise.

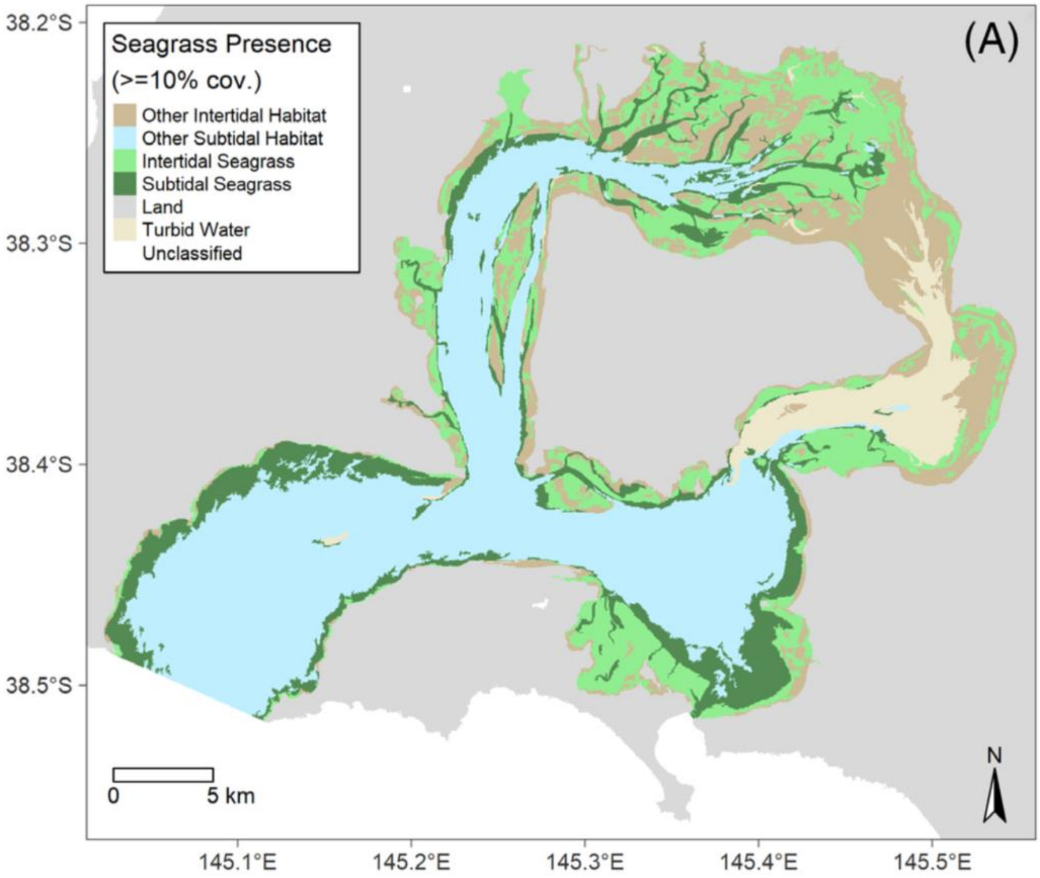


Figure 11. Seagrass extent in Western Port 2019
(Dalby et al 2022)

Extensive seagrass losses in of the late 1970s and early 1980s in northern Western Port were due to the loss of a single species, *Heterozostera nigricaulis.* The losses to this species only occurred where it inhabited intertidal mudflats. Subtidal meadows of the same species survived. This is inconsistent with turbidity and reduced light being the cause of the losses (Bulthuis 1984, Bulthuis et al 1984). It seems that previous assessments did not emphasise that this normally subtidal species was occupying a marginal intertidal habitat on the mudflats in northern Western Port. It is likely that the losses of *Heterozostera nigricaulis* (known as *Heterozostera tasmanica* at the time) were exposure to air (Bulthuis et al 1984) and heat at low spring tides during a period of extreme heat in the late 1970s.

Table 1 Summary of *Heterozostera nigricaulis* lower depth limit data

Segment	Sites	Depth limits (metres below MSL)			Median light attenuation Jan 2014 (K_d, m^{-1})
		Max	Min	Median	
Upper North Arm	11	-4.7	-1.7	-2.8	0.35
Lower North Arm	36	-7.5	-1.3	-4.7	0.36
Confluence Zone	4	-4.0	-1.6	-2.3	0.27
Rhyll	3	-2.9	-1.0	-1.3	0.37
Corinella	5	-2.9	-1.0	-1.3	0.34

Some of the recovery of seagrass on the northern mudflats in 1995 was noted to be *Heterozostera tasmanica*, while other areas were the intertidal species *Z muelleri*. Mapping subsequent to 1995 has not differentiated the species of seagrass involved in the recovery. These two species usually have different habitat requirements.

During studies for the Port of Hastings Development Authority in 2014, the maximum depths limits for *H. nigricaulis* were generally found on the west side of Lower North Arm, *including* the area immediately north of the Port of Hastings (Table 1, Chidgey et al 2014).

H *nigricaulis* grew in patches or depth bands of dense meadows. The density decreased at the deepest extents and was mixed with another seagrass (*Halophila*) and macroalgae (*Caulerpa*) (Figure 12, Chidgey et al 2014). The deepest depths of H *nigricaulis* presence (6 m to 7 m) corresponded with a light availability of approximately 5-10 per cent of surface light, whereas the deepest depth of the dense meadows (5 m) corresponded with approximately 12 per cent of surface light.

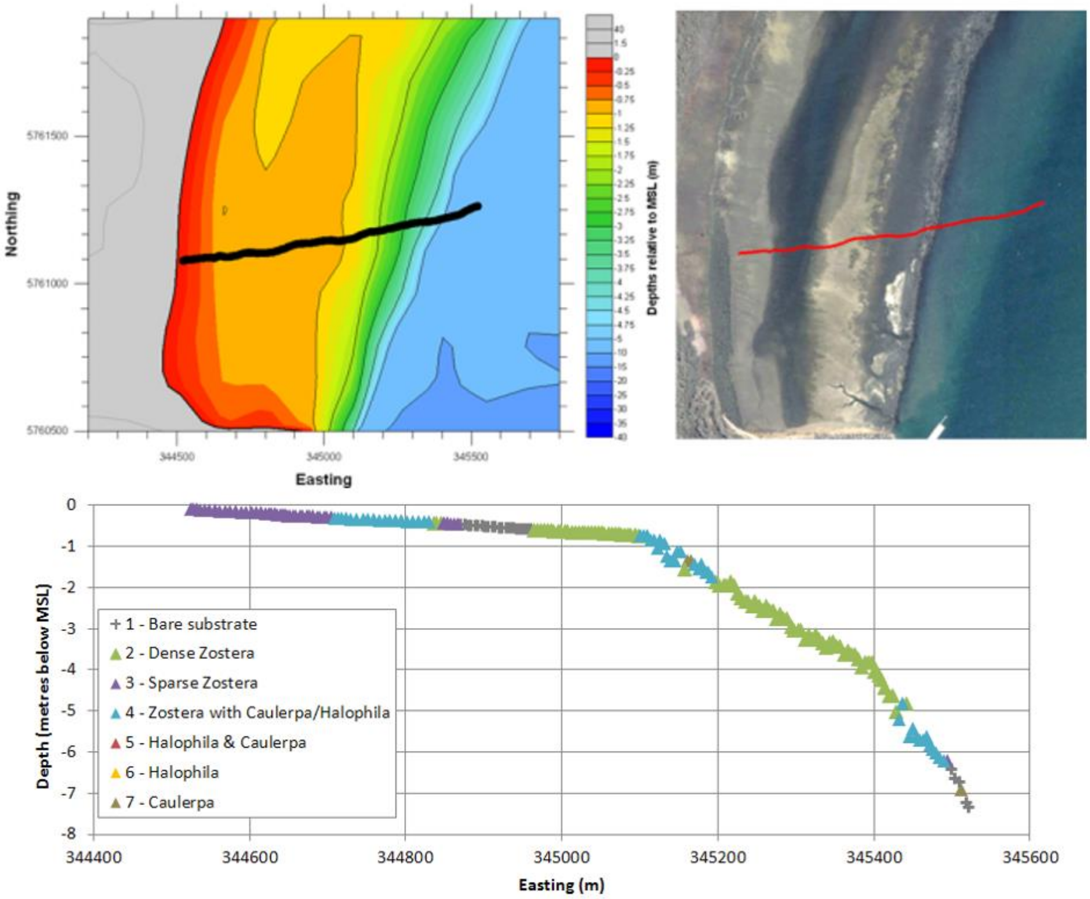


Figure 12 : Seagrass profile, gentle slope just north of Bluescope, January 2014

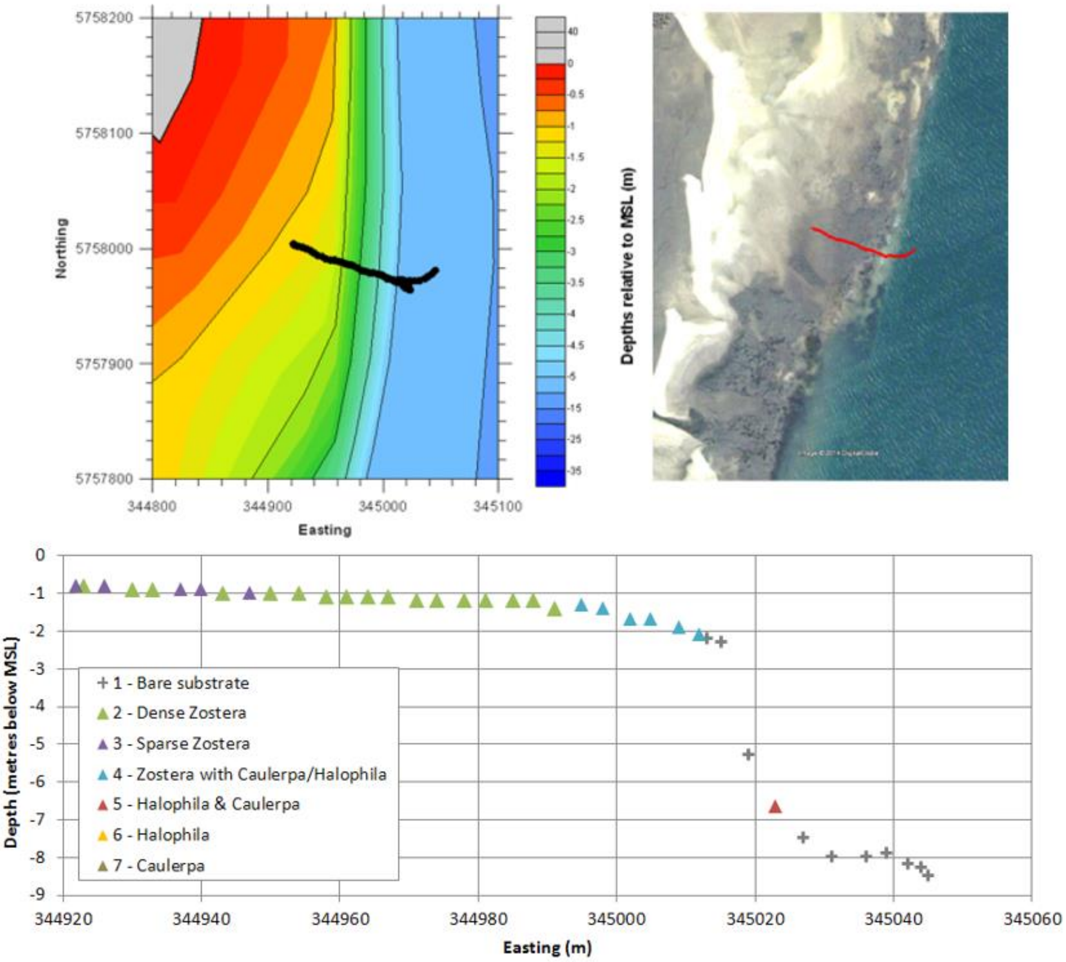


Figure 13 Seagrass profile undercut, steep slope at Long Island Point, January 2014

It was interpreted that light availability at the deeper sites was close to that which is limiting for *H. nigricaulis* in Western Port. At most sites however, light did not appear to be limiting to *H. nigricaulis* at its lower depth limit and seabed condition appeared to be the limiting factor.

Sites where *H. nigricaulis* reached its greatest depths were those with gently sloping seabed (< 4 % gradient) shown in Figure 13 (Chidgey et al 2014). At many sites with relatively shallow *H. nigricaulis* limits, the gradient of the seabed below the seagrass was steeper than 10% and the lower boundary of the continuous dense *Heterozostera* seagrass bed was marked by a clear, undercut edge (Figure 13). Other physical factors not documented in these investigations are also likely to be influential to the distribution of subtidal *H. nigricaulis* in Western Port such as current speeds, aspect and wave exposure.

4 Benthic Fauna

Most of Western Port's 270 km² of intertidal and 410 km² of subtidal habitats comprise unconsolidated sediments. Only small areas of rock reef were generally known in Western Port, such as Crawfish Rock and Eagle Rock off northwest French Island, rocky outcrops in the Western Entrance and around San Remo and Newhaven in the eastern entrance.

The physical features of the subtidal habitats in Western Port were known through studies on seabed composition from collection of grab samples around the bay (Marsden et al 1979, Coleman et al 1978), bathymetry (Aust. Hydrographic Office, DEECA CoastKit) and hydrodynamics (Harris et al 1979, Hinwood and Jones 1979, EPA 2011).

As discussed previously, DELWP compiled LiDAR and multibeam-derived high-definition bathymetry of Western Port that provides detail of the on the seabed topography not previously available (Figure 14). The hypsometric shading on CoastKit (Figure 8), indicates that the sediment seabed of Lower North Arm is more topographically complex than previous bathymetry and available information indicated. Seabed composition and topography are fundamental determinants of ecological community characteristics.

This section shows that the analysis of high-definition bathymetry of Western Port and use of towed under water cameras and ROVs in the past ten years have provided a greater insight into the diversity of the extensive subtidal soft seabed habitat (Figure 15) and associated ecological communities in Western Port.

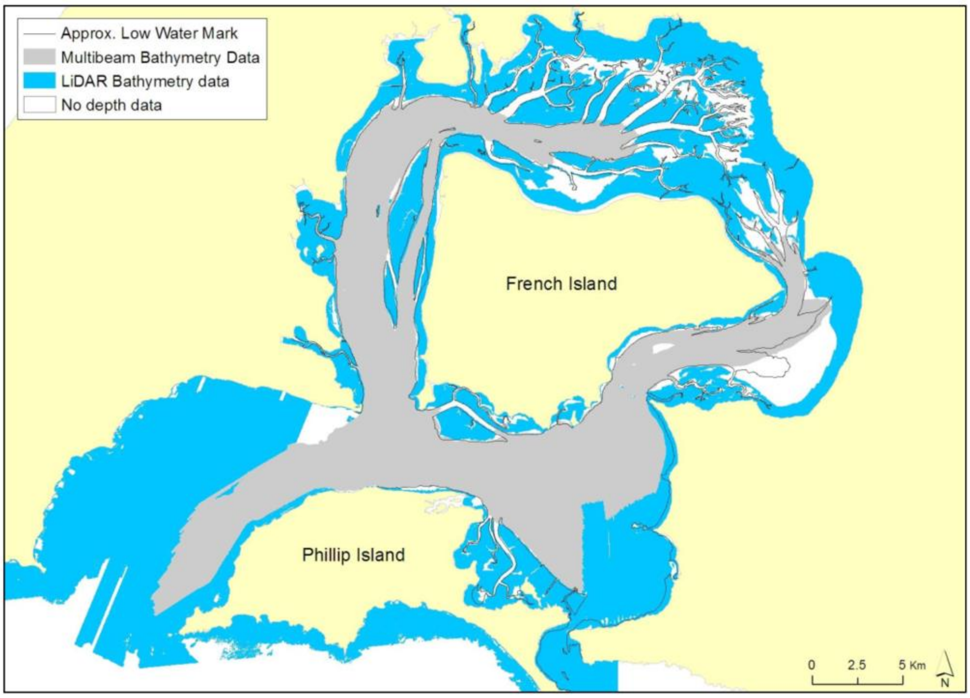


Figure 14. Extent of DWELP LiDAR and multibeam bathymetric data for Western Port (Blake et al 2013)

Figure 15. Examples of seabed character in Lower North Arm, Western Port
(Chidgey et al 2019b)

4.1 Epifauna

Epifauna are the animals that grow on or attached to the surface of the seabed. The characteristics and distribution of invertebrate biota are strongly influenced by seabed character, such as reefs, areas of rubble, banks and channels. The distribution of seabed character can be determined from a variety of methods including aerial photography, detailed bathymetry (multibeam), side scan and direct or indirect observation.

Epibiota were monitored in the shipping basin at the then BHP-Lysaght wharf (now BlueScope) from 1972 to 1981 by Dr Jan Watson and colleagues Marine Science and Ecology (MSE 1990, 2009). The epibiota present on the seabed of the study area during the program was sparse, comprising small red algae, small sponges, ascidians *Pyura stolonifera* and *Stolonica australis,* the small seapen *Sarcophyllum* sp., some erect tube dwelling polychaetes, brachiopods *Magellania flavescens* and several species of hydroids.

MSE considered that these species generally require firm substrate and grow attached to subfossil oyster shells embedded in the sediments. *Pyura stolonifera* is an opportunistic and locally widely distributed species. Colonies of this sea squirt had established within three months of completion of dredging in the swinging basin. *Sarcophyllum* was often very abundant in the North Arm and also colonised the swinging basin in large numbers after dredging, but populations gradually declined over the years. *Magellania flavescens* is a deep-water brachiopod was widespread but patchily abundant in Western Port.

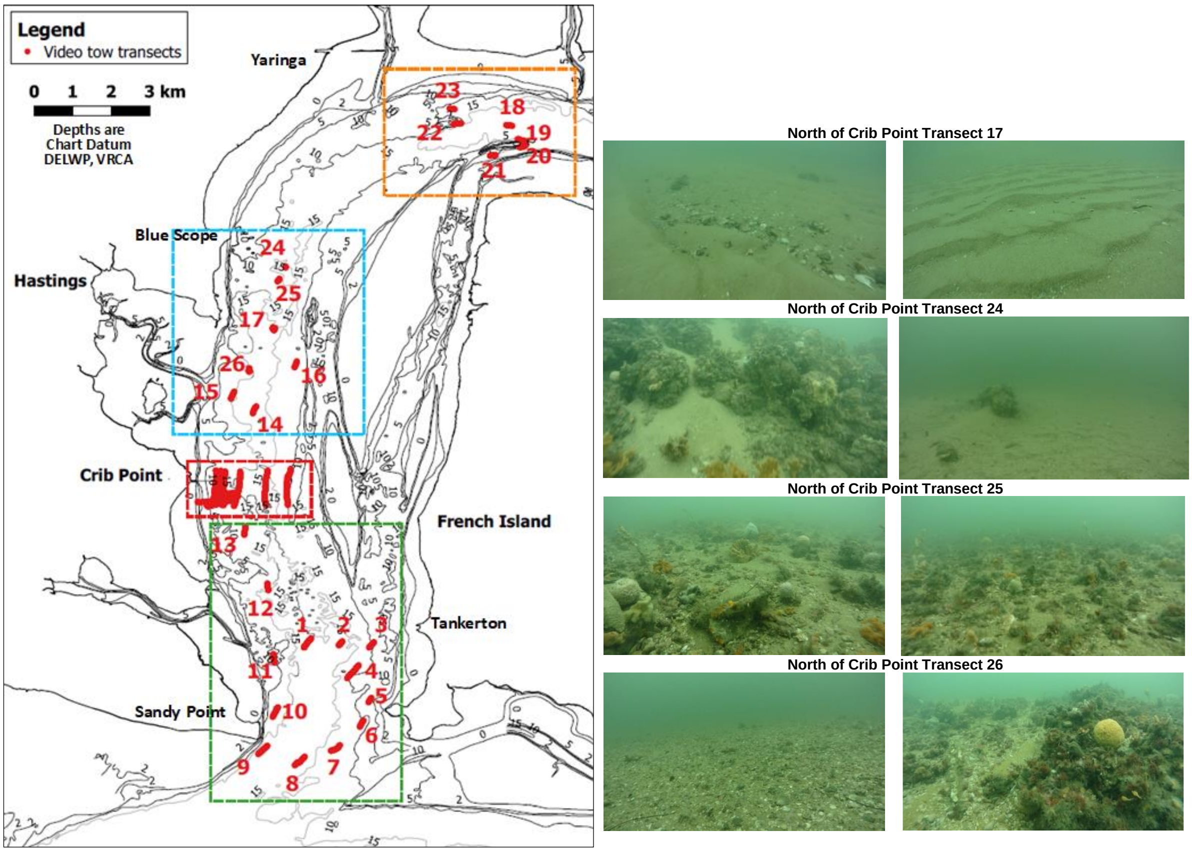
Underwater visibility progressively declined over the monitoring program and the program was discontinued after 9 years due to the difficulty of seeing and distinguishing seabed biota due to high suspended solids, low light and poor under water visibility.

The epibiota of pier piles at Crib Point, Long Island Point and BlueScope have been periodically monitored for Esso from 2010 to 2021 (Bok et al 2017, Chidgey and Northey 2022, Hall and Chidgey 2013).

The epifauna of the subtidal channels of Lower North Arm are characterised by sparsely distributed sessile and mobile invertebrates, and patches of seabed where invertebrate species are concentrated in high numbers or species-diverse ‘clumps’ that may be classified as biogenic reefs (Edmunds and Flynn 2018, Flynn et al 2018, Harvey and Bird 2008).

Epibiota include a wide range of sponges, bryozoans, hydroids, ascidians, crustaceans and echinoderms (Chidgey et al 2009). There are a number of notable sessile epibenthic invertebrate species including the brachiopod *Magellania flavescens*, the ‘living fossil’ bivalve *Neotrigonia margaritacea*, tube-forming polychaete worm *Eunice* sp., sea-pen *Sarcoptilus grandis*, ascidian *Pyura dalbyi* and bryozoans *Celleporaria* and *Tryphyllozoan*. Mobile species include the sea urchins *Goniocidaris tubaria* and *Heliocidaris erythrogramma* and the seastars *Nectria ocellata, Tosia magnifica* and *Meridiastra gunnii* and the spider grab *Leptomithrax gaimardii*.

Images from benthic transects T17, T24 and T25 recorded from video tows offshore from the proposed VRET in the lower North Arm during 2019 (Chidgey et al 2019b) are shown in Figure 16, with corresponding quantitative data of key taxa shown in Table 2.



North of Crib Point Transect 17

North of Crib Point Transect 24

North of Crib Point Transect 25

North of Crib Point Transect 26

Figure 16. Towed underwater camera transects in Lower North Arm 2019
(CEE 2020b)

Table 2. Key benthic taxa from underwater camera tows in Lower North Arm 2019

(Transects from Figure 16)

Towed video Transect	Brown Algae	Red Algae	Green Algae	Seagrass	Sponges	Cnidaria	*S. grandis*	*Eunice sp.*	*M. asperimma*	*M. flavescens*	*Bryozoans*	*Celleporaria spp.*	*Echinoderms*	*G. tubaria*	Ascidians	*P. dalbyi*
Crib Point																
01	1	35	1	14	41	10	0	1	6	24	4	4	7	6	5	1
02	0	40	0	0	44	4	0	0	13	46	13	13	27	21	4	0
03	0	19	0	0	27	18	2	0	4	38	5	3	23	23	0	0
04	0	3	0	0	7	2	0	2	2	5	2	2	3	3	5	0
05	0	45	0	0	29	6	0	9	12	76	3	2	11	10	9	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	16	0	0	14	2	0	30	1	4	1	1	5	5	9	7
08	0	22	0	0	28	10	0	0	9	35	13	12	12	9	7	2
09	0	9	0	0	24	7	0	2	5	3	2	2	17	16	12	10
South of Crib Point																
01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	0	50	0	0	50	31	0	63	0	13	31	13	38	13	38	31
03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	0	94	0	0	59	6	0	9	3	31	59	31	22	13	50	38
05	9	100	0	0	55	9	0	0	0	0	0	0	18	18	9	0
06	0	44	0	0	89	0	0	17	0	0	11	11	50	0	94	94
07	0	67	0	0	57	0	0	81	0	0	67	48	14	0	67	62
08	0	6	0	0	88	0	0	100	0	0	38	31	25	13	44	44
09	0	13	0	0	94	0	0	50	0	0	19	19	6	0	81	81
10	0	30	4	0	96	4	0	57	0	0	26	26	70	17	30	30
11	0	100	0	0	96	0	0	43	4	4	26	26	39	4	13	4
12	0	82	0	0	41	0	0	53	0	35	0	0	0	0	41	35
13	0	53	0	0	42	0	0	32	5	32	5	5	21	16	11	5
North of Crib Point																
14	0	0	0	0	11	0	0	94	0	0	6	6	0	0	0	0
15	0	0	0	0	19	0	0	50	6	6	0	0	0	0	0	0
16	0	86	0	0	93	0	0	36	0	0	0	0	21	21	57	57
17	0	5	0	0	24	0	0	10	0	0	5	5	24	19	0	0
24	0	43	0	0	71	0	0	0	0	14	14	14	14	14	57	43
25	0	39	0	0	100	17	0	61	0	0	11	6	44	44	56	56
26	0	75	0	0	69	0	0	56	6	50	31	25	75	75	31	25
Crawfish and Eagle Rocks																
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	14	45	17	0	79	3	0	0	0	0	31	3	24	0	14	0
20	26	63	11	0	95	32	0	0	0	0	63	0	0	0	42	0
21	0	0	0	0	21	0	0	0	0	0	0	0	7	0	0	0
22	0	38	0	0	84	16	0	0	0	3	50	28	28	16	44	19
23	0	57	0	0	43	0	0	14	0	0	7	7	7	7	36	36
All	1	31	1	1	39	6	0	16	4	19	12	8	16	11	17	12

4.2 Subtidal Infauna

Infauna are the burrowing invertebrates found in the sediments below the surface of the seabed. They comprise a wide array of species and abundances that vary between locations depending on ambient environmental conditions. Typical infauna groups found at most coastal environments include burrowing worms, shrimps, crabs, brittle stars, clams, snails, urchins and burrowing species of other groups including fish.

Infauna across Western Port were sampled comprehensively during the 1973/74 Ministry for Conservation Western Port Bay study. The intertidal and subtidal infauna communities were found to be species rich and abundant (Coleman et al 1978). The fauna was dominated by polychaete worms (the most numerous group), various crustaceans (the most species rich group) and molluscs (clams and snails).

The 1973/74 sampling process recognised a range of physical factors that might influence infauna community structure and divided the Bay into eleven different strata of which the subtidal channel of North Arm was one entire stratum. The spatially comprehensive sampling program found that the most abundant species were widely spread. The errant polychaete worm *Nepthys australiensis* was the second most common species collected and was distributed over 85 per cent of all stations sampled.

Affinity analysis of the infaunal data from the combined eleven different sampling strata divided the infaunal community into two general groups based on sediment particle size. These were a clean medium sand assemblage – with average mean grain size of medium sand and a mud content <10 per cent, and a fine sand and mud assemblage – with mud contents greater than 20 per cent. These two groups appear to be correlated with depth: the first group being found in predominantly deeper channels and the second, muddier group, being found along the margins of the Bay including the intertidal habitat.

- The clean medium sand assemblage was characterised by polychaete species *Scoloplos*, *Rhodine*, *Travisa*, clams *Neotrigonia margaritacea*, *Notocallista diemensis*, *Solen vaginoides* and *Venericardia bimaculata*, and crustaceans *Halicarcinus rostratus, Ampelisca, Cheiriphotis megachelis, Leptanthura diemensis* and *Paranchialina angusta*.

- The fine sand and mud assemblage is characterised by the polychaete worms *Amaeana* and *Mediomastus* and bivalve molluscs *Tellina* and *Katelysia*.

Species diversity was marginally higher in the clean medium sand assemblage, although the difference was not statistically significant. In all strata, the order of taxonomic group abundance was polychaetes>crustaceans>molluscs, except for stratum 1 (North Arm channel) and stratum 6. Crustaceans were more numerous than polychaetes in North Arm channel.

Infauna communities were also monitored near the steel wharf north of Long Island Point (BlueScope) by Marine Science and Ecology from 1972 to 1989 (MSE 1990, MSE 2009). Results of the program from showed the mean population density of infauna over the period was 4,260 organisms m^{-2} in the swinging basin and 2,301 organisms m^{-2} in the channel. The species composition over the monitoring period was estimated at approximately 100 species/m^2 in the swinging basin and 75 species/m^2 in the channel. Polychaetes and crustaceans comprised 40% and 45 % respectively of the populations over the monitoring period. Molluscs comprised 10% and other groups approximately 5% of the populations. Dominant crustaceans were amphipods and ostracods.

Although molluscs comprised a smaller percentage of the populations, several scientifically interesting large bivalve species, namely *Neotrigonia margaritacea*, *Notocallista diemenensis* and *Sigapatella calyptraeformis* were dominant. Populations of these bivalves declined markedly with increasing water turbidity and deposition of fines on the bed during the period of intertidal seagrass decline in the 1980s.

The higher populations and greater number of species recorded in the swinging basin over later stage of the monitoring period compared with the channel system are thought to be due to colonisation of new substrate by opportunistic local species. In contrast, the infauna of the adjacent channel remained relatively stable over the monitoring period. The change in the swing basin infauna was attributed to sediment changes caused by the winnowing effect of ship propellers (Marine Science & Ecology 1990).

The MSE data provides a useful baseline for future monitoring and could provide data on the extent, if any, of long-term changes in the channel and changes in the swinging basin due to shipping movement.

4.3 Intertidal infauna

Unvegetated intertidal mudflats occur extensively in Western Port, particularly in the Upper North Arm and the Corinella segments.

Data presented by Blake and Ball (2001) indicated that there was up to 168 km^2 of unvegetated intertidal mudflat in Western Port, or 22 per cent of the total seabed. Unvegetated intertidal mudflats occur between the seaward extent of mangroves (or the shoreline where mangroves are absent) and the landward extent of intertidal seagrass, as well as in between patches of intertidal seagrass below mean sea level. The area of unvegetated intertidal mudflat in Western Port increased significantly between 1973/74 and 1983/84 due to broadscale decline in intertidal seagrass cover, with only partial recovery documented to 2001 (Blake and Ball, 2001). The largest declines in intertidal seagrass, and the most limited recovery, have occurred in Upper North Arm and Corinella segments, which have shifted from predominantly intertidal seagrass to predominantly unvegetated mudflat habitat.

The intertidal mudflats support diverse and species rich assemblages of invertebrate infauna and epifauna. Benthic microalgae (microphytobenthos) contribute some primary production on unvegetated intertidal mudflats. The invertebrate fauna of intertidal unvegetated mudflats derive their food from detritus (such as seagrass and algae wrack), microphytobenthos and phytoplankton and zooplankton (at high tide).

Intertidal mudflats are important foraging areas for shorebirds and waders that feed on the infauna and epifauna, particularly at low tide. Fish and mobile invertebrates can forage over the intertidal flats at high tide, moving in from adjacent deeper habitat.

The structure of the invertebrate community in bare sediment habitats is variable at small and large spatial scales and relates to sediment particle sizes and depth/elevation. Infauna diversity tends to increase downslope (with inundation period) on intertidal flats (Edgar *et al* 1994).

The most numerous invertebrate fauna on unvegetated intertidal mudflats are polychaete worms and crustaceans. Grazing snails and burrowing clams (filter feeders) are also common and occasionally present in high numbers. Other invertebrate groups occur in low numbers.
Invertebrate diversity and abundance are generally lower in unvegetated areas compared to vegetated (seagrass) areas (Edgar *et al* 1994, Watson *et al* 1984).

5 Plankton

Plankton are the small and microscopic plants and animals that live in the water column. Plankton play an important role in marine ecosystems. The phytoplankton are the primary producers that use nutrients, carbon dioxide and the energy of the sun to create biomass. Phytoplankton are food for the small filter feeding or grazing invertebrates in the water column (zooplankton) or on the seabed (benthic invertebrates).

The small invertebrates that feed on the phytoplankton may also feed on drifting organic particles, marine bacteria or other plankton in the water column. They become food for larger invertebrates and filter feeding fish in the water column or on the seabed. These are a food source for larger invertebrates, fish, birds and mammals that inhabit Western Port. Hence, the plankton community links the benthic communities of the mudflats and channels.

The strong tidal water currents in the deeper main channels at Crib Point and throughout most of Western Port result in thorough mixing of the water column and the planktonic biota it contains. The plankton in the mixed water column are transported back and forth for kilometres along the channels over each tide.

Wave action on the shallow intertidal mudflats and seagrass detritus from the extensive intertidal and subtidal seagrass beds results in relatively high amounts of suspended sediments and organic detritus in the water column in northern and eastern Western Port. Suspended material is highest in the shallow waters of the tidal divide in the northeast of the Western Port. Suspended material reduces through North Arm and Corinella and to very low concentrations at the Western Entrance near Flinders and Cape Grant as it mixes with the clear oceanic waters of Bass Strait. These factors influence the nature of the plankton communities throughout Western Port including those in North Arm.

5.1 2019 North Arm Plankton Study

The phytoplankton, zooplankton and fish eggs and larvae of North Arm in Western Port from Sandy Point in the south to BlueScope in the north (Figure 17) were intensively studied as part of multidisciplinary investigations for a proposed regassification development at Crib Point Jetty from December 2018 to December 2019 (CEE 2020 a,c,d). The plankton study design was based on the 1982 to 1984 zooplankton investigations of Western Port and Port Phillip Bay (Kimmerer and McKinnon 1985, 1987), which provided spatial and temporal information on zooplankton in East Arm and the Western Entrance. Fish egg and larval sampling was based on fish recruitment studies in the Eastern Entrance, Bass Strait and Port Phillip by University of Melbourne (Jenkins).

The results and outcomes of the 2019 phytoplankton, zooplankton and ichthyoplankton studies were reported as Technical Appendices to the Crib Point Gas Import Jetty Environmental Effects Statement 2020 (CEE 2020a,c,d). The results of the EES technical studies of the Western Port plankton community are the most comprehensive integrated monthly study of an embayment plankton community in Australia.

All plankton sampling used depth integrated samples to sample the same depth band of the water column. This was consistent with the previous plankton, fish larval and phytoplankton sampling designs to inform assessment of spatial and temporal patterns in plankton populations.

The north-south axis sites were designed to document spatial variability along the tidal gradient in Lower North Arm: waters in the south of Lower North Arm are exchanged with Bass Strait water on a shorter time-scale than those in the north of Lower North Arm (Figure 17).

The east-west sites document spatial variability between waters on the 10 m contour east (CPE10) and west (CPW10) of Crib Point that may be influenced by shallow subtidal and intertidal benthic habitats. CPC1 represents mid-channel habitat. Phytoplankton samples were collected only at sites along the north-south axis and at Berth 2.

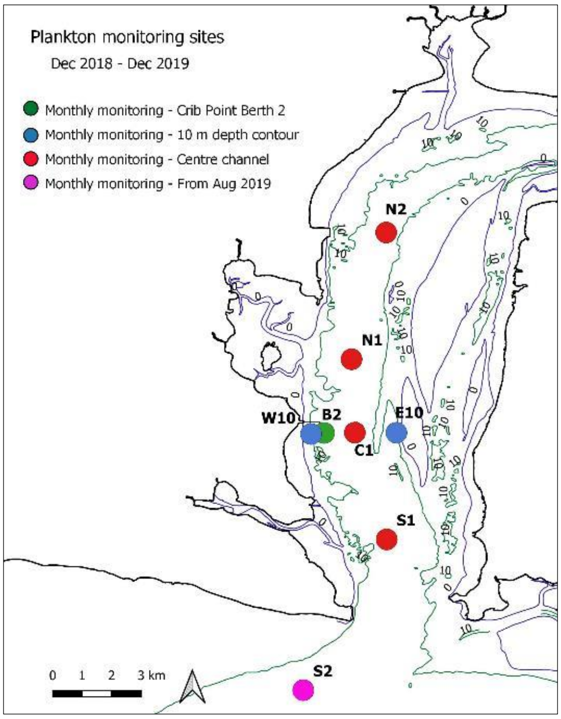


Figure 17. Plankton Monitoring Sites 2018/19

5.2 Phytoplankton

Phytoplankton are an important part of the food web. Autotrophic phytoplankton absorb nutrients and provide a food source for both zooplankton and heterotrophic and mixotrophic phytoplankton. The mixotrophic and heterotrophic phytoplankton are also a very important part of the trophic web, having a key role in the ‘microbial loop’ that recycles nutrients within the water column, as well as being a major food source for zooplankton (Suthers et al 2019).

Almost all phytoplankton have limited ability to move through the water column, although some are more suited to calm conditions (e.g. flagellates) and others are suited to turbulent conditions (e.g. diatoms). In either case, the strong tidal currents in the main channels of Western Port are sufficiently turbulent to prevent stratification of the water column or layering of phytoplankton over the water column.

The phytoplankton of Western Port sampled in 2018-2019 (CEE2020a) included species that are:

- autotrophic (obtain all their energy from photosynthesis)
- heterotrophic (obtain all their energy from ingesting organic matter, bacteria or other small phytoplankton); and
- mixotrophic (obtain energy from both photosynthesis and heterotrophy).

Most of the species observed in the study were considered cosmopolitan and are widespread in coastal waters of southeast Australia (Brett et al 2019, Hallegraeff et al 2009). Any potentially toxic species collected were at densities below aquaculture alert levels.

The phytoplankton community was dominated by small cell-size diatoms and flagellates, with larger celled diatoms occurring sporadically. These characteristics are typical of a low-nutrient, well-mixed ecosystem where internal generation and recycling of nutrients is important and population turnover is rapid. This is consistent with the relatively low nutrient input to Western Port from the catchment or exchange with the waters of Bass Strait, which are classified as oligotrophic (low nutrient content).

Figure 18 shows the average number of phytoplankton species per sample and average phytoplankton abundance over all sites for each month of the survey.

Figure 19 shows data for individual sites along with average total phytoplankton abundance. The average number of taxa per sample ranged from 35 to 45, with no clear seasonal trend in the average number of taxa. Phytoplankton abundance steadily increased from May to September, before a steep reduction in May. As shown later in this discussion, the decrease corresponds with a seasonal increase in grazing and predation activities in zooplankton and fish larval populations in the bay. Figure 19 shows that there were no consistent differences in the number of species between sampling sites along North Arm.

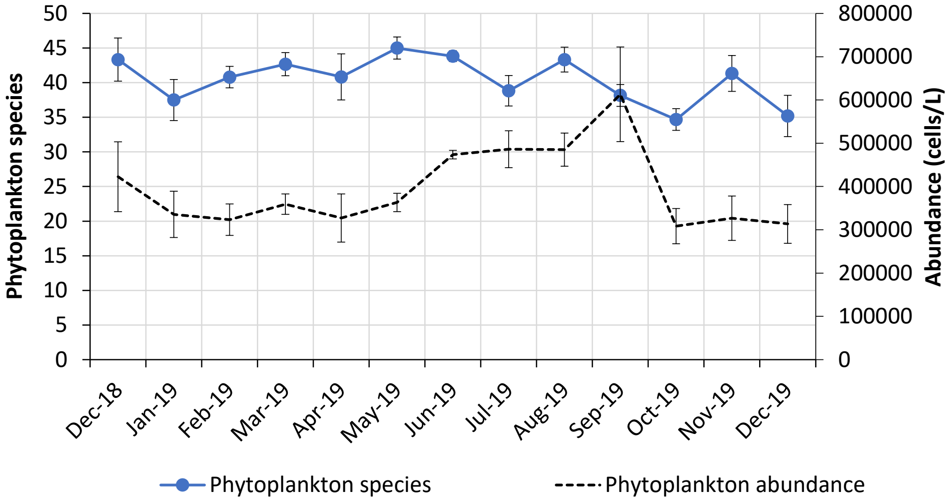


Figure 18. Monthly average phytoplankton species per sample
Error bars show ± SEM

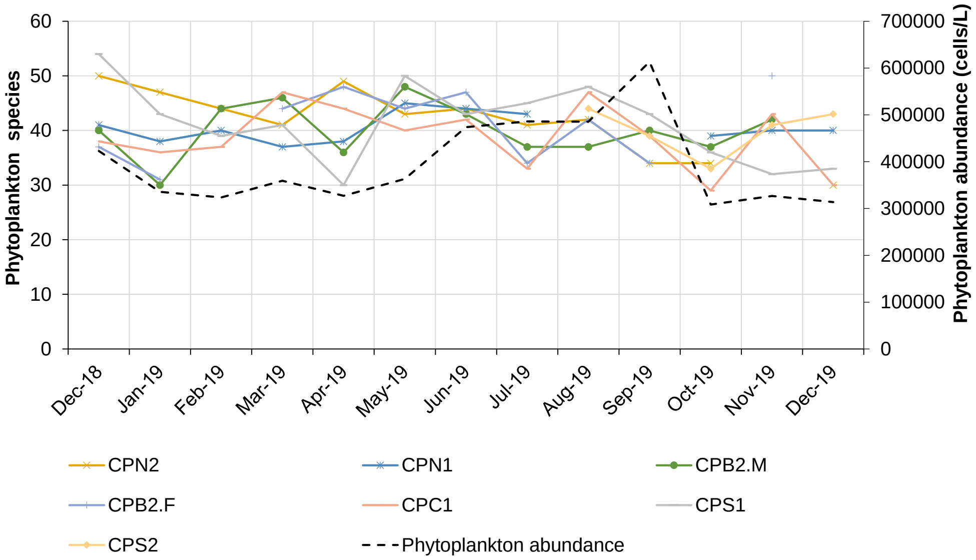


Figure 19. Phytoplankton species by site and month

5.3 Zooplankton

Zooplankton were sampled during the Westernport Bay Environmental Study More than 40 taxa of zooplankton were recorded in samples from the Lower North Arm sites over the 13-month sampling period from December 2018 to December 2019 (CEE 2020d). The mean density of zooplankton was 2895 individuals per m^3 and a mean monthly number of taxa of 24. More than 80% of the zooplankton collected were represented by seven species of copepod. Copepods are typically the most abundant zooplankton in the sea and are a key trophic link in planktonic and pelagic food webs (Kimmerer and McKinnon 1990). All species of zooplankton identified were common to marine waters in South-eastern Australia including Bass Strait and Port Phillip Bay.

More than 60 per cent of the individual plankton collected over the sampling period were the copepod *Acartia* spp which was present in all samples in all surveys. The copepod *Paracalanus indicus* was the only other taxon collected in all months of the monitoring period. It was the second-most abundant taxon, but its numbers represented only 6% of the total zooplankton collected. Copepods *Euterpina acutifrons* and *Pseudodiaptomus cornutus* each represented almost 5% of the total zooplankton.

All major zooplankton community categories in North Arm over the sampling period showed strong seasonal patterns (Figure 20). The monthly pattern in total number of zooplankton mostly followed the monthly abundance of copepods except for January 2019 when small snails were present in the sampled water column and November and December 2019 when the heterotrophic diatom *Noctiluca scintillans* was abundant.

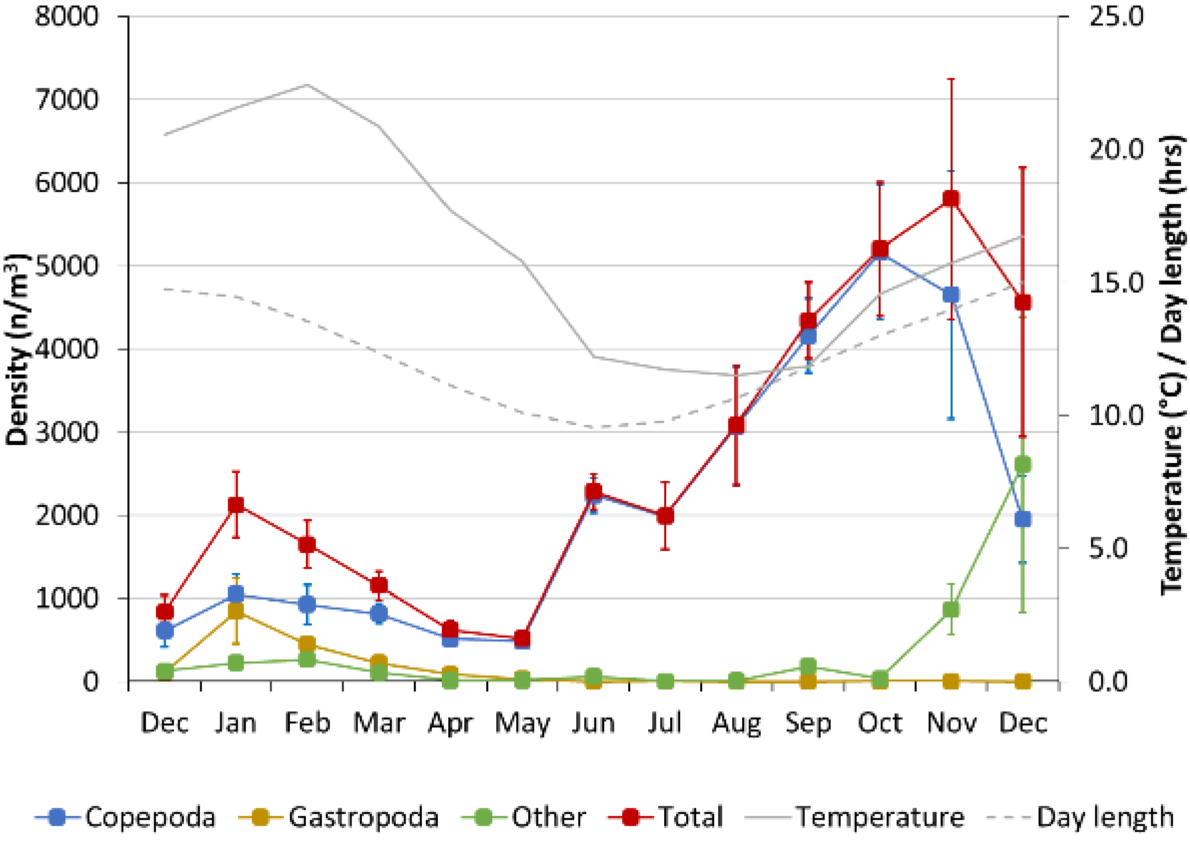


Figure 20. Monthly average abundance of key zooplankton categories

5.4 Ichthyoplankton

The marine environment of Western Port is characterised by a range of habitats, including seagrass, mangroves, algae and reefs, that support a rich and diverse fish fauna. Some species from these diverse habitats release their eggs and larvae into the water column where they mix and are dispersed by currents until they reach the early juvenile stage. Some fish and molluscs do not release eggs into the water column, but attach them to the seabed (southern calamari) or brood them (pipefish). Others have short egg phases and larvae rapidly migrate to suitable seabed habitat where they develop into juveniles. Some species found as juveniles (King George Whiting) or adults (snapper) in Western Port do not breed in Western Port. The egg and larval stage in marine fish (ichthyoplankton) is characterised by high mortality rates, and the early stages are important in determining levels of recruitment and abundance of the population (Houde 2008). Spatial and temporal variability in Western Port ichthyoplankton communities are the product of life history (spawning location, spawning period, larval period), mortality (mainly predation), and dispersal related to the wind driven hydrodynamics in Bass Strait and tide dominated hydrodynamics in Western Port.

Fish larvae and eggs were sampled monthly in Western Port at the same eight sites as phytoplankton and zooplankton in 2018-2019 shown in Figure 17 (CEE 2020a,c). Total fish egg and fish larvae (CEE2020c) monthly abundances are shown in Figure 21 and Figure 22, respectively.

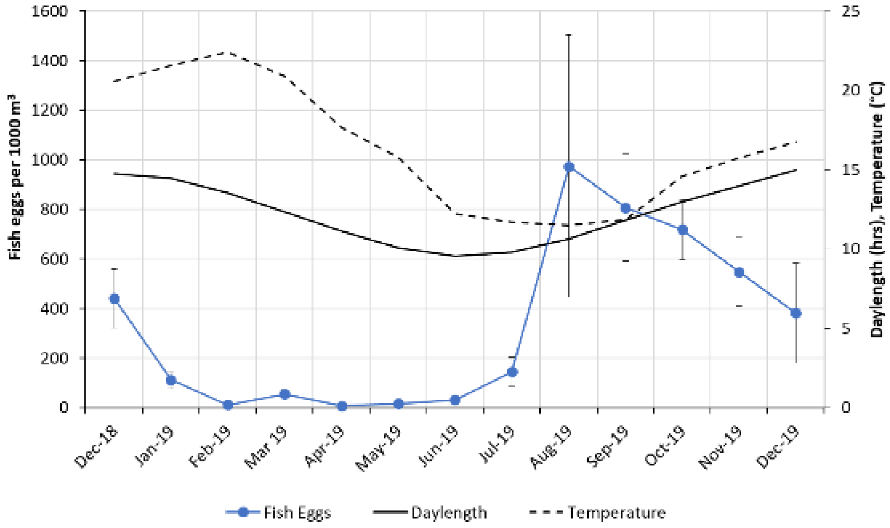


Figure 21. Average fish egg concentrations in Lower North Arm.
(mean ± se)

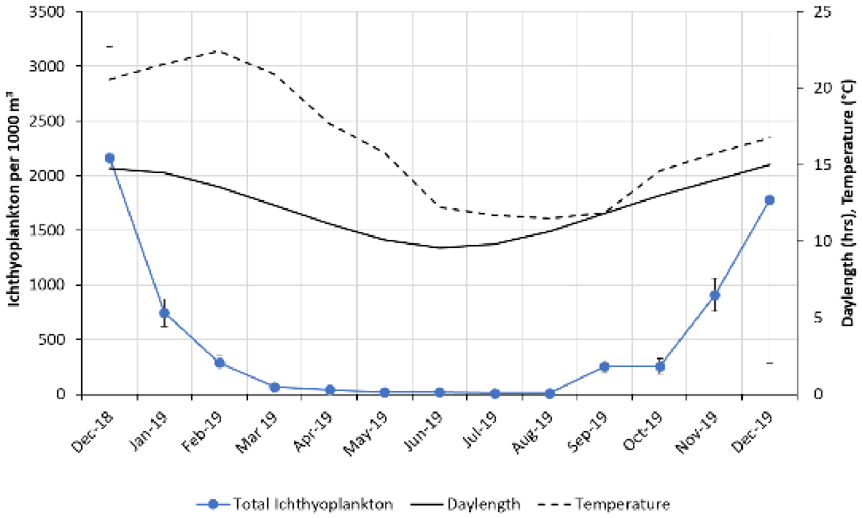


Figure 22. Average fish larvae concentrations in Lower North Arm
(mean ± se)

The results show that fish eggs became abundant in late-winter and persisted through spring, with very low numbers from late-summer (February) to early winter (June). Fish larval abundance initially lagged the fish egg pattern, with lagged demonstrate an increasing number of larvae initially in spring (September) progressing to highest abundance in December followed by decreasing numbers to in January and February. This is the natural sequence of eggs being laid by adults in winter and spring, which develop into larvae late in spring and persist into summer. Most larvae have grown to juveniles or adults by summer, leaving a juvenile and adult population of sedentary species in North Arm over autumn and winter.

Fish larvae came from 28 fish families and were dominated by the Gobiidae (14 species of gobies), which represented more than 80% of all fish larvae and to a lesser extent by the Syngnathidae (seahorses and pipefish) and Tetrarogidae (scorpionfish and cobblers) which together represented 10 percent of all fish larvae. Cephalopods were dominated by adults of one small species, the pygmy squid, *Xipholeptos notoides*.

6 Saltmarsh and Mangroves

Saltmarsh and mangrove habitats occur along the west and north shorelines of North Arm, the west and north shoreline of French Island, the east side of Phillip Island and around the mouth of the Bass River. More extensive areas of saltmarsh and mangrove habitat occur in Hastings Bight to the north of Crib Point, and Hanns Inlet south of Crib Point. Areas of saltmarsh and mangroves in the vicinity of the study area are shown previously in Figure 7 and Figure 8 of Section 2.2 of this report.

Saltmarsh and mangrove habitats form two of the three important marine vegetation components (the other is seagrass) in the Western Port Ramsar site (DSE, 2003, Boon et al, 2011).

Saltmarsh occurs above mean high tide level in areas subject to intermittent tidal inundation or saline groundwater, usually between terrestrial vegetation and mangroves. Saltmarsh vegetation is generally less than 0.5 metres tall and consists primarily of salt-tolerant succulent herbs, low succulent shrubs, rushes and sedges.

Saltmarsh provides habitat for many bird species. It is likely saltmarsh provides foraging opportunities for some marine fish species that move into saltmarsh from the mangrove and mudflat habitat offshore during periods of inundation (Boon et al, 2011). Saltmarsh can stabilise and accumulate sediment, and also colonises suitable new habitat created by changes in sea level or seabed level due to natural and anthropogenic processes (Boon *et al* 2011). The area of saltmarsh habitat at Western Port that existed around the time of European colonisation is estimated to have been reduced by around 15 per cent due to infilling and harbour construction activities at Hastings and Yaringa (Boon *et al* 2011). Saltmarsh that remains in these areas has also been damaged by vehicles (four-wheel drives and motorbikes, Boon et al, 2011).

A single species of mangrove, *Avicennia marina subsp*. *australasica*, occurs within Western Port, which is near the southern-most extent for mangroves in the southern hemisphere. The latest estimates (Boon *et al* 2011) are that there are 1,800 hectares of mangroves around the shores of Western Port.

Mangroves provide a substrate for the growth of algae and colonization by sessile invertebrates such as barnacles. The sediment within mangrove stands is habitat for benthic invertebrates, including gastropods, crustacea and polychaete worm. They also provide habitat structure for (mainly juvenile) fish, which are most abundant at the edge of mangrove habitat. The distribution of mangroves around Western Port appears to have been relatively stable since European colonisation, but their area has decreased in some areas and increased in others due to human activities (Dittman, 2011).

Whilst mangrove and saltmarsh are present immediately south of the study area, there were no areas extensive enough within the development site to be identified as a patch of native vegetation (Biosis 2023).

7 Fish and Fishing

Western Port supports a rich and diverse fish fauna due to its many and varied habitats (Jenkins et al. 2015). Many of these habitats occur in the Lower North Arm. Fish in Western Port include species of ecological, conservation and fishing importance. As the study area includes an area of intertidal sandflat that is covered in patchy seagrass, an area of steeply sloping seabed and open water over seabed, the distribution of fish species (that may be present) is discussed in the context of the different habitat types present within the study area,

The characteristics of fish communities in Western Port was reviewed and described by Prof Greg Jenkins from the University of Melbourne (Melbourne Water 2011). Prof. Jenkins provided greater detail related to Lower North Arm fish communities in a review in 2018. The following descriptions are taken from his report (Jenkins 2018).

7.1 Fish Species in Pelagic Habitat

The fish community in the pelagic environment of Western Port includes the small clupeoid fish, such as Australian Anchovy and Australian Sardine, that are key elements of the food chain to larger fish and birds, as summarised in Jenkins 2019a. Hoedt et al. (1995) surveyed clupeoid fish by examining stomach contents of Australian Salmon caught in the Lower North Arm and the Western Entrance segment. Australian Anchovy and Australian Sardine were the dominant species in most samples and Sandy Sprat were occasionally common. Adult clupeoids were found to be temporary inhabitants in Western Port, migrating into the bay between October and December and leaving between February and June (Hoedt et al. 1995). Juvenile Australian Anchovy and Australian Sardine were common in samples between February and April, indicating that Western Port serves as a nursery area for both species (Hoedt et al. 1995).

Eggs and larvae of Australian Anchovy and Australian Sardine were sampled in the Lower North Arm as part of a broader sampling program (Hoedt and Dimmlich 1995). Anchovy eggs and larvae were common in the Lower North Arm from December to March while Sardine eggs and larvae were rare (Hoedt and Dimmlich 1995). Anchovy eggs and larvae were distributed both inside Western Port and offshore, while Sardine eggs and larvae mainly occurred offshore or near the western entrance (Hoedt and Dimmlich 1995). Recent ichthyoplankton sampling in the Lower North Arm from December 2018 to December 2019 has recorded the presence of Sardine larvae from December to February, and Anchovy larvae in February and May (Chidgey et al 2019c, Jenkins 2019b).

Fish from various habitats inhabit the pelagic environment in the larval stage. Ichthyoplankton sampling in the eastern entrance and Rhyll Segment of Western Port found that larval abundances were strongly seasonal, with a peak around December and a minimum around June (Kent et al. 2013). The species composition was dominated by larvae of small, benthic species, such as the gobies (*Gobiidae*) and the triplefins (*Tripterygiidae*) (Kent et al. 2013). Seasonal occurrence of larvae included Australian Anchovy in summer, goby larvae in spring and summer, triplefin larvae in spring – early summer, clingfish and shore eel (*Gobiesocidae*) larvae and Tasmanian Blenny *Parablennius tasmanianus* larvae in spring (Acevedo et al. 2010).

Recent ichthyoplankton sampling in the Lower North Arm from December 2018 to December 2019 found a similar seasonal pattern of larval fish abundance (Chidgey 2019c, Jenkins 2019b). Peak abundance occurred at the start of sampling in December 2018, and this declined to a low level by March (Figure 22). This pattern largely reflected the pattern for goby larvae that were the dominant group, but other abundant groups such as the pipefish (*Syngnathidae*), leatherjackets (*Monacanthidae*), boxfish (*Aracanidae*) and toadfish *(Tetraodontidae*) also showed this pattern (Chidgey 2019c). Juveniles and adults of these latter groups are primarily associated with seagrass (see next section).

7.2 Fish Species in Seagrass Habitat

Fish associations with seagrass habitats in Western Port were summmarised by Prof G Jenkins, University of Melbourne, in 2019 (Jenkins 2019c). detailed study of fish in seagrass habitat was carried out at Crib Point in the mid-1970s as part of the Western Port Bay Environmental Study (Robertson 1978). The sampling was conducted on an intertidal mudflat where meadows of seagrass *Heterozostera nigricaulis* were covered with pooled water at low tide but beds of *Z. muelleri* and unvegetated areas were exposed (Jenkins 2019c, Robertson 1978). Samples were collected with either a large or small beach seine net (Robertson 1978).

The dominant fish species were either residents — including the Southern Longfin Goby, *Favonigobius lateralis*, Bridled Goby, *Arenigobius bifrenatus*, Common Weedfish, *Heteroclinus perspicillatus*, Cobbler *Gymnapistes marmoratus* and juvenile Greenback Flounder *Rhombosolea tapirina* — or tidal transients — including Silver Fish, *Leptatherina presbyteroides*, Smallmouth Hardyhead, *Atherinosoma microstoma*, Pikehead Hardyhead, *Kestratherina esox*, and Smooth Toadfish, *Tetractenos glaber* (Robertson 1978, 1980, 1984).

King George Whiting and Yellow-eye Mullet were resident as young juveniles but tidal transient as older (> 6 months) juveniles (Robertson 1980). Juvenile Western and Eastern Australian Salmon were also tidal transients (Robertson 1978). Permanent residents and Smooth Toadfish were more active at night, while hardyheads, Yelloweye Mullet and King George Whiting were more active during the day (Robertson 1980).

Deeper (~4 m) sub-tidal seagrass, *Heterozostera nigricaulis*, were sampled between Hastings and Yaringa in autumn with a mini otter-trawl (Jenkins et al. 2015). The dominant fish species in terms of abundance was the Spotted Pipefish, *Stigmatopora argus*, while the Grass Whiting, *Haletta semifasciata*, Little Weed Whiting, *Neoodax balteatus*, and the leatherjacket, *Acanthaluteres sp*., were also important (Jenkins et al. 2015). Species of potential fishing importance included the Rock Flathead and the Sixspine Leatherjacket, *Meuschenia freycineti*. Differences in the dominant species reported in the studies of Robertson (1978, 1980) and Jenkins et al. (2015) largely reflects the difference in depth sampled, as depth has been shown to strongly-affect fish species composition in central Victorian seagrass habitats (Jenkins et al. 1997b; Hutchinson et al. 2014).

Subtidal Seagrass beds were sampled with a fine-mesh seine net at three sites in the Lower North, three in the Upper North Arm, and one in the Rhyll Segment in winter (Hindell et al. 2004). The beds of *Heterozostera nigricaulis* were near the edge of channels in the shallow subtidal zone (Hindell et al. 2004). Most fish were small (< 10 cm) sedentary species such as gobies and pipefish (Hindell et al. 2004). The Widebody Pipefish, *Stigmatopora nigra*, was the most abundant species, while other common species included the Spotted Pipefish, *Stigmatopora argus* and the Halfbridled Goby, *Arenigobius frenatus*. Five species of potential fishing importance were collected — King George Whiting, Sixspine Leatherjacket, Australian Anchovy, Grass Whiting and Southern Calamari — and many of these fish were juveniles (Hindell et al. 2004).

Subtidal seagrass, unvegetated and channel habitat was sampled with seine and gill nets at sites in the Upper North Arm and the Rhyll Segment (Edgar and Shaw 1995a). The pattern of fish abundance, and to a lesser extent fish production, was strongly seasonal, with highest levels in summer and a consistent decline through autumn and winter (Edgar and Shaw 1995a). This variation was more pronounced in seagrass than in unvegetated habitats (Edgar and Shaw 1995a) and was consistent with higher seagrass biomass, and higher invertebrate production over summer (Edgar et al. 1994).

7.3 Fish Species in Unvegetated Sediment Habitat

The fish assemblage on unvegetated mud flats at Jacks Beach, between Crib Point and Hastings was sampled with pop and seine nets between October and January (Hindell and Jenkins 2005). Fish species collected included three species of goby, Smooth Toadfish, and juveniles of two species of importance to fishing, King George Whiting and Greenback Flounder.

Sampling of subtidal channels and embayment plains with a mini otter-trawl was undertaken as part of a PhD thesis on the biology of Red Cod, *Pseudophycis bachus* (Kemp 2010). Species that occurred frequently in samples from the Lower North Arm included ornate cowfish, *Aracana ornate*, Spiky Globefish *Diodon nicthemerus*, red mullet, *Upeneichthys vlamingii*, and species of flathead, flounder and stingray.

In their study of mangroves and unvegetated mudflats in Western Port and Corner Inlet, Hindell and Jenkins (2004) found that Yelloweye Mullet, Smooth Toadfish, Silver Fish, and Southern Longfin Goby were common species on intertidal mudflat habitat. Apart from Yelloweye Mullet, juveniles of other species important to fishing included Greenback Flounder, Longsnout Flounder, *Ammotretis rostratus*, and King George Whiting (Hindell and Jenkins 2004).

In addition to seagrass, Edgar and Shaw (1995a) sampled unvegetated intertidal mudflat and subtidal channel habitat in the Upper North Arm and the Rhyll Segment. Species characteristic of unvegetated intertidal mudflats were the Eastern Bluespot Goby, the Tamar Goby *Afurcagobius tamarensis*, Greenback Flounder and Longsnout Flounder. Juvenile Rock Flathead were also found on unvegetated mudflat areas). Sand Flathead were common in both unvegetated mudflat and channel habitat, while species of stingaree *Urolophus spp*. were most common in channel habitat. Elephant Fish were caught in both mudflat and channel habitat, but were most abundant at a silty-substrate site within the Rhyll Segment (Edgar and Shaw 1995a).

7.4 Commercial Fishing

There has been some form of commercial fishing in Western Port since the early 1900’s (or earlier) (Conron et al. 2016). Commercial netting was banned in Western Port in 2009, and only 8 commercial fishers remain using line fishing methods in Western Port and Port Phillip bays, combined (VFA 2022). Closure of commercial net fishing in Western Port in 2009 resulted in a substantial reduction in the commercial fish catch (Figure 23).

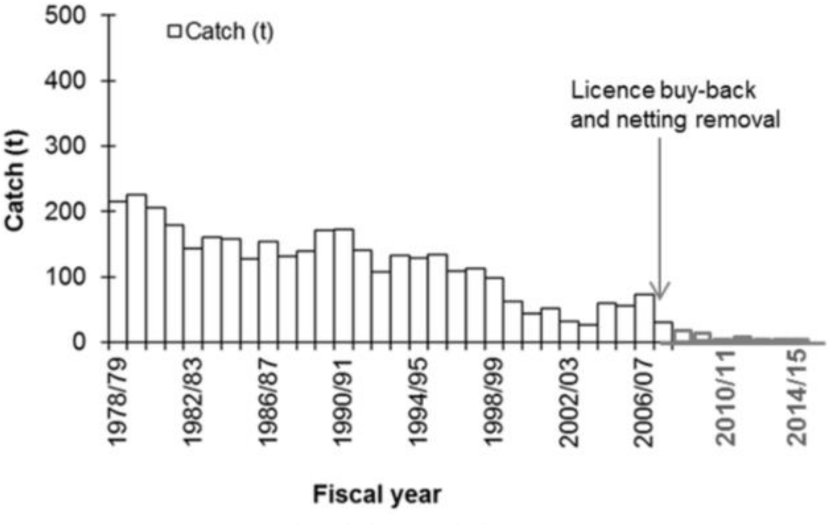


Figure 23. Total commercial fish catch in Western Port 1970 o 2015
(Conron et al 2016)

The annual combined commercial catch limits in Western Port and Port Phillip bays for snapper, shark and other fish are 88 tonne, 1 tonne and 2 tonne, respectively. Commercial catching of King George whiting, calamari, yellowtail kingfish and mulloway in the two bays is banned.

Native flat oysters *Ostrea angasi* once formed extensive intertidal and subtidal beds in Western Port that formed the basis of a fishery from the mid-1980s to early 1900s (Bennett 2004, Ford and Hamer 2016). These oysters were initially collected by hand in the intertidal area and subsequently by small harvesters (dredges) by small fishing boats after the intertidal stocks were depleted (Bennett 2004). Intertidal oyster leases were established for a short period in Hastings Bight. There is no oyster fishery in Western Port in the present day, but scattered oyster shells are visible on the seabed surface and are found in shell strata below the surface. Introduced oysters are present on the tidally exposed piles of some the shipping jetties in Lower North Arm.

7.5 Recreational Fishing

The recreational fishery in Western Port is very important and represents the second-largest recreational fishery in Victoria (Conron et al. 2016). Recreational fishing pressure in Port Phillip and Western Port has replaced or exceeded that from commercial fishing as Melbourne’s population and standard of living has increased (Conron 2016, Jenkins 2018).

Based on boat ramp survey results from 1998-2015 (Conron et al. 2016), most fishers in Western Port fished more than 5 days per year, primarily by line fishing from boats, although there is also a small amount of shore-based angling and some spearfishing. The majority (70%) of the catch is taken in summer and autumn. The main recreational target species are: King George Whiting, Elephant Fish, Snapper, Flathead, Southern Calamari, Garfish, Australian Salmon, and Gummy Shark. The present total recreational fish catch in Western Port is uncertain.

8 Seals and Penguins

8.1 Seals

The nearest seal colony to the study area is Seal Rocks which is a colony of Australian fur seals (*Arctocephalus pusillus doriferus*) located off the western tip of Phillip Island near the western entrance of Western Port. Satellite tracking of 60 seals over 10 years showed that the seals rarely enter Western Port, remaining around the rocky shorelines at the edge of the western entrance.

Small numbers of seals enter Western Port and are seen around the jetties and wharves in Lower North Arm including Blue Scope, Long Island Point and Cribb Point (CEE observations, Figure 24).

Several other species of seals have been recorded in Western Port but are uncommon. These include the New Zealand Fur Seal – 1 record (Menkhorst, 1995); Subantarctic fur seal – 1 record (Menkhorst, 1995); Australian sea lion – 1 record (Kirkwood et al ,1999); Leopard Seal – multiple records (Menkhorst, 1995) (Renwick and Kirkwood, 2004) and the Southern Elephant seal – 1 record (Menkhorst, 1995).

Figure 24, Seal at Crib Point Jetty 2019

8.2 Penguins

The nearest penguin colony to the study area is the Little Penguin colony located at Phillip Island. The largest colony is located at the ‘Penguin Parade’ colony at the southwestern end of Phillip Island. Penguin tracking programs (Dann et al 1996) showed that penguins from the main Phillip Island colony seldom travel into lower North Arm. There is also a small breeding colony of little penguins off the northwest corner of French Island in the upper North Arm and penguins are expected in Lower North Arm, though less commonly than in the Western Entrance and Corinella Segment. Little penguins can acclimate to human presence and shipping as demonstrated by the colonisation of the St Kilda Breakwater and establishment of around 400 breeding penguins, that feed in Port Phillip including the shipping channels adjacent to St Kilda (Chiaradia et al 2011).

9 Conservation areas and species

9.1 Ramsar Site

The Western Port Ramsar site covers 59,950 ha of Western Port. It comprises a large area of shallow intertidal mudflats, deep channels and some narrow strips of coastal land. The Ramsar site includes all areas of Western Port north of a line between Point Leo (Mornington Peninsula) and Observation Point (Phillip Island) and a line between Newhaven and San Remo (The Narrows), excluding the land areas of French Island and Phillip Island (Figure 25).

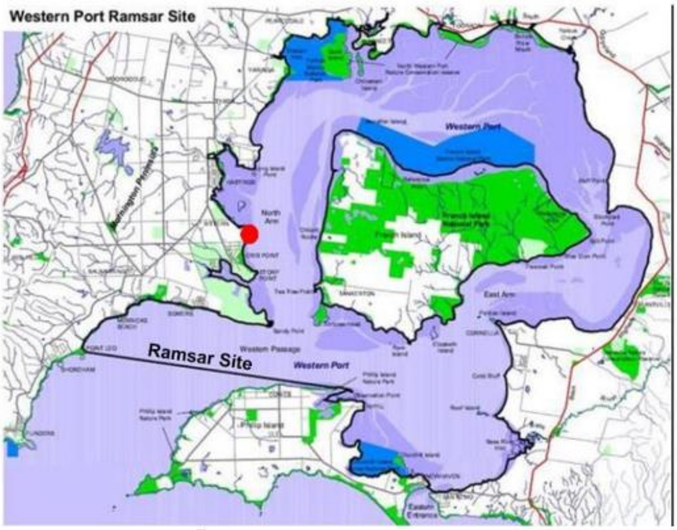


Figure 25. Ramsar Site and protected areas in Western Port

9.2 Marine Conservation Reserves

The high environmental, social and economic worth of Western Port is recognised further through the declaration of Western Port as an UNESCO Biosphere Reserve and the presence of three Marine National Parks.

UNESCO Biosphere Reserves are areas comprising terrestrial, marine and coastal ecosystems established to promote sustainable use compatible with the conservation of biodiversity. The Western Port Biosphere Reserve includes the Mornington Peninsula, Western Port, French and Phillip Islands and the southern part of the Western Port catchment.

Western Port contains three marine national parks:

- Yaringa Marine National Park (980 hectares), in the northwest corner of Western Port approximately 10 km north of Crib Point, contains area of saltmarsh, mangroves, bare intertidal mud and sand flats and subtidal seagrass, with bare sandy sediment in the deeper channels (French et al 2014);
- French Island Marine National Park (2,800 hectares) is located in the Upper North Arm approximately 12 km northeast of Crib Point, extending 15 km on the northern side of French Island. Habitat within the park is primarily intertidal and subtidal mud and sand flats supporting seagrass beds. A small patch of intertidal reef is present. Some mangroves are within the southern park boundary, but the majority of the shoreline mangroves and saltmarsh are outside of the park boundary (French et al 2014); and
- Churchill Island Marine National Park (670 hectares), located approximately 18 km south southeast of Crib Point between Churchill Island and Long Point on the north-eastern side of Phillip Island. Habitats present include seagrass beds, mangroves, mudflats and sandy beaches.

9.3 Threatened species

Marine species that are listed as threatened and migratory on the Flora and Fauna Guarantee Act 1988 (FFGA) and Environment Protection and Biodiversity Conservation Act 1999 (EPBCA) lists that may occur in North Arm of Western Port are identified in this section.

Species listed in the FFGA and EPBCA are assigned a likelihood of regular occurrence within the study area, or North Arm. The likelihood is based on our understanding of the life cycle and environmental habitats of the species, the known geographic range of the species, experience on previous investigations and reviews of the North Arm marine environment, information in relevant biodiversity databases and reports, and knowledge of the marine characteristics in North Arm including water quality, tidal currents, and habitats on site. Likelihood of occurrence is ranked as Common, Known, Possible, Unlikely.

- Common (C): numerous individuals or groups are known to be resident or occur on an annual basis in North Arm
- Known (K): Individuals or small groups from larger populations elsewhere are known to occur infrequently compared with known preferred areas or migratory routes.
- Possible (P): Environmental conditions may be suitable and within geographic range but species have not been recorded or records are old.
- Unlikely (U): Habitat and environmental conditions are unfavourable for the species, although individuals may occur inadvertently and very infrequently.
- Known but Unlikely (K/U): Individuals occasionally occur in Western Port, but unlikely to occur in the project area due lack of suitable conditions.
- Possible but Unlikely: Suitable physical habitat may occur within the project area, but the project area is outside the known geographic range.

9.3.1 EPBC Listed Species

Table 3 show the 13 marine species (other than birds) listed on May 2023 using MNES Search Tool for an area of within 2 km of the project area under the EPBC Act (Table 3), including:

- 9 EPBC Act listed threatened species; and
- 12 EPBC Act listed migratory marine species (including seven of the EPBC threatened species above)

Table 3 EPBC Listed Species

Scientific Name	Common Name	Class	EPBC Listing	Likely Occurrence
Carcharodon carcharias	Great White Shark	Fish	Vulnerable, Migratory	K/U
Balaenoptera borealis	Sei Whale	Mammal	Vulnerable, Migratory	U
Balaenoptera musculus	Blue Whale	Mammal	Endangered, Migratory	U
Balaenoptera physalus	Fin Whale	Mammal	Vulnerable, Migratory	U
Caperea marginata	Pygmy Right Whale	Mammal	Migratory	U
Eubalaena australis	Southern Right Whale	Mammal	Endangered, Migratory	K/U
Lagenorhynchus obscurus	Dusky Dolphin	Mammal	Migratory	U
Megaptera novaeangliae australis	Southern Humpback Whale	Mammal	Migratory	K/U
Orcinus orca	Killer Whale	Mammal	Migratory	U
Caretta caretta	Loggerhead Turtle	Reptile	Endangered, Migratory	U
Chelonia mydas	Green Turtle	Reptile	Vulnerable, Migratory	U
Dermochelys coriacea	Leathery Turtle	Reptile	Endangered, Migratory	K/U
Thunnus maccoyii	Southern bluefin tuna	Fish	Conservation dependent	U

Some of the species of cetacean are known to have occurred in North Arm on occasion as they stray from their migration path through Bass Strait. They are seen more usually near the Western Entrance during migratory periods. Leathery turtles are must unlikely in North Arm, although a decaying carcass was found among mangroves in the past few years. Southern bluefin tuna carcasses (heads and bones) may also be found around boat ramps in North Arm where they are left after being caught in Bass Strait by recreational fishers. It is not considered likely that the southern bluefin tuna would occur within close proximity to the Project

Great white sharks may occur near the seal colony at the Western Entrance, or follow season snapper (*Pagrus auratus*) migrations into North Arm.

Conclusion to EPBCA threatened species

Table 3 indicates that EPBCA threatened or migratory marine species are not present in numbers or resident nor occur on an annual basis in the North Arm of Western Port and that the project area of Western Port is not an important area for any populations of the EPBCA species listed in Table 3.

9.3.2 FFG Listed Species

The Flora and Fauna Guarantee list of threatened species and communities was most recently updated in May 2023.

Table 4 shows 34 FFG listed threatened species that may occur in the vicinity of the study area (including five species also listed from the EPBC Act search of North Arm). Of the 34 listed species, 15 are marine invertebrates (three species of crustacean, eight species of echinoderm, three species of mollusc and one cnidarian).

Table 4 FFG Listed Threatened Species

Scientific Name	Common Name	FFGA threat	Likely Occurrence
Ralpharia coccinea	Stalked Hydroid species	Critically Endangered	K
Athanopsis australis	Southern Hooded Shrimp	Endangered	U
Michelea microphylla	Michelea Species 5256	Critically Endangered	K/U
Pseudocalliax tooradin	Ghost shrimp	Endangered	K
Amphiura trisacantha	Brittle Star species	Endangered	P/U
Apsolidium densum	Sea Cucumber 5251	Endangered	U
Apsolidium falconerae	Sea-cucumber	Critically Endangered	U
Apsolidium handrecki	Sea Cucumber 5052	Endangered	P/U
Clarkcoma australis	Brittle Star species	Critically Endangered	U
Pentocnus bursatus	Sea Cucumber (species 5258)	Critically Endangered	P/U
Rowedota shepherdi	Sea-cucumber species	Critically Endangered	P/U
Thyone nigra	Sea-cucumber species	Endangered	U
Bassethullia glypta	Chiton 5254	Critically Endangered	U
Platydoris galbana	Sea slug	Endangered	U
Rhodope rousei	Marine opisthobranch	Critically Endangered	U
Heterozostera nigricaulis	Australian Grass-wrack	Endangered	C
Heterozostera tasmanica	Tasman Grass-wrack	Endangered	U
Carcharias taurus	Grey Nurse Shark	Critically Endangered	U
Carcharodon carcharias	Great White Shark	Endangered	K/P
Lovettia sealii	Australian Whitebait	Critically Endangered	U
Neochanna cleaveri	Australian Mudfish	Endangered	U
Thunnus maccoyii	Southern Bluefin Tuna	Conservation Dependent	U
Mugilogobius platynotus	Flatback Mangrove goby	Endangered	K/P
Prototroctes maraena	Australian Grayling	Endangered	U
Seriolella brama	Blue Warehou	Conservation Dependent	U
Sphyrna lewini	Scalloped Hammerhead	Conservation Dependent	U
Thunnus maccoyii	Southern bluefin tuna	Conservation dependent	U
Arctophoca australis forsteri	Long-nosed Fur Seal	Vulnerable	U
Megaptera novaeangliae	Southern Humpback Whale	Critically Endangered	K
Neophoca cinerea	Australian Sea-lion	Endangered	P
Tursiops australis	Burrunan Dolphin	Critically Endangered	K
Balaenoptera musculus	Blue Whale	Endangered	U
Eubalaena australis	Southern Right Whale	Endangered	K
Dermochelys coriacea	Leathery Turtle	Critically Endangered	U

The seagrass *Heterozostera nigricaulis* is listed as endangered in Victoria. As discussed in Section 3, this species of seagrass is found widely in Victoria including Western Port, including the project area.

The Western Port ghost shrimp *Calliax tooradin* (*Pseudocalliax tooradin* in the FFGA list) was found originally as four individuals in fine subtidal sands at shallow water depths near Crib Point. Others were found in shallow seagrass habitat in Swan Bay. *Calliax tooradin* has been captured subsequently at shallow depths elsewhere in Western Port and Port Phillip Bay and may not be as rare as was initially thought when recommended for listing in 2000 (Poore 2019). It is possible that it may occur within the fine sands and seagrass at the development site. In relation to *Michelea microphylla,* Poore (2019) considered that "*the sand-gravel habitat at Crib Point near the entrance to Western Port does occur at similar depths throughout Bass Strait and the species could exist outside the entrance*". Further, Poore documents that that most species of marine invertebrates could be considered as rare in sampling programs due small-scale sampling of sparsely distributed individuals dispersed over wide spatial ranges are (Poore et al. 2014)

The flatback goby *Mugilogobius platynotus* occurs in suitable habitat from the Maroochy River estuary along the New South Wales and Victorian coast to Western Port. It is also found in the Port River estuarine system near to Adelaide. The flatback goby inhabits soft silty or muddy intertidal areas in bays and estuaries, usually amongst mangroves. While there are no mangroves within the development area that provide favoured habitat for this species, it is possible that some individuals may occur in the area if the seabed is sufficiently soft for these fish to build burrows.

Some other species may be recorded from parts of Western Port including Lower North Arm (some of the invertebrates) or in the region generally (whales, fish, sharks and seals), but conditions in the project area the project area are not likely to represent particularly high value to these species.

The threatened communities list includes two threatened communities from Western Port: San Remo Marine Community and Western Port Bryozoan Reef Community. Both of these communities are located in the southeast of the Rhyll Segment of Western Port and are remote from the North Arm.

Conclusion to FFGA threatened species

The study area includes patches of the FFGA listed seagrass *Heterozostera nigricaulis*.

The study area includes shallow subtidal sand habitat that is potentially suitable habitat for the Western Port ghost shrimp *Calliax tooradin*. This is likely to represent a very small proportion of the total area of habitat suitable for this species, but has not been quantified.

While there are no mangroves within the study area that provide favoured habitat for flatback gobies, this species, it is possible that some individuals may occur in the area if the seabed is sufficiently soft for these fish to build burrows. This is likely to represent a very small proportion of the total area of habitat suitable for this species, but has not been quantified.

10 Introduced Species

The anthropogenic translocation and establishment of non-indigenous marine species (NIMS) is considered to pose one of the greatest threats to marine biodiversity, as well as specific environmental, economic and human health impacts. The coasts of Australia have proven to be particularly vulnerable to invasions of exotic marine species, and a recent assessment reports the number of introduced and cryptogenic marine species in Australia to be 429 (Hewitt and Campbell, 2008). Temperate harbours and embayments on the southern coasts are particularly vulnerable having been colonised by numerous species from temperate marine environments in the northern hemisphere, particularly the north-west Pacific and the Mediterranean/north-east Atlantic regions. While many of the exotic species now established in Australian waters have limited impact, a number of species are perceived to have caused high impact and are considered to be invasive marine pests. These include the Northern Pacific seastar (*Asterias amurensis*), the Japanese kelp (*Undaria pinnatifida*), the European shore crab (*Carcinus maenas*), and the Mediterranean fan worm (*Sabella spallanzanii*).

Shipping and other maritime vessel traffic is one of the most significant vectors for both the primary introduction and secondary dispersal of non-indigenous species. Ports, or the waters in the vicinity of ports, are therefore often “hot spots” for NIMS, and both ships’ ballast water discharge and hull biofouling (particularly sea-chests) are recognised as vectors for marine pest incursions. Once a pest becomes established in one port, this port can then become a source for secondary dispersal to nearby environments by natural means or to other domestic ports, marinas or harbours by maritime traffic. In Victoria this has occurred with both *Asterias amurensis* and *Undaria pinnatifida* – which have since been detected at various locations outside Port Phillip Bay.

During a 1997 baseline survey of the Port of Hastings (Currie and Crookes, 1997), a total of 355 species were collected. Only seven of these were confirmed as introduced species:

- the European green crab *Carcinus maenus;*
- the European clam *Varicorbula gibba* (as *Corbula gibba*);
- the Asian bag mussel *Musculista senhousia*;
- the Asian bivalve *Theora lubrica*; and
- three cosmopolitan bryozoan species: *Bugula dentata*; *Bugula neritina*; and *Watersipora subtorquata*.

For comparison, nine exotic species were detected in the baseline port survey of Portland, 20 in Geelong, and 37 exotic or cryptogenic species in Melbourne. *Bugula dentata* was the only species considered abundant enough within the Port of Hastings to cause significant ecological impact, as its erect flexible growths were found on the surfaces of pier pylons of all commercial wharves. However, this species has since been reconsidered to be native (Hewitt *et al,* 1999), with a widespread distribution in the Indo-Pacific.

The 2000 survey of marine pests in Western Port increased the number of recorded exotic species in the bay to 14 (Cohen *et al,* 2000). Species additional to those in the 1997 port survey were:

- Four species of ascidians (*Ascidiella aspersa*, *Ciona intestinalis*, *Styela plicata* and *Styela clava)*,
- the Mediterranean fanworm *Sabella spallanzanii*;
- the bivalve *Crassostrea gigas*; and
- two green algal species (*Codium fragile subsp. fragile and Ulva lactuca).*

Only the crab *Carcinus maenas* appeared to be widely distributed in Western Port in 2000, with the remainder apparently limited in their distribution. *Sabella spallanzanii* and *Styela clava* were found on mussel ropes transferred to Flinders from Port Phillip Bay, but were not found on the nearby Flinders Pier or on the sea floor below the mussel farms.

A single occurrence of the Japanese kelp *Undaria pinnatifida* in Western Port is known from near Flinders Pier. These plants were removed and there were no further findings in subsequent monitoring of the site.

In late 2007 several juvenile New Zealand green-lipped mussels (*Perna canaliculus*) were found in the sea chests of one of the vessels that voyages between Port Kembla and Hastings when it was dry-docked for routine maintenance (Lewis 2019). Although follow up searches found no mussels near the relevant wharf at Hastings, the finding demonstrates a potential pathway for marine pest introduction to Western Port.

None of the large pests found in Port Phillip Bay (U. *pinnatifida*, A. *amurensis*, S. *spallanzanii*) have ever been observed during the BlueScope marine biological monitoring program (MSE, 2009) or biological monitoring of the Crib Point, Long Island Point or BlueScope jetties (Bok et al, 2017) or targeted diver-based survey of marine pests in Lower North Arm of Western Port in 2022 (Table 4, Crockett et al 2022).

Table 5. Summary of known marine pest species in Western Port 2022
(Crockett et al 2022)

Common Name (CABI)	Species	W'Port	Port Phillip	PortKembla
Wakame or Asian kelp	*Undaria pinnatifida**	N^	Y	N
Asian green mussel	*Perna viridis**	N	N	N
Black striped false mussel	*Mytilopsis sallei**	N	N	N
Brown mussel	*Perna perna**	N	N	N
Charru mussel	*Mytella charruana**	N	N	N
New Zealand green lipped mussel	*Perna canaliculus**	N	N	N
European sea squirt	*Ascidiella aspersa*	Y	Y	N
Sea vase	*Ciona intestinalis*	Y	Y	Y
Pleated tunicate	*Styela plicata*	Y	Y	Y
European fan worm	*Sabella spallanzanii*	N^	Y	N
Pacific oyster	*Magallana gigas*	Y	Y	N
Asian date or bag mussel	*Arcuatula senhousia*	Y	Y	N
Dead man's fingers	*Codium fragile fragile*	Y	Y	N
Club sea squirt	*Styela clava*	Y	Y	N
Bryozoan	*Watersipora subtorquata*	Y	Y	Y
Devil's tongue weed	*Grateloupia turuturu*	N	Y	N
Titan barnacle	*Megabalanus coccopoma*	N	Y	N
White colonial sea squirt	*Didemnum perlucidum*	N	N	N
Carpet sea squirt	*Didemnum vexillum**	N	N	N

* species on the Australian Priority Marine Pest List (APMPL) or EEPL

^ Detected at or near Flinders aquaculture zone, not known to be established in Western Port

Victoria's Department of Agriculture initiated the Victorian Commercial Ports Marine Pest Surveillance program comprising a multi-level targeted marine pest sampling program in major Victorian Ports (R Stafford-Bell, Biosecurity Principal Officer *pers comm*). The program commenced at five sites in the Port of Melbourne in 2020 and expanded to four sites in Western Port, two sites in the Port of Portland and one site in the Port of Geelong in late 2021. The sites in Western Port are Stony Point Jetty, Crib Point Jetty, Long Island Point Jetty and Bluescope Wharf. The program at all sites includes collection of water samples, plankton tows, settlement plants and biological 'scrape' samples for genetic eDNA (environmental DNA) analysis. Research in Victoria has shown that eDNA detection and decay models are effective at detecting the presence of introduced marine pest species to 750 m from the source biota (Ellis et al 2022). The Department of Agriculture program is ongoing.

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