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Kamay Ferry Wharves seagrass pre-construction monitoring report: Baseline 3 (Winter 2022)

Prepared for Transport for NSW | 11 November 2022

Document control

Project number	Client	Project manager	LGA
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Version	Author	Review	Status	Date
D0	Luke Stone	Matthew Russell David Cummings	Draft	12/10/2022
D1	Luke Stone David Cummings	Matthew Russell	Draft	19/10/2022
R1	Luke Stone David Cummings	Matthew Russell	Final	11/11/2022

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Glossary and list of abbreviations

Term or abbreviation	Definition
BOM	Bureau of Meteorology
CHIRP	Compressed High-Intensity Radiated Pulse
CPCe	Coral Point Count with Excel extensions
DPI	The NSW Department of Primary Industries
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EIS	Environmental Impact Statement
FM Act	*Fisheries Management Act 1994* (NSW)
IOD	Indian Ocean Dipole
Shoot (seagrass)	A shoot is considered the section of seagrass from the sheaf up and may consist of one or various leaves.
TBC	To be completed
TfNSW	Transport for New South Wales

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1. Introduction

1.1 Project background

Transport for New South Wales (TfNSW) is proposing to reinstate the ferry wharves at La Perouse and Kurnell in Botany Bay (Figure 1 and Figure 2 respectively). The Project was classified State Significant Infrastructure (SSI) under the NSW Planning Framework and is a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (EPBC Act referral 2020/8825).

The Project would allow for an alternative to the road connection between La Perouse and Kurnell. Its main purpose would be to operate a public ferry service for visitors and the community. In addition, the Project would provide supplementary temporary moorings for tourism-related commercial vessels and recreational boating.

A Marine Biodiversity Assessment Report was prepared as part of the Environmental Impact Statement (EIS) (TfNSW 2021a). This report identified that the project would result in impact to seagrasses, including the endangered *Posidonia australis* ecological community and population in Botany Bay, listed under the *Fisheries Management Act* 1994 (FM Act). Impacts on seagrasses will include some losses of seagrass within the Construction Footprint and associated 15 m buffer from shading, disturbances during construction works and ongoing operation of the wharves and ferries (TfNSW 2021a). In addition, a large and significant bed of *P. australis* seagrass occurring adjacent to and beyond the Project Boundary at Kurnell is considered of ecological significance to the population in Botany Bay and an important conservation requirement of the Project.

Investigations of seagrass in or nearby the Project Boundaries at La Perouse and Kurnell have found seagrass bed distribution and morphology (i.e. shoot density, leaf length) to be highly temporally and spatially variable, especially off Silver Beach at Kurnell. In some places, distribution was wider than previously mapped (Larkum and West 1990, Otway and Macbeth 1999, NSW DPI 2021). At both La Perouse and Kurnell, several vessel moorings within or adjacent to the Project Boundaries are likely to be having, and may have ongoing, impacts on seagrass distribution in these areas. At Kurnell in particular, exposure to large easterly swells is considered a major driver of temporal changes in seagrasses within the Project Boundary and expansion of the adjacent large *P. australis* bed to the east. The *Zostera* and *Halophila* species of seagrass are typically much widely distributed within the Project Area. These species and colonise new areas more quickly than *P. australis* and undergo much greater temporal fluctuations in distribution, density and dominance, which is typically driven by environmental conditions and establishment from the seed bank from sediments within the locality (Waycott et al 2014).

1.2 Project description

The Project includes the construction of two new wharves, one at La Perouse and one at Kurnell. The wharves would be designed to accommodate ferries up to 40 m length, along with recreational and commercial vessels up to 20 m in length.

The total construction period is anticipated to take up to 13 months and will require the following:

- Use of a temporary crane and rig platform (onshore) to install nearshore piles and piers at La Perouse.
- Construction of a causeway to provide piling shoot access to install nearshore piles and piers at Kurnell.
- Repositioning and anchoring of a jack-up barge to provide a platform for construction works for the wharves.

1.3 Monitoring purpose

The EIS has identified the need for the establishment of a seagrass monitoring program that includes pre-construction (baseline) surveys and designed to determine construction and operation impacts. The pre-construction surveys require four surveys and two years of data to obtain a sufficient baseline. Furthermore, pre-construction monitoring is required to determine baseline distribution and condition of seagrasses both within and adjacent to the Project Boundary to guide final offset requirements and monitor for long-term changes of the adjacent large *P. australis* bed as a result of the Project.

The purpose of the monitoring program is to identify any large-scale changes in seagrass composition and distribution within the Project Boundary and monitor for any changes in the adjacent large bed of *P. australis* at Kurnell during construction and operation that may be attributable to the Project.

1.4 Monitoring to date

This report details the methods and findings of the third baseline seagrass monitoring surveys completed in the winter of 2022, with the first baseline survey being completed in winter 2021 (Niche 2021a) and second in summer 2022 (Niche 2022). Monitoring surveys that have been completed as part of the monitoring program to date are identified in Table 1.

Table 1: Seagrass monitoring surveys completed to date

Survey	Season	Survey date	Period	Reference
Baseline 1	Winter 2021	July – September 2021	Pre-construction	Niche (2021a)
Baseline 2	Summer 2022	February – April 2022	Pre-construction	Niche (2022)
Baseline 3	Winter 2022	August – September 2022	Pre-construction	Current Report

This report focussed on the outcomes of the Baseline 3 surveys completed in winter 2022. General comparisons are made to the Baseline 1 and Baseline 2 surveys where appropriate to identify any major changes in baseline seagrass distribution and condition within the Project Boundary. A comprehensive baseline report will be developed following the collection of the Baseline 4 surveys (complete baseline dataset) in summer 2022/2023, which will investigate any trends or changes in detail.

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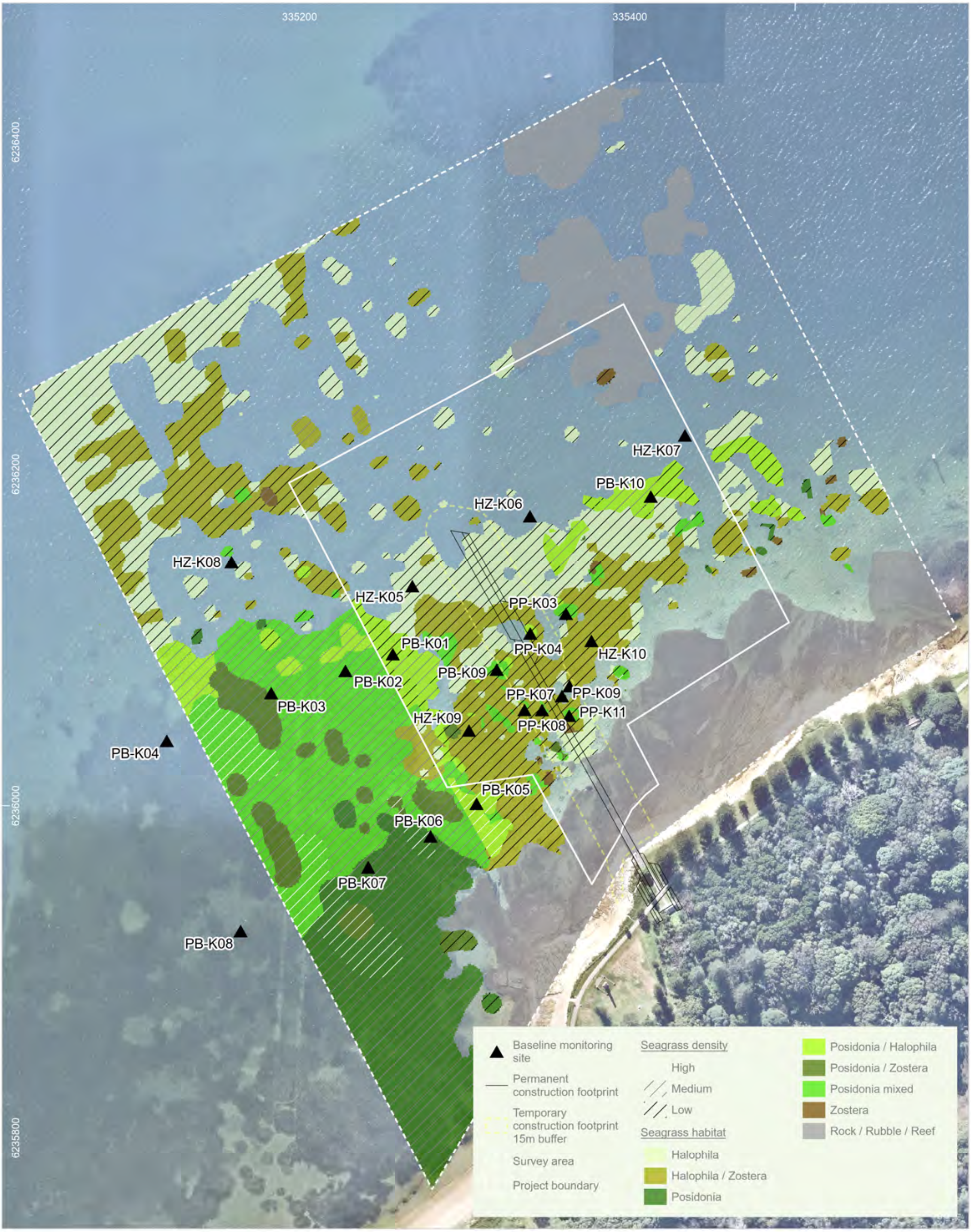
Survey Sites and Habitat Mapping: La Perouse Winter 2022

Kamay Ferry

Niche PM: Matthew Russell
Niche Proj. #: 7476
Client: Transport for NSW

Figure 1

World Imagery: Maxar/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.



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Survey Sites and Habitat Mapping: Kurnell Winter 2022

Kamay Ferry

Niche PM: Matthew Russell
Niche Proj. #: 7476
Client: Transport for NSW

Figure 2

World Imagery: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community/Terrain: Multi-Directional Hillshade: Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community | Watercourses, Waterbodies, Road and Rail alignments, Protected areas of NSW © Spatial Services 2021. | Niche uses GDA2020 as standard for all project-related data. In order to ensure that data from numerous sources and coordinate systems is aligned, on-the-fly transformation to WGS1984 Web Mercator Auxilliary Sphere is used in the map above. For ease of reference, the grid tick marks and labels shown around the border of the map are presented in GDA2020, using the relevant MGA zone.

2. Methods

2.1 Overview

The seagrass monitoring program has been developed to align with the requirements identified within the Marine Biodiversity Offset Strategy (TfNSW 2021b). The program includes four survey approaches:

- Seagrass Mapping: Seagrass distribution mapping of the seagrass composition and density within the Survey Area.
- Drop Camera Surveys: Collection of photo quadrats from within *Halophila* and *Zostera* seagrass beds for quantitative analysis of seagrass composition and density;
- *Posidonia* Bed Monitoring: Diver based quadrat surveys of seagrass morphology (composition, biomass and condition) *P. australis* beds (typically >100 m^2); and
- *Posidonia* Patch Monitoring: Seagrass morphology surveys of smaller *P. australis* patches (typically <100 m^2).

Specific monitoring sites are shown for La Perouse in Figure 1, and for Kurnell in Figure 2. A full list of site codes and GPS coordinates can be found in Appendix 1.

2.2 Survey frequency and timing

Surveys are undertaken twice per year (biannually) – with consideration of winter and summer seasons. This being the third baseline survey. The pre-construction baseline survey program, including previous surveys completed to date, is summarised in Table 2.

Table 2: Pre-construction survey program and previous surveys

Survey	Status	Season	Survey dates	Reference
EIS survey surveys				
EIS survey	Complete	Winter 2020	June 2020	(Niche 2020a)
EIS survey	Complete	Winter 2020	August – September 2020	(Niche 2020b)
EIS survey	Complete	Summer 2020	December 2020	(Niche 2021b)
Pre-construction baseline monitoring surveys				
Baseline 1	Complete	Winter 2021	July – September 2021	Niche (2021a)
Baseline 2	Complete	Summer 2022	February – April 2022	Niche (2022)
Baseline 3	Complete	Winter 2022	July – August 2022	Current Report
Baseline 4	TBC	Summer 2022/23	Planned for December 2022	TBC

The third baseline survey was completed during winter over July and August of 2022. Dates for each survey method undertaken are identified in Table 3.

Table 3: Baseline 3 (winter 2022) seagrass monitoring survey dates

Methodology	Survey date Kurnell	Survey date La Perouse
Seagrass mapping	25/7/22 - 18/8/22	18/8/22 - 22/8/22
Drop camera surveys	29/8/22	29/8/22
Posidonia Bed Monitoring	10/8/22-12/8/22	12/8/22
Posidonia Patch Monitoring	10/822-12/8/22	12/8/22

2.3 Seagrass mapping

2.3.1 Objective

To determine a baseline measure of seagrass composition and distribution within the Survey Area.

2.3.2 Survey areas

La Perouse

Subtidal areas of seagrass habitat within 50-100 metres of the Project Boundary (Figure 1).

Kurnell

Subtidal areas of seagrass habitat within 50-100 metres of the Project Boundary (Figure 2).

2.3.3 Methodology

Preliminary desktop works included review of the most recent Nearmap imagery (captured: 17/05/2022) and previously prepared polygons of seagrass distribution from previous surveys (Niche 2021a, Niche 2022).

Previously developed layers and associated Nearmap imagery were displayed in a GIS based field collection device with GPS accuracy of approx. +/-3m. Verification of habitat was recorded on the device as point data using customised applications within the Field Maps Software package.

Visual observations to verify the seabed habitat were made using a combination of towed camera (Plate 1) transects through the Survey Area and spot observations using a bathoscope, drop camera or, in the cases of shallow areas and during periods of clear water, observation from the side of the boat. The towed camera was towed within 1 m of the seabed and positioned so imagery was being provided from directly under the survey vessel where seagrass boundaries occurred or within ~2 m of the stern of the survey vessel when verifying larger uniform areas. The towed and drop cameras allowed for in situ field verification of mapping by providing video imagery live to the topside monitor on the survey vessel. The vessel sonar, which included CHIRP ClearVu and SideVu sonar that incorporates a thin, wide beam to provide clear images of structure and any larger seagrasses (with lengths of approximately 10cm or greater) below the vessel, was also used to aid mapping and target seabed areas with structure, especially during periods of reduced water visibility.

Field verification survey effort within seagrass habitat inside the Survey Area consisted of collection of 3,174 points at La Perouse and Kurnell during the Baseline 3 survey, with no greater than 23.95 metres between two verification points.

Post-collection analysis of field verification points was undertaken using GIS software to construct an updated set of habitat polygons. The dataset depicting the distribution and extent of seagrass and non-seagrass habitats was created from interpolated point observations collected on site. Each point was assigned a value for the habitat type (seagrass or non-seagrass) and seagrass habitats were assigned a density value (Low, Medium, High). Polygon data was interpolated by distance, with spatially associated points forming distinct patches of habitat and density. The data was then cleaned to remove errors, and a manual verification and editing pass was conducted by the Niche GIS team to better align boundaries to those observed in recent, high-resolution Nearmap imagery. Finally, the data was verified for accuracy by the Ecology team and edited where required to depict more detailed field notes for small patches of *P. australis* habitat, especially within the construction footprint and associated buffer.

2.3.4 Data analysis

The following calculations were made using GIS Software for La Perouse and Kurnell:

- Seagrass area within the Project Boundary
- Seagrass area within the Construction Footprint
- Seagrass area within the 15 m Buffer Zone around the Construction Footprint.

2.4 Drop camera surveys

2.4.1 Objective

To determine the baseline community composition and density of *Zostera*- and *Halophila*-dominated seagrass beds in the Project Boundary.

2.4.2 Survey area

Each baseline monitoring site was a circular area with a radius of 10 m from a central point, amounting to a total area of 314 m^2.

La Perouse

Four drop camera monitoring sites were re-surveyed at La Perouse (Figure 1):

- Two (2) potential 'impact' sites (HZ-LP-01 & HZ-LP-02) within the Project Boundary, that were established during the Baseline 1 survey.
- Two (2) 'control' sites (HZ-LP-03 & HZ-LP-04) outside the Project Boundary, that were established during the Baseline 1 survey.

Kurnell

Six drop camera monitoring sites were re-surveyed at Kurnell (Figure 2):

- Four (4) potential impact sites, two in deeper areas near the seaward end of the wharf (HZ-K-05 & HZ-K-06) and two nearer to the shore in shallower water (HZ-K-09 & HZ-K-10) that were established during the Baseline 1 survey.
- Two (2) control sites (HZ-K-07 & HZ-K-08) outside the Project Boundary that were established during the Baseline 1 survey.

2.4.3 Methodology

The centre point of each monitoring site was located using handheld GPS. Once located, a temporary float was positioned at the centre of the site. Each photo quadrat was haphazardly collected within 10 m of the centre of the site.

Photoquadrats were collected with a drop camera custom designed for seagrass surveys (Plate 1), which can obtain a high-resolution image of a known area of the seabed. Care was taken to avoid collecting photographs of the seabed that overlapped during the field survey.

Photos that were of poor quality, taken when the frame was not stationary on the seabed, duplicates or identified to have overlapping imagery were removed from the dataset. A total of 30 photos were then randomly selected from the dataset and uploaded into Coral Point Count with Excel Extensions (CPCe) Software for analysis. Within the CPCe software a digital photoquadrat was created to form an area of 0.25 m^2 (0.5 x 0.5 m) and 30 points were randomly assigned to the image. Under each point a habitat category was assigned (Table 1).

Table 4: Major and sub-categories used with the CPCe Software.

Major category	Sub-categories
SEAGRASS (S)	Halophila, Zostera, Posidonia

Major category	Sub-categories
ALGAE (A)	Macroalgae, Turfing Algae, Epiphytic Algae (when identified to be attached to the seagrass)
CORAL (C)	Hard Coral, Soft Coral
SUBSTRATE (SU)	Gravel & Shell, Rock & Rubble, Sand & Silt
OTHER BIOTA (OB)	Sessile Invertebrate
TAPE WAND SHADOW (TWS)	Tape, Wand (frame), Shadow (insufficient resolution), Macroalgae Wrack, Seagrass Wrack, Other Debris.

2.4.4 Data analysis

Within the CPCe software percent cover for each of the categories (except Tape, Wand and Shadow) and sub-categories were calculated for each photoquadrat (Plate 1), while Tape, Wand and Shadow were excluded from the percent cover calculations. Summaries for each site including means and standard errors were then calculated for:

- Seagrass cover by type
- Sediment/silt cover
- Turfing algae cover
- Epiphytic algae cover.

2.5 *Posidonia* bed monitoring

2.5.1 Objective

To determine the baseline community composition, biomass (density and leaf lengths) and condition of *P. australis* seagrass beds (>100 m^2) with potential to be impacted during construction and operation.

2.5.2 Survey area

Each monitoring site was a circular area with a radius of 5 m from a central point, amounting to a total area of 79 m^2.

La Perouse

Two *P. australis* bed monitoring sites were re-surveyed at La Perouse (Figure 1):

- One (1) potential impact site (PB-LP11) within the Project Boundary that was established during the Baseline 1 survey.
- One (1) control site (PB-LP12) outside the Project Boundary that was established during the Baseline 1 survey.

Kurnell

Ten *P. australis* bed monitoring sites were re-surveyed at Kurnell (Figure 2):

- Eight (8) potential impact sites within the large extensive bed of *P. australis* to the west of the Project Boundary (PB-K01 to PB-K08) that was established during the Baseline 1 survey. These sites are positioned within the main western bed to allow for a gradient-based approach to monitoring for impacts to the large bed of *P. australis* to the west of the Project Boundary. Sites are located along two longshore transects (one near shore and one offshore) at a range of distances from the Construction Footprint (Approx. 75 m, 100 m, 150 m and 230 m).
- Two (2) additional potential impact sites within much smaller beds of *P. australis* inside the Project Boundary (PB-K09 and PB-K10) that was established during the Baseline 1 survey.
- Control sites will be determined at the completion of the baseline monitoring. It is envisaged they will be selected from monitoring sites in the main western bed outside the Project Boundary (e.g. PB-K03,

-K04, -K07 and -K08). There is also potential to include the most easterly site in the Project Boundary as a control site, where impact from the proposal is considered unlikely.

2.5.3 Methodology

The centre point of each monitoring site was located using handheld GPS. Once located a temporary float was positioned at the centre of the site. Seagrass was haphazardly surveyed via five 0.25 m^2 (0.5 x 0.5 m) quadrats within 5 m of the centre of the site.

Within each quadrat the following data were recorded by experienced Scientific Divers:

- Shoot density (counted from the sheaf) for each seagrass species present (Note *Halophila* also counted as shoots).
- Percent of shoots with visible sheafs for 10 randomly selected *P. australis* shoots.
- Visible sheaf Length for 10 randomly selected *P. australis* shoots.
- Epiphyte Load (scored 1-5, see Appendix 2) for 10 randomly selected leaves for each seagrass species present.

In addition to the above measurements a photograph was taken above each quadrat for archiving purposes.

2.5.4 Data analysis

Data calculations and summaries included means and standard errors for the following:

- Shoot (Shoot *Halophila*) count per 0.25 m^2
- Leaf length (cm)
- Epiphyte load score.

In the first and second baseline surveys, many seagrass sheafs for *P. australis* shoots were found to be covered by sediment and sheaf measurements could not be obtained. For the purposes of the program it was deemed more appropriate to present sheaf data as percent of shoots with visible sheafs rather than as measurements of sheaf length. As such the sheaf length is no longer recorded.

2.6 *Posidonia patch monitoring*

2.6.1 Objective

To determine the baseline community composition, biomass (shoot density and leaf lengths) and condition of *P. australis* seagrass patches (<100 m^2) in close proximity to the Construction Footprint.

2.6.2 Survey area

Patches (<100 m^2) of *P. australis* seagrass that met the following criteria were surveyed:

- Inside or within 15 m of the Construction Footprint
- Shoot density of at least five shoots per 1 m^2
- Has a size of at least 10 m^2 and minimum average width/radius of 2 m.

La Perouse

Two *P. australis* patches were re-surveyed at La Perouse that were established during the Baseline 1 survey (Figure 1):

- PP-LP-01: Approximately 10 m east of the 15 m buffer
- PP-LP-02: Approximately 15 m east of the 15 m buffer

Kurnell

Ten *P. australis* patches were re-surveyed at Kurnell that were established during the Baseline 1 survey. (Figure 2):

- PP-K-03: Approximately 15 m east of the 15 m buffer.
- PP-K-04: Inside the Construction Footprint and 15 m buffer.
- PP-K-07: Approximately 3 m west of the 15 m buffer.
- PP-K-08: On the western edge of the 15 m buffer.
- PP-K-09: On the eastern edge of the 15 m buffer.
- PP-K-11: On the eastern edge of the 15 m buffer. Note that this site has a *Zostera* patch in the middle that is not sampled.
- PP-K-12: On the eastern edge of the 15 m buffer.

2.6.3 Methodology

The centre point of each monitoring site was located using handheld GPS. Once located a temporary float was positioned at the centre of the site. Seagrass was haphazardly surveyed via up to five 0.25 m^2 (0.5 x 0.5 m) quadrats within 5 m of the centre of the site.

Within each quadrat the following data were recorded by experienced Scientific Divers:

- Shoot density (counted from the sheaf) for each seagrass species present (Note *Halophila* counted as shoots).
- Leaf Length of 10 randomly selected leaves for both *Zostera* and *P. australis*.
- Percent of shoots with visible sheafs for 10 randomly selected *P. australis* shoots.
- Epiphyte Load (scored 1-5, see Appendix 2) for 10 randomly selected leaves for each seagrass species present.

In addition to the above measurements a photograph was taken above each quadrat for archiving purposes.

2.6.4 Data analysis

Data calculations and summaries included means and standard errors for the following:

- Shoot (Shoot *Halophila*) count per 0.25 m^2
- Leaf length (cm)
- Percent of shoots with visible sheafs
- Epiphyte load score.

3. Results

3.1 Survey conditions

Rainfall over the nine months between summer 2021 to winter 2022 (December 2021 to August 2022) totalled 1924.8 millimetres (Bureau of Meteorology (BOM) station number 66037), exceeding the annual median total of 1045.8 millimetres (BOM 2022a), as shown in Table 5. Significant levels of rainfall persisted through each of the summer, autumn and winter seasons of 2022. A combined total of 411.6 millimetres of rain fell over the winter months in June, July and August 2022. Rainfall was above average in July and August, (Table 5), with particularly high falls in the month of July.

Table 5: Monthly rainfall summaries from BOM station number 66037 (BOM 2022a)

Summary data (mm)	December 2021	January 2022	February 2022	March 2022	April 2022	May 2022	June 2022	July 2022	August 2022
Median (1929-2022)	65.2	71.7	86.1	94.8	81	79	100.4	51.6	45.8
Total (2021, 2022)	83.0	110.2	383.8	489.4	247.2	199.6	9.6	344.2	57.8

June was predominantly dry although several peaks in daily rainfall exceeding 10 millimetres of rainfall over a 24 hour period were recorded during the wider winter season, in particular throughout July and to a lesser extent August (Figure 3). The highest daily rainfall total (126 millimetres) was recorded on 3 July 2022 resulting in a major flood level within the Georges River. Conditions across the survey period (25 July 2022 to 29 August 2022) were predominantly dry, although two rainfall events greater than 10 millimetres of rainfall over a 24 hour period, occurred on 10 August 2022 and 24 August 2022.

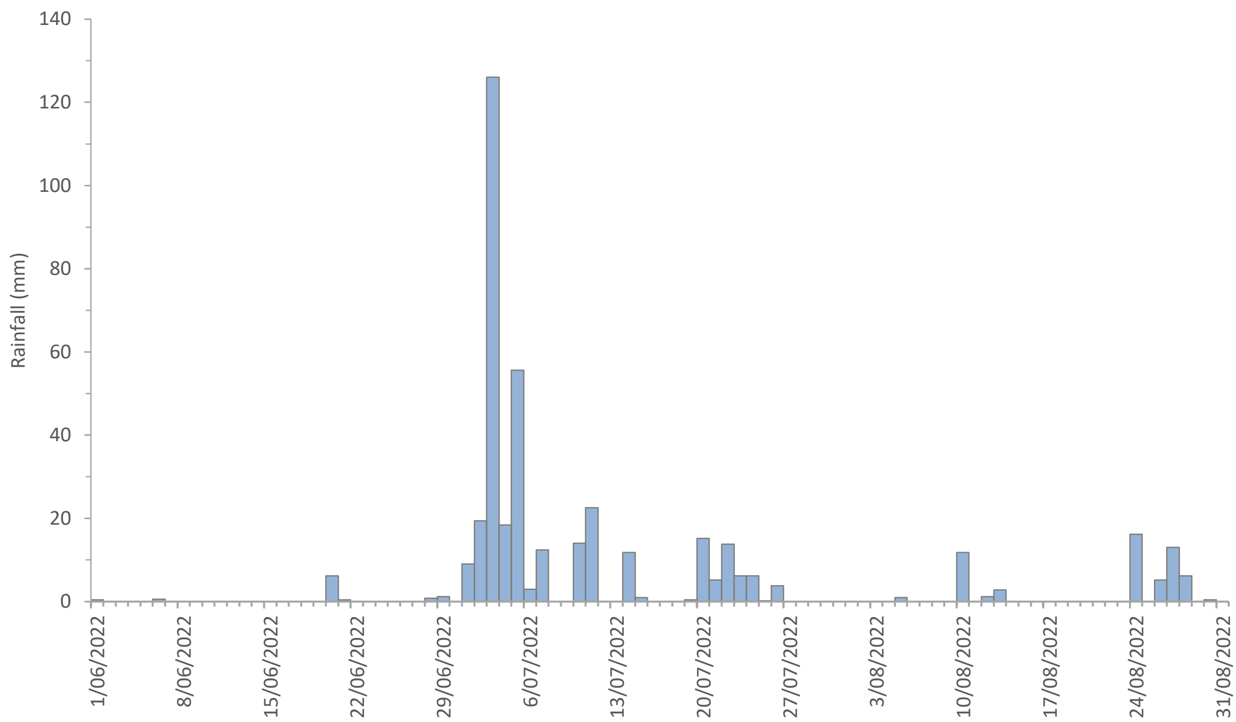

Figure 3: Rainfall June – August 2022 from station no. 66037 (Bureau of Meteorology 2022a)

The elevated levels of rainfall that occurred throughout the winter season impacted on water visibility at the time of survey. The high rainfall events were also associated with low pressure systems forming along the NSW east coast, which generated easterly swells with potential to impact on seagrass communities in less protected parts of Botany Bay. Extensive shoreline erosion as result of wave refraction from the easterly swell was observed at La Perouse, while this swell also had the potential to impact upon seagrass communities around Kurnell (addressed in section 3.2).

3.2 Seagrass distribution

As part of Baseline 3 monitoring surveys in winter 2022, 32,618 m^2 (3.262 ha) of seagrasses were mapped within the entire Project Boundary at La Perouse and Kurnell (Table 6, Figure 1, Figure 2). This included 823 m^2 (0.082 ha) of seagrasses within the Construction Footprint and an additional 3,860 m^2 (0.386 ha) within the 15 m buffer area at Kurnell. At La Perouse, no seagrass was recorded within the Construction Footprint, with only 78 m^2 (0.008 ha) of seagrass mapped within the 15 m buffer area, during the Baseline 3 monitoring survey.

The majority of seagrass mapped within the entire Project Boundary at La Perouse and Kurnell in Baseline 3 was comprised of *Halophila* beds (Table 6), although sand or silt were the dominant habitats mapped within the Project Boundary. The areas of seagrass based on mapping from each baseline monitoring survey to date are provided in Appendix 3. A substantial reduction in seagrass cover was observed in Baseline 3 when compared to Baseline 1 (Appendix 3). While the overall total of seagrass mapped in Baseline 3 was comparable to Baseline 2, in Baseline 3 there was a marked decline in extent of *Halophila* (only) seagrass beds.

Table 6: Seagrass areas mapped during Baseline 3 (winter 2022) within the Project Boundary, Construction Footprint (area of direct impacts) and associated Buffer area (area of indirect impacts).

Area	Baseline 3 (winter 2022)		
	Kurnell (m^2)	La Perouse (m^2)	Total (m^2)
Project Boundary			
Halophila	5879.71	9072.77	14952.48
Halophila / Zostera	7727.74	295.43	8023.17
Posidonia	18.61	137.25	155.86
Posidonia / Halophila	3175.47	0.00	3175.47
Posidonia / Zostera	84.97	0.00	84.97
Posidonia mixed	1083.18	0.00	1083.18
Rock / Rubble / Reef	5958.78	9462.61	15421.39
Sand or silt	22140.33	42776.83	64917.16
Zostera	246.83	135.00	381.83
Total seagrass	*18216.51*	*9640.45*	*27856.96*
Buffer area (area of indirect impacts)			
Halophila	1884.08	77.55	1961.63
Halophila / Zostera	1690.77	0.00	1690.77
Posidonia	6.28	0.00	6.28
Posidonia / Halophila	65.26	0.00	65.26
Posidonia / Zostera	48.97	0.00	48.97
Posidonia mixed	142.60	0.00	142.60
Rock / Rubble / Reef	1695.96	1626.12	3322.08
Sand or silt	1635.59	3736.03	5371.62
Zostera	22.13	0.00	22.13
Total seagrass	*3860.09*	*77.55*	*3937.64*

Area	Baseline 3 (winter 2022)		
	Kurnell (m^2)	La Perouse (m^2)	Total (m^2)
Construction Footprint (area of direct impacts)			
Halophila	435.07	0.00	435.07
Halophila / Zostera	365.41	0.00	365.41
Posidonia	0.00	0.00	0.00
Posidonia / Halophila	5.11	0.00	5.11
Posidonia / Zostera	0.00	0.00	0.00
Posidonia mixed	0.00	0.00	0.00
Rock / Rubble / Reef	228.59	518.80	747.39
Sand or silt	273.65	1035.43	1309.08
Zostera	17.86	0.00	17.86
Total seagrass	*823.45*	*0.00*	*823.45*

The combined total of *P. australis* seagrass (including *Posidonia*, *Posidonia / Halophila*, *Posidonia / Zostera* and *Posidonia* mixed beds) mapped in all baseline surveys are presented in Table 7. The key results of *P. australis* mapping include:

- In the Baseline 3 survey a total of 268 m^2 of *P. australis* seagrass was mapped within the Construction Footprint and Buffer area at Kurnell (Figure 2), with a total of 5 m^2 within the Construction Footprint alone.
- There has been an overall decline in the area of *P. australis* mapped within the Construction Footprint at Kurnell during the baseline surveys. Although there has been a small increase within the Buffer area since Baseline 2. A trend of decline in *P. australis* distribution has also been detected in the Project Boundary at Kurnell, although at a much lower rate than within the Construction Footprint.
- Within the Project Boundary at La Perouse, an overall decline has occurred between Baseline 1 and Baseline 3, despite a minor increase in the extent of *P. australis* seagrass between Baseline 2 and Baseline 3.

Table 7: *P. australis* seagrass (including *Posidonia, Posidonia / Halophila, Posidonia / Zostera* and *Posidonia* Mixed beds) areas mapped during baseline surveys to date.

Area	Baseline 1 (winter 2021)			Baseline 2 (summer 2022)			Baseline 3 (winter 2022)		
	Kurnell (m^2)	La Perouse (m^2)	Total (m^2)	Kurnell (m^2)	La Perouse (m^2)	Total (m^2)	Kurnell (m^2)	La Perouse (m^2)	Total (m^2)
Project Boundary	4479	170	4649	4876	132	5008	4362	137	4499
Construction Footprint (area of indirect impacts)	20	0	20	14	0	14	5	0	5
Buffer area (area of indirect impacts)	228	0	228	220	0	220	263	0	263

3.3 *Zostera* and *Halophila* seagrasses

The key results for cover of *Zostera*- and *Halophila*-dominated beds (Figure 5) in the Baseline 3 survey (winter 2022) are summarised below, with further data provided in Appendix 4:

- Seagrass was detected at nine of the ten *Zostera*- and *Halophila*- dominated beds in Baseline 3, with no seagrass detected at one site (HZ-LP01).

- *Zostera* and *Halophila* seagrass cover was very low at both Kurnell (0.11% – 3.46%) and La Perouse (0.00% – 0.56%).
- Monitoring sites for *Zostera*- and *Halophila*-dominated beds inside the Project Boundary at La Perouse recorded lower seagrass covers than at the control sites outside the Project Boundary, a trend also identified in Baseline 2 (Niche 2022).
- The monitoring sites for *Zostera*- and *Halophila*-dominated beds further from shore at Kurnell recorded lower seagrass cover than the two sites closer to shore and adjacent to the Construction Footprint. These sites further from shore were dominated by *Halophila* seagrass that were observed to decrease. Substantial decreases in the cover of *Halophila* at the two sites closer to shore and adjacent to the Construction Footprint were also observed.

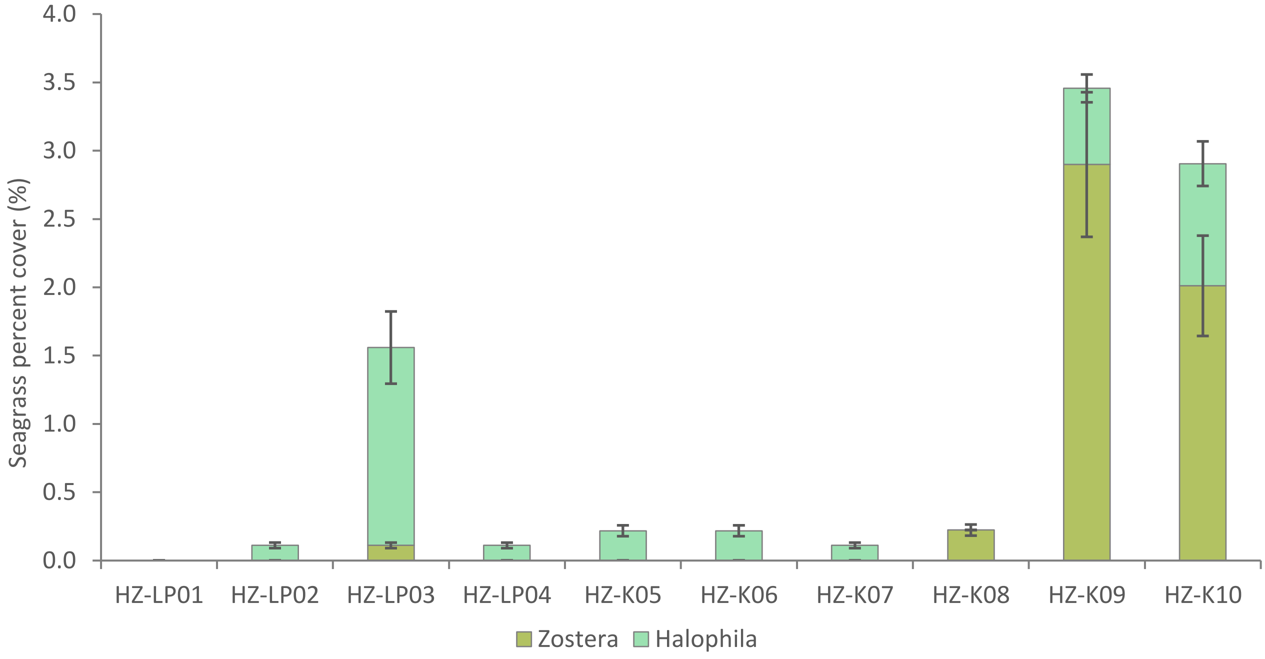

Figure 4: Baseline 3 (winter 2022), mean *Halophila* and *Zostera* seagrasses cover (+/- SE total seagrass cover).

When these results are compared against the previous baseline surveys (Figure 5), the following changes and patterns are notable:

- An overall substantial and continuous reduction in seagrass cover across the monitoring sites has been observed since Baseline 1.
- Declines in *Zostera* cover were particularly evident in Baseline 2, with declines in *Halophila* particularly evident in Baseline 3.
- At La Perouse, sites inside the Project Boundary (HZ-LP-01 and HZ-LP-02) continue to show a trend of lower *Halophila* and *Zostera* seagrass cover than at the control sites outside the Project Boundary (HZ-LP-03 and HZ-LP-04).
- The monitoring sites further from shore at Kurnell (HZ-K05 to HZ-K08) also continue to have very different compositions of *Halophila* and *Zostera* seagrass cover in comparison with the two sites closer to shore and adjacent to the Construction Footprint (HZ-K-09 and HZ-K-10).

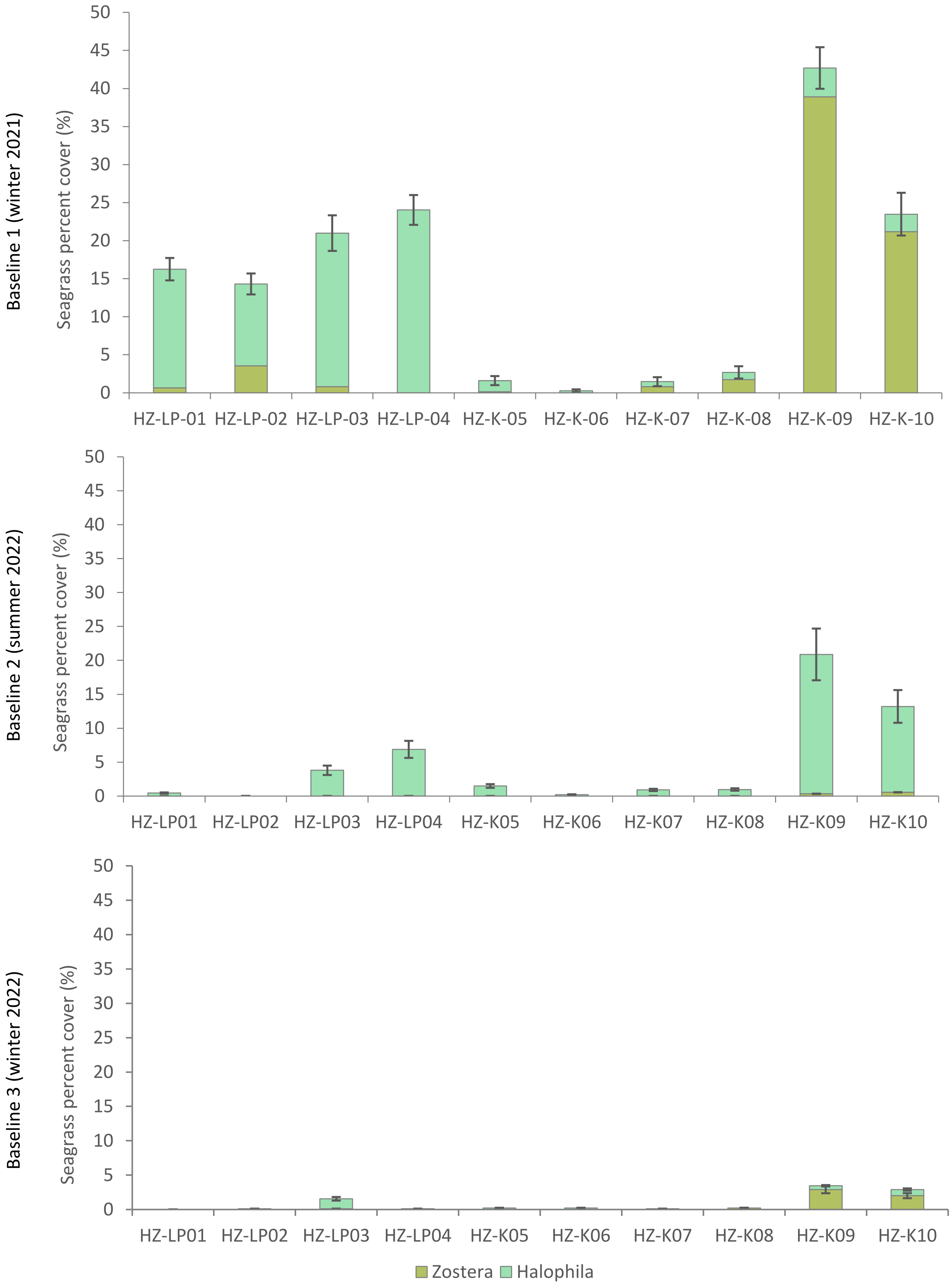

Figure 5: Baseline survey comparison: mean *Halophila* and *Zostera* seagrasses cover (+/- SE total seagrass cover).

The results for covers of sediment, turfing algae and epiphytic algae at each site for Baseline 3 and the previous baseline surveys are presented in Table 8. The key findings include:

- At La Perouse, sediment cover was high in Baseline 3, ranging between 83% - 93.3% cover. Sediment cover at Kurnell was also high, ranging between 90% - 99%.
- Turfing algae was present at all sites except HZ-K-10.
- No epiphytic algae were recorded at La Perouse in Baseline 3, Epiphytic algae were only recorded at the two sites closer to shore (HZ-K09 and HZ-K10) at Kurnell in Baseline 3.

Table 8: Mean covers of sediment, turfing algae and epiphytic algae at each site over the three baseline surveys.

Site	Sediment (SS) (%)			Turfing algae (TA) (%)			Epiphytic algae (EA) (%)		
Season	Baseline 1 (winter 2021)	Baseline 2 (summer 2022)	Baseline 3 (winter 2022)	Baseline 1 (winter 2021)	Baseline 2 (summer 2022)	Baseline 3 (winter 2022)	Baseline 1 (winter 2021)	Baseline 2 (summer 2022)	Baseline 3 (winter 2022)
HZ-LP-01	67.77	51.77	85.43	0.00	0.23	0.33	0.00	0.00	0.00
HZ-LP-02	83.16	82.94	93.30	0.00	4.11	0.11	0.48	0.00	0.00
HZ-LP-03	75.45	91.40	92.65	0.03	0.00	0.33	0.00	0.00	0.00
HZ-LP-04	46.92	74.27	82.78	0.07	0.00	0.44	0.03	0.00	0.00
HZ-K-05	94.90	98.40	90.40	0.33	0.12	1.31	0.50	0.00	0.00
HZ-K-06	95.06	99.55	90.40	0.07	0.00	1.31	0.90	0.00	0.00
HZ-K-07	96.64	98.42	99.33	0.00	0.00	0.00	0.43	0.00	0.00
HZ-K-08	92.35	99.03	95.87	0.57	0.00	0.22	0.57	0.00	0.00
HZ-K-09	57.00	78.78	90.75	0.00	0.34	0.11	0.03	0.00	0.45
HZ-K-10	76.22	86.79	92.40	0.00	0.00	0.00	0.07	0.00	0.11

3.4 *Posidonia* seagrass

3.4.1 Shoot density

The key results from the shoot density surveys at *Posidonia* bed monitoring sites (PB-) and *Posidonia* patch monitoring sites (PP-) in Baseline 3 (winter 2022) (Figure 6, Table 9) are summarised below:

- All three species of seagrass were detected at the majority of monitoring beds and patches, with *Zostera* and *Halophila* was absent at monitoring beds PB-LP11 and PB-LP12, patches PP-LP01 and PP-LP02, with *Zostera* also absent at beds PB-K10 and PB-K07.
- Average *P. australis* shoot density at *Posidonia* beds at La Perouse and Kurnell ranged between 9.80 shoots per 0.25 m^2 (PB-K05) and 36.20 shoots per 0.25 m^2 (PB-K08).
  - The highest *P. australis* densities were recorded at monitoring sites towards the centre of the main *Posidonia* bed at Kurnell (southwest of the Project Boundary), with the smaller *Posidonia* beds within The Project Boundary and to the east recording lower densities.
  - At La Perouse the monitoring site within the Project Boundary (PB-LP-11) had a lower *P. australis* shoot densities (11.00 shoots per 0.25 m^2) than the control site (PB-LP-12) (21.40 shoots per 0.25 m^2). No *Zostera* or *Halophila* seagrass was recorded at either of the La Perouse monitoring sites in this survey.
- The relative density of *Halophila* was observed to decline in Baseline 3, in many cases to levels below that of Baseline 1, with the decline in Zostera density identified in Baseline 2 (Niche 2022) continuing in Baseline 3.

Further data are provided in Appendix 5.

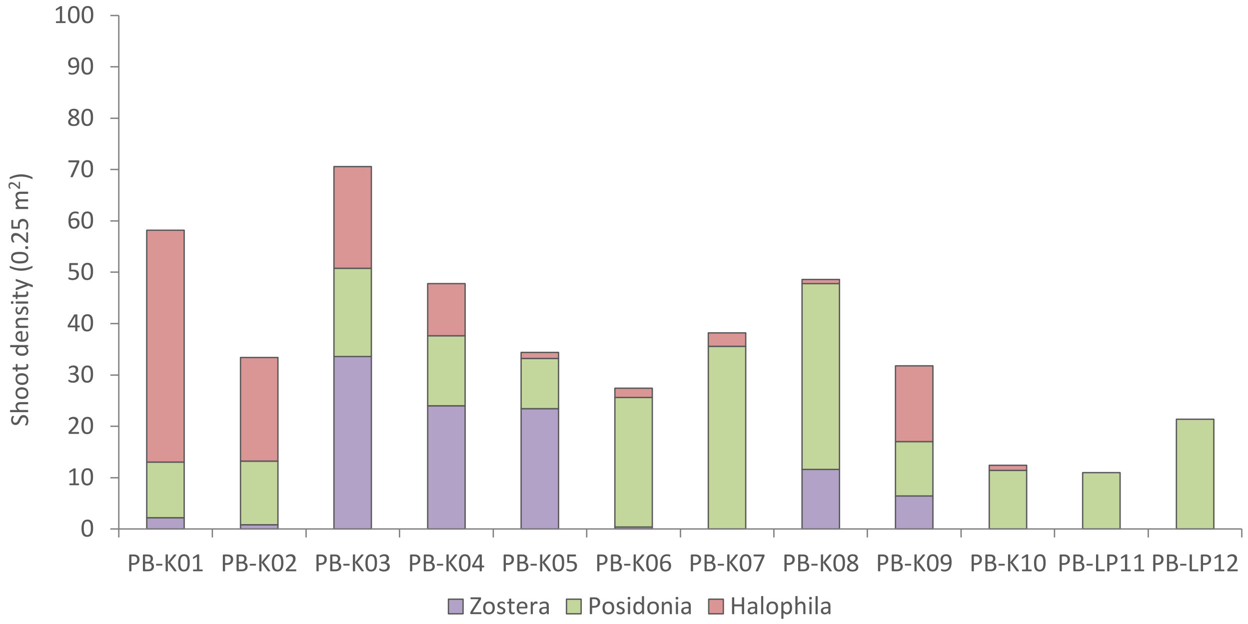

Figure 6: Mean shoot density of seagrass within the *Posidonia* bed monitoring sites in Baseline 3 (winter 2022).

Table 9: Average shoot density recorded at *Posidonia* bed monitoring sites and patches during Baseline 3.

Seagrass	*Halophila* density (0.25 m^2)		*Zostera* density (0.25 m^2)		*Posidonia* density (0.25 m^2)	
	Mean	SE	Mean	SE	Mean	SE
***Posidonia* beds**						
PB-K01	45.20	13.43	2.20	1.28	10.80	1.28
PB-K02	20.20	3.99	0.80	0.80	12.40	1.96
PB-K03	19.80	4.87	33.60	9.17	17.20	2.29
PB-K04	10.20	1.66	24.00	4.28	13.60	0.93
PB-K05	1.20	1.20	23.40	6.01	9.80	2.13
PB-K06	1.80	0.97	0.40	0.40	25.20	1.66
PB-K07	2.60	1.47	0.00	0.00	35.60	4.31
PB-K08	0.80	0.58	11.60	5.01	36.20	3.79
PB-K09	14.80	2.20	6.40	3.39	10.60	0.75
PB-K10	1.00	0.63	0.00	0.00	11.40	0.51
PB-LP11	0.00	0.00	0.00	0.00	11.00	0.84
PB-LP12	0.00	0.00	0.00	0.00	21.40	2.79
***Posidonia* patches**						
PP-K03	8.60	3.03	2.60	1.60	7.40	1.03
PP-K04	1.40	1.40	0.20	0.20	14.00	0.45
PP-K07	2.20	1.43	15.00	7.38	9.80	2.60
PP-K08	6.40	4.53	71.00	22.53	5.80	1.56
PP-K09	6.75	2.14	13.00	3.42	11.00	2.20
PP-K11	15.80	4.39	53.60	7.65	17.40	1.78
PP-LP01	0.00	-	0.00	-	7.75	1.49
PP-LP02	0.00	-	0.00	-	11.75	1.03

The seagrass density results recorded at the *Posidonia* beds during each baseline survey are presented in Figure 7. Key changes and patterns identified across the baseline surveys are:

- Overall, the relative density of *P. australis* across the monitoring beds has regularly shown a trend of decrease or decline the previous survey.
- The density of *P. australis* has been found at most sites to be the greatest in the previous survey (Baseline 2), and lowest in this survey.
- The biggest changes in *P. australis* density have occurred at the Kurnell monitoring sites, this has included PB-K03 and PB-K04, where there have been trends of decline since the first survey (Baseline 1), and PB-K07 and PB-K08 where the density has increased since the first survey.

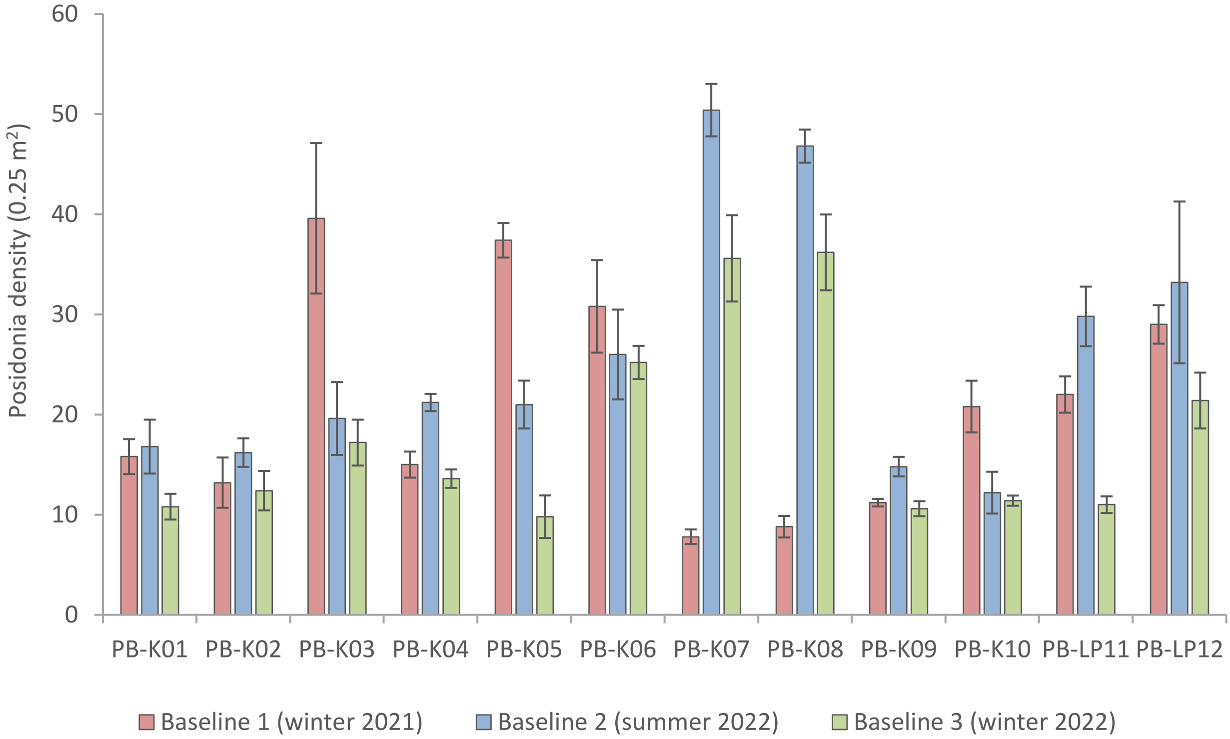

Figure 7: Baseline survey comparison: mean shoot density of seagrass within the *Posidonia* bed monitoring sites).

In Baseline 3, a weak trend of overall increase in *P. australis* density with distance from the Construction Footprint is observed along the outer transect. This is consistent with the pattern observed in previous baseline surveys (Figure 8). A trend of increase in *P. australis* density with distance from the Construction Footprint (Figure 9) are observed along the inner transect. This pattern is consistent with that observed in Baseline 2, but in contrast to Baseline 1 where greater densities were encountered closer to the Construction Footprint.

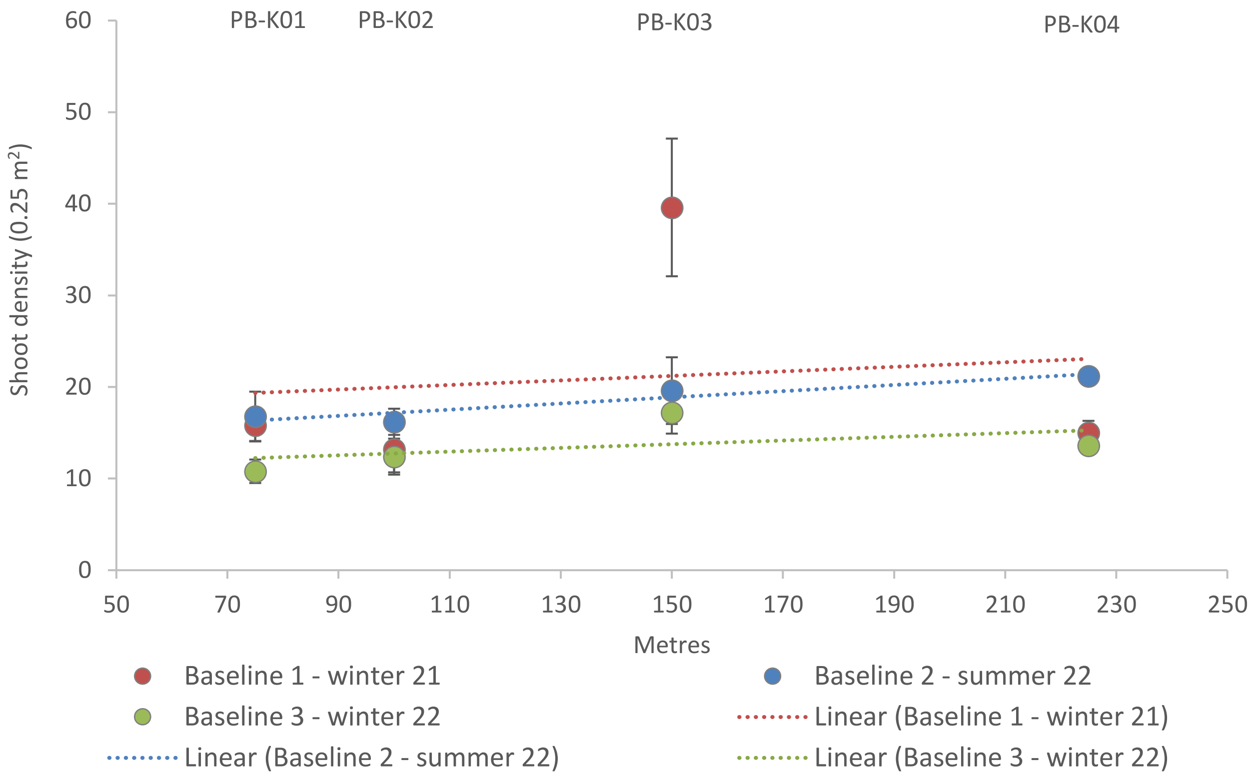

Figure 8: Mean *P. australis* shoot density at *Posidonia* bed monitoring sites (+/-SE), positioned at different distances from the Construction Footprint along the outer transect (PB-K01, PB-K02, PB-K03, PB-K04).

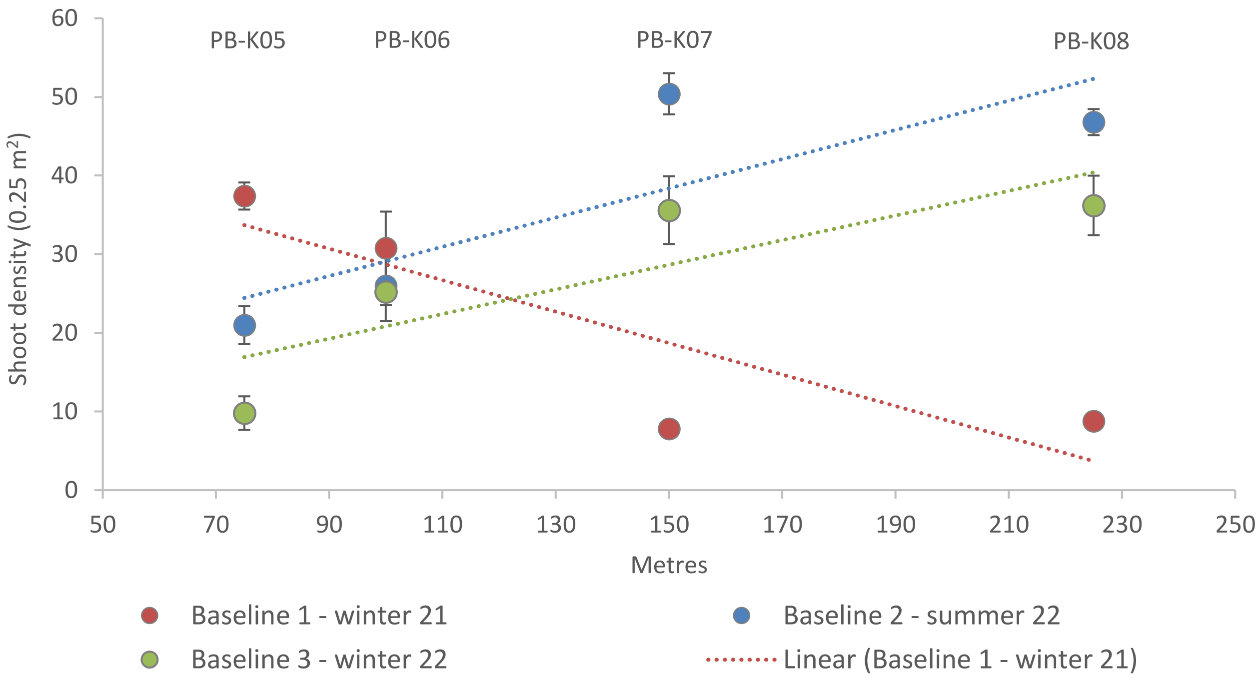

Figure 9: Mean *P. australis* shoot density at *Posidonia* bed monitoring sites (+/-SE), positioned at different distances from the Construction Footprint along the inner transect (PB-K05, PB-K06, PB-K07, PB-K08).

3.4.2 Leaf lengths

The key results for leaf lengths at *Posidonia* bed monitoring sites and patches in the Baseline 3 survey (Table 10, Figure 10) are summarised below:

- Mean leaf lengths for *P. australis* found for this survey were relatively similar irrespective of site or location, ranging between 17.92 cm (PB-K08) and 27.00 cm (PB-K06).
- The monitoring sites at Kurnell PB-K03 and PB-K06 had the longest average *P. australis* leaf lengths in this survey.
- In comparison with previous surveys, *P. australis* leaf lengths were:
  - On average shorter at all monitoring sites in this survey compared with the previous survey.
  - Decreases in mean leaf lengths since the previous survey were most noticeable at the La Perouse monitoring sites in this survey.
- The average leaf lengths found during this survey for *Halophila* ranged between 0.98 (PB-K07) and 2.54 (PB-K06), and *Zostera* ranged between 5.00 (PB-K06, PB-K08) and 12.33 (PP-K04).

Table 10: Mean values for leaf length measurements, visible seagrass sheafs (*P. australis* only) and epiphyte cover scores during Baseline 3 (winter 2022).

Average	Leaf length (cm)			Epiphytic cover score			Sheaf visible (%)
Species	***Halophila***	***Zostera***	***Posidonia***	***Halophila***	***Zostera***	***Posidonia***	***Posidonia***
Posidonia beds							
PB-K01	2.26	5.31	21.40	2.08	2.00	3.58	0.00
PB-K02	2.38	8.50	19.93	2.44	3.00	3.45	25.11
PB-K03	2.20	10.88	25.26	1.98	1.86	3.54	0.00
PB-K04	1.45	9.68	21.34	1.76	1.88	3.56	26.00
PB-K05	2.19	8.04	22.60	1.00	1.64	3.63	14.00
PB-K06	2.54	5.00	27.00	1.70	1.00	3.40	12.00
PB-K07	0.98	-	21.16	1.61	-	3.68	0.00
PB-K08	1.50	5.00	17.92	1.20	1.55	3.52	30.00
PB-K09	2.18	7.33	21.34	2.95	2.59	3.48	0.00
PB-K10	1.92	-	20.24	2.33	-	3.68	0.00
PB-LP11	-	-	19.98	-	-	3.02	14.89
PB-LP12	-	-	25.34	-	-	4.56	0.00
Posidonia beds							
PP-K03	2.38	8.75	25.58	2.72	1.35	2.66	0.00
PP-K04	2.50	12.33	21.52	2.30	1.00	2.68	4.00
PP-K07	2.15	7.89	21.39	2.70	2.30	3.78	0.00
PP-K08	2.12	6.60	22.88	2.32	2.18	3.44	0.00
PP-K09	1.67	7.86	24.39	2.09	2.59	3.73	0.00
PP-K11	1.83	7.32	32.16	1.81	2.34	4.30	0.00
PP-LP01	-	-	21.45	-	-	3.00	2.50
PP-LP02	-	-	21.60	-	-	4.19	0.00

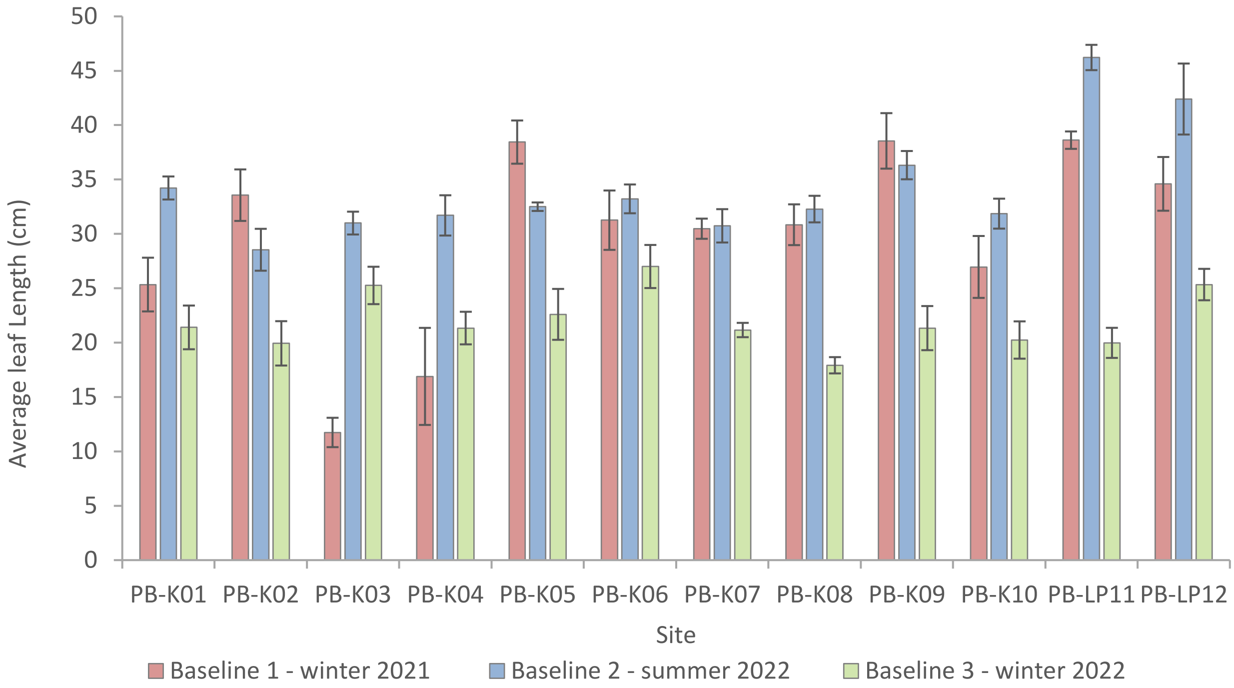

Figure 10: Mean *P. australis* leaf length at the *Posidonia* bed monitoring sites (+/-SE) in Baseline 1, Baseline 2 surveys and Baseline 3 monitoring surveys.

In this survey (Baseline 3), a weak trend of increasing leaf length with from the Construction Footprint along the outer transect was observed (Figure 11). The pattern of increasing leaf length with distance from the Construction Footprint is in contrast to the Baseline 1 and Baseline 2 surveys that have been very variable with distance from the construction footprint (Figure 11). A weak trend of increasing leaf length with distance along the inner transect was also observed (Figure 12). This pattern in Baseline 3 is in contrast to that observed in previous surveys., when weak trends of decreasing leaf length with distance from the Construction Footprint were observed.

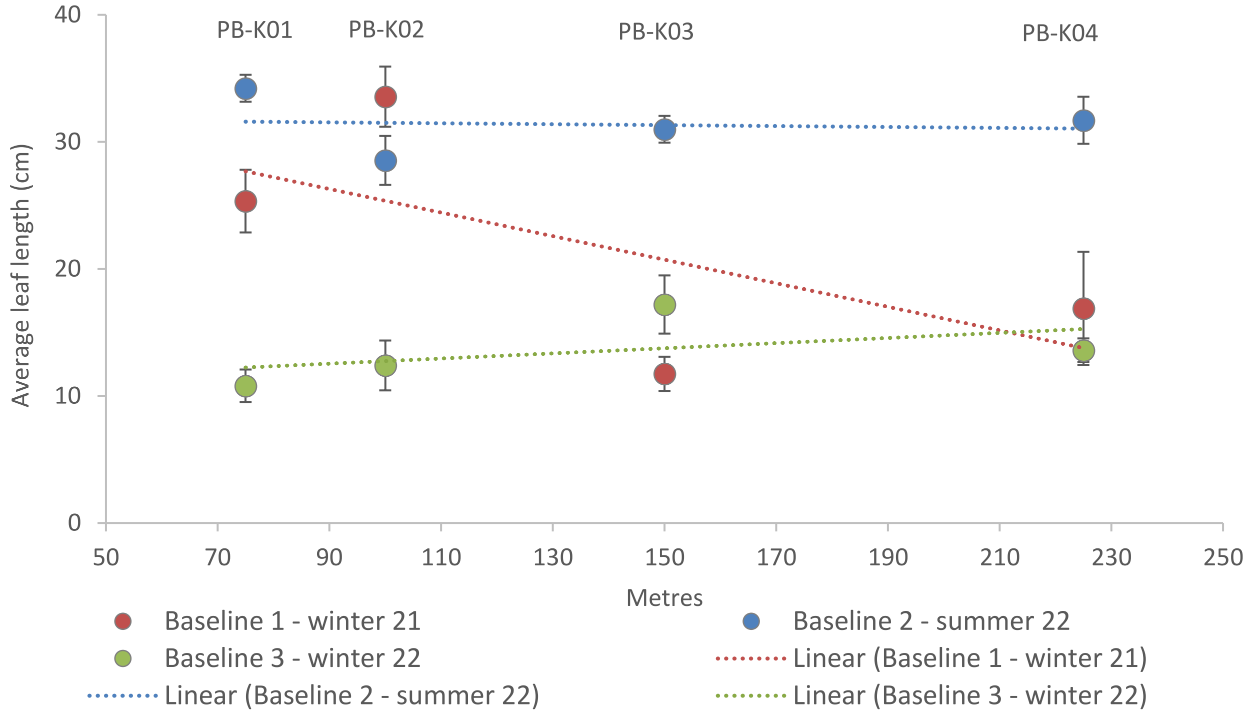

Figure 11: Mean *P. australis* leaf length at *Posidonia* bed monitoring sites (+/-SE), positioned at different distances from the Construction Footprint along the outer transect (PB-K01, PB-K02, PB-K03, PB-K04).

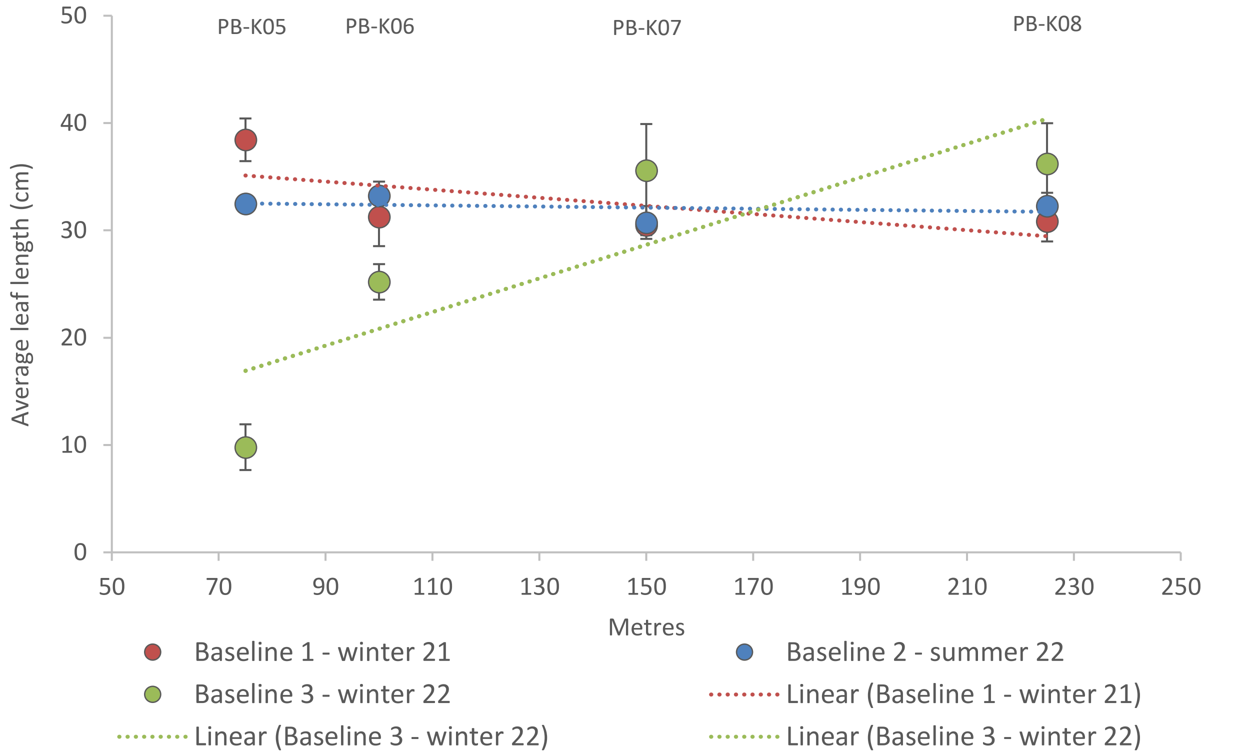

Figure 12: Mean *P. australis* leaf length at *Posidonia* bed monitoring sites (+/-SE), positioned at different distances from the Construction Footprint along the inner transect (PB-K05, PB-K06, PB-K07, PB-K08).

3.4.3 Seagrass sheafs

The average percentage of visible sheafs was found to be highly variable across the sites in Baseline 3 (Table 10). Within the *Posidonia* beds, PB-K8 recorded the highest average percentage of visible sheafs at 30.00% (PB-K8). A number of *Posidonia* beds recorded no visible sheafs (PB-K01, PB-K03, PB-K07, PB-K09, PB-K10, PB-LP12) during Baseline 3. Within the smaller *Posidonia* patches, the average was much lower, with only PP-K04 (4.00%) PP-LP01 (2.50%) recording visible seagrass sheafs.

3.4.4 Epiphyte cover

The epiphyte cover results (Table 10) show that epiphytic growth was found to typically be higher on *P. australis* shoots than on *Halophila* or *Zostera*. The epiphyte cover scores across the *Posidonia* bed and patch monitoring sites ranged between 2.66 (PP-K03) and 4.30 (PP-K11) for *P. australis* in Baseline 3. For *Zostera,* the range was between 1.00 (PB-K06 and PP-K04) and 3.00 (PB-K02). The range for *Halophila* seagrass was between 1.00 (PB-K05) and 2.95 (PB-K09).

4. Discussion

4.1 Significant weather conditions in 2022

Above average rainfall conditions in 2022 have continued through autumn and into winter, with a significant weather event, which include above average rainfall and a large easterly swell in July 2022. This followed above average rainfall over summer and a large easterly swell in early March (Niche 2022). Rainfall associated with these events has resulted in major flood levels in the Georges River and Cooks River that have lowered salinities, increased turbidity levels and reduced light availability with high sediment loads, for extended periods. The large and powerful easterly swells that have been associated with these weather events have also resulted in significant coastal erosion, further increasing sedimentation and reducing water quality and directly impacting on some areas. This, at times, has included directly impacting more exposed areas to the east around Kurnell. At La Perouse, although very protected, refraction of waves back into Frenchman's Bay has also resulted in significant seabed and shoreline disturbances. The results detailed in this round of baseline monitoring survey need to be interpreted with consideration of the significant weather conditions experienced throughout 2022, which have been attributed to the prevailing La Niña weather pattern.

La Niña increases the probability of above average rainfall for eastern Australia during spring and summer seasons and was underway during the Baseline 3 survey (BoM 2022b). This is the third consecutive La Niña event, with the first event occurring between late-September 2020 and March 2021, followed by a second La Niña event from November 2021 to June 2022 (during Baseline survey 2). The occurrence of three La Niña events in a row is uncommon and has previously occurred only three times since records began (1954–57, 1973–76 and 1998–2001).

The BoM Climate Driver Update (BoM 2022b) indicates that La Niña may peak during spring 2022 and return to neutral conditions early in 2023, also that the negative Indian Ocean Dipole (IOD) event currently occurring is likely to persist into late spring, further increasing the chance of above average spring rainfall. It is likely that similar significant weather conditions will persist into summer 2022/2023, i.e. large swells and significant rainfall. As such, it is likely that associated impacts to seagrass will continue, with calmer weather periods that would assist seagrass recovery less likely.

4.2 Seagrass distribution and density

Overall seagrass distribution and density appears to have declined in this survey. These declines amount to a reduction of greater than 50% since the first baseline survey and is in most part due to the declining distribution of *Halophila* and/or *Zostera* seagrass beds. Furthermore, where these *Halophila* and/or *Zostera* seagrass beds have persisted, the seagrass density has also substantially declined to covers of less than 1% at the majority of the monitoring sites. In Botany Bay, these Z*ostera* and *Halophila* beds are known to be highly variable in distribution, species composition and density (Larkum and West 1990). Both *Zostera* and *Halophila* seagrasses can re-establish areas quickly from floating vegetative material or the seed bank (Larkum and West 1990, Inglis 1999, Cumming et al 2017), show high levels of seasonal variability (Cardno 2018), and may undergo larges reductions in distribution following weather events (Larkum and West 1990, Rasheed et al 2014). The high variability in distribution and more seasonal nature of *Halophila* and *Zostera* seagrasses, as well as the relatively short leaf lengths of *Zostera* within the Project Area indicates that these beds are not representative of stable and established seagrass habitats and beds. As a result, they are likely to have less developed and shallower rhizomes systems that anchor them into the seabed, making them more vulnerable to disturbances from storm events. Furthermore, weather events have had prolonged impacts on water quality and environmental conditions significant for the persistence of these seagrasses around the deeper fringes of their distribution within Botany Bay. These weather events that have coincided with the seasonal reduction in biomass of *Zostera* during the winter months (West 2000) and although less documented, *Halophila* in Botany Bay (Cummings Pers. Obs) is likely responsible for these large reductions in seagrass distribution and cover detected during this baseline survey.

Declines in *P. australis* distribution are of a much lesser magnitude and in most part confined to Kurnell. The lesser impact of these weather events on *P. australis* distribution is likely reflective of the deeper and much greater biomass of rhizomes of this species, which likely provide greater resilience to such disturbances. While an overall decline in distribution was detected, the mapped area of *P. australis* within the Buffer Area at Kurnell increased. These fine scale changes are likely as much a measure of mapping limitations of the Baseline 3 winter survey then actual distribution changes. Due to the patchiness of *P. australis* at Kurnell, especially within the Construction Footprint and Buffer area, the ability to supplement the wide scale mapping data with detailed notes and perimeter mapping of these smaller *P. australis* patches, was much more limited during this survey than in previous surveys. This is because this survey had to be completed during very poor in-water conditions. As a result, delineation between the boundaries of *P. australis* and other seagrasses, soft sediment and reef, which is normally much clearer (in both aerial imagery and during *in situ* observations), was not as clear and buffering between observations in some instances needed to be more conservative. For the final baseline survey, additional in-water observations to accurately map the perimeters of these small patches may be required.

Although *P. australis* distribution changes are considered relatively minimal this survey, a strong trend of reduced biomass was evident. With lesser shoot densities and reduced leaf lengths at the majority of sites. This is likely reflective of the poor environmental conditions for growth as a result of water quality disturbances e.g. reduced available light (Larkum 1976) and physical disturbances during these weather events from sedimentation and seabed disturbance.

In conclusion, seagrasses within the Project Boundary have substantially reduced, with the majority of this reduction associated with *Halophila* and *Zostera* beds. Changes in *P. australis* distribution are much lesser and more variable, although a reduction in biomass does appear to be more evident. These changes are likely the result of seasonal reductions in biomass and weather event related disturbances.

In summary, the total area of seagrasses that were mapped in this survey within the Construction Footprint (area of direct impacts) amounted to 823 m^2, while there was an additional 3,938 m^2 within the Buffer area (area of indirect impacts). For *P. australis* this was limited to 5 m^2 (at Kurnell only) within the Construction footprint and an additional 263 m^2 within the Buffer Area.

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6. Plates

Plate 1: Survey equipment and methodologies a) Towed camera used to map seagrasses, b) Drop camera used to collect photoquadrats, c) CPCe digital photoquadrat analysis screen, d) DoD rod installed within the main *P. australis* seagrass bed at Kurnell, e) dive survey, f) 0.25 m^2 quadrat.

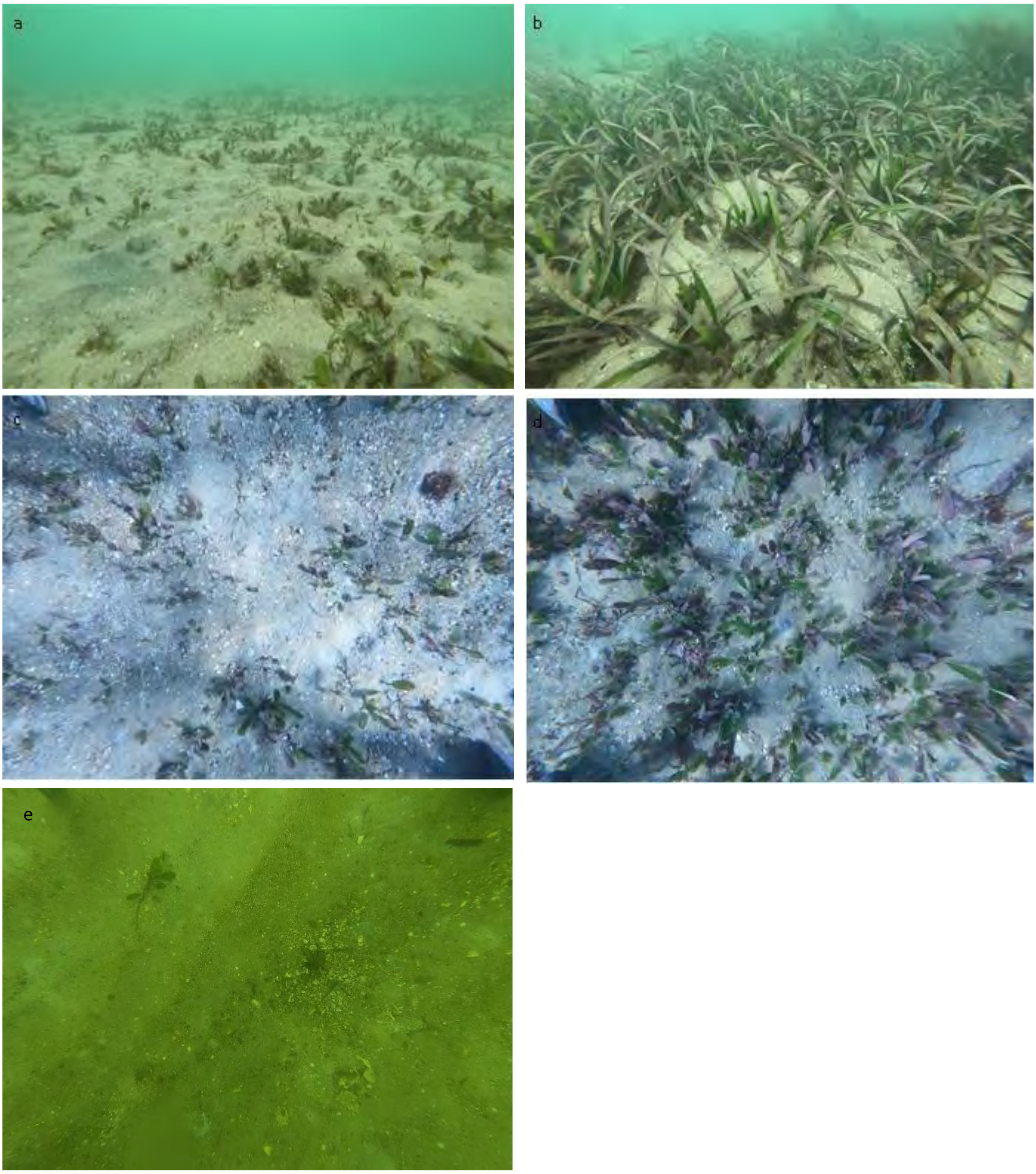


Plate 2: Seagrasses in the Project Area at La Perouse, a) Low density *Halophila* dominated seagrass within *Zostera / Halophila* beds, b) *Posidonia australis*, c) low density *Halophila*, d) medium density *Halophila*, e) reduced *Halophila* density in summer 2022 (HZ-LP02), previously *Zostera / Halophila* in winter 2021 (Niche 2021a).

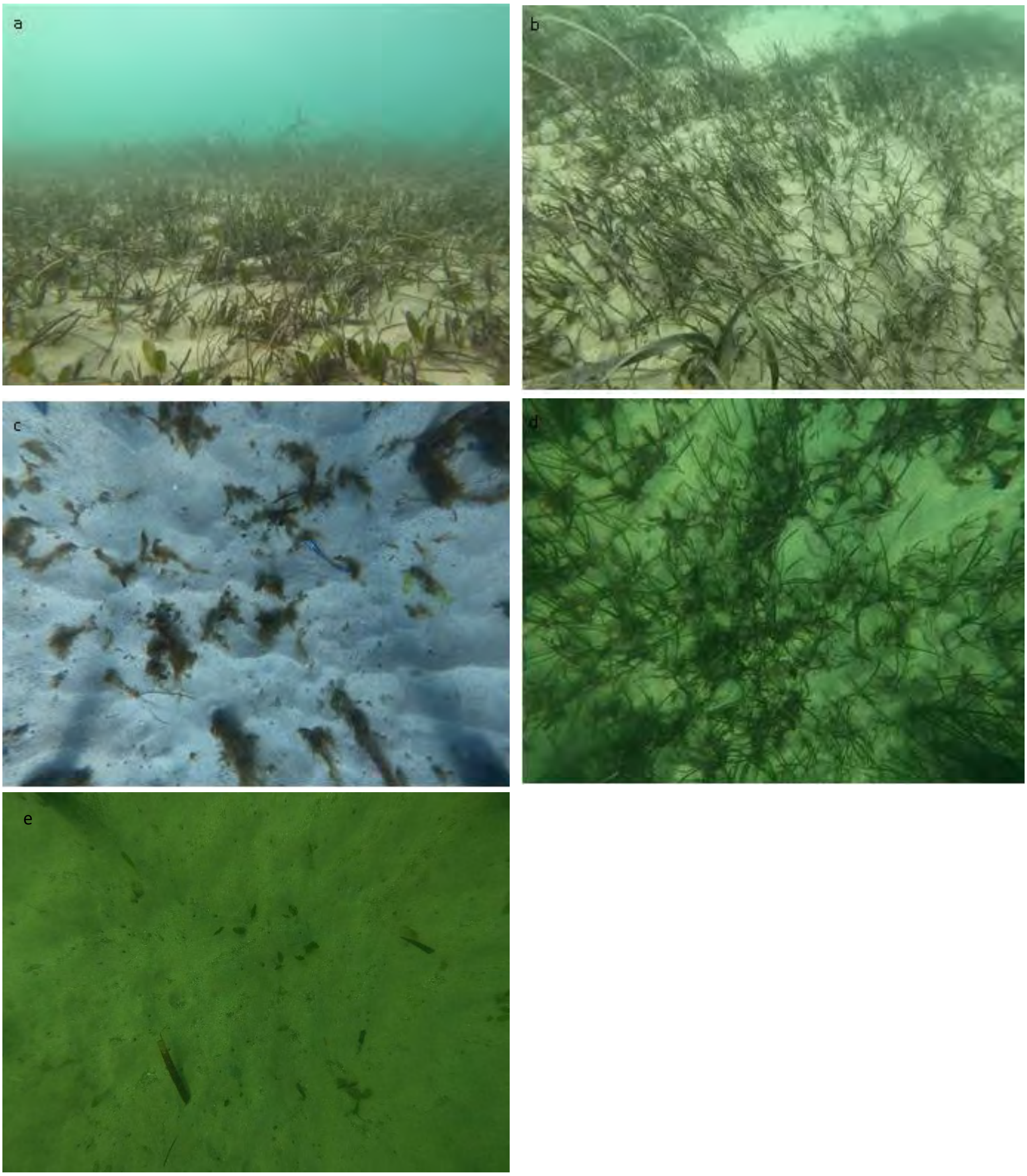
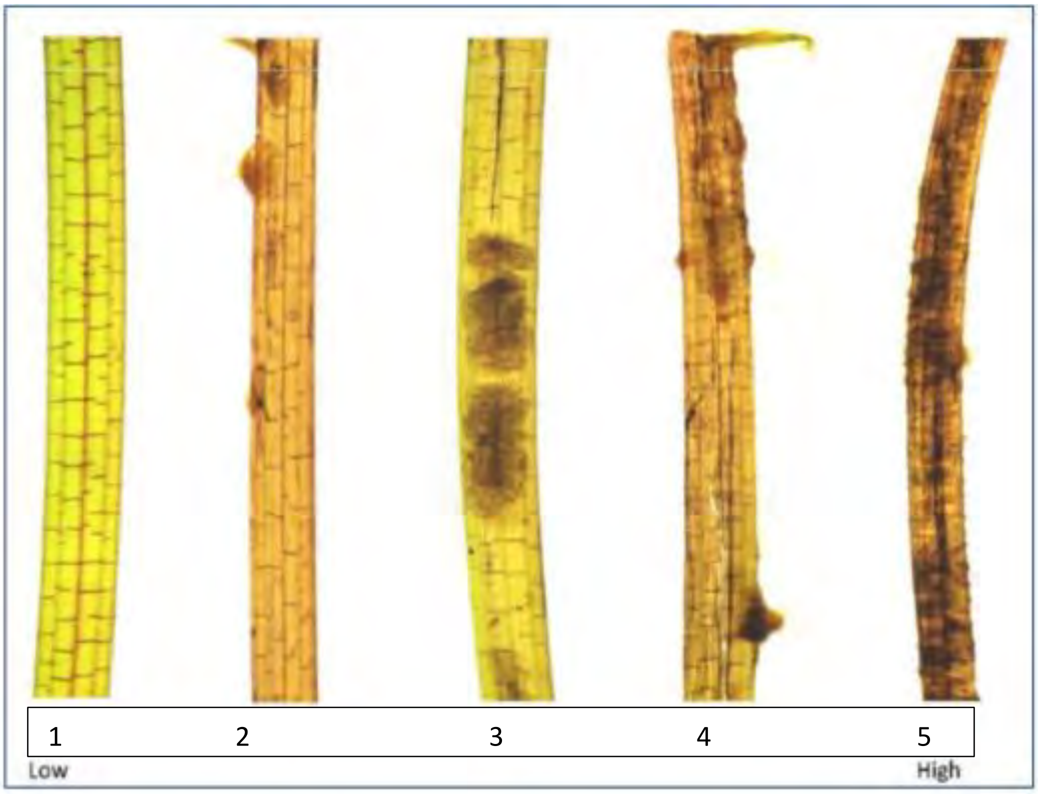


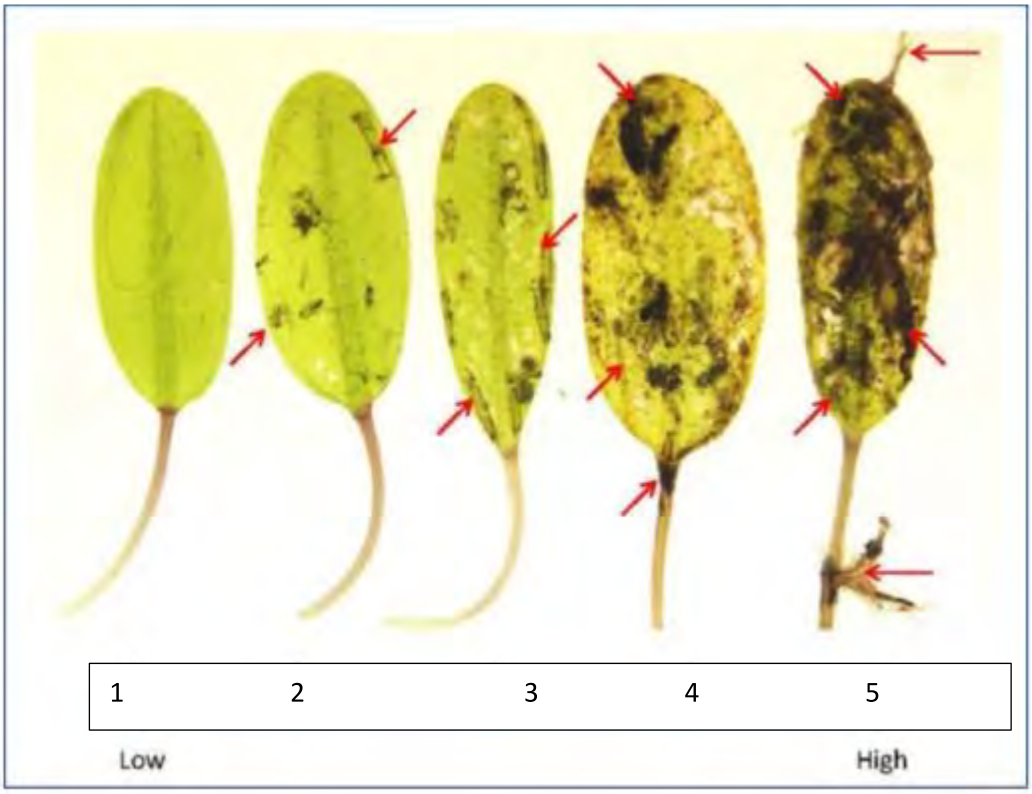
Plate 3: Seagrasses in the Project Area at Kurnell, a) Medium density *Zostera* dominated seagrass within *Zostera* / *Halophila* beds with *P. australis* in the background, b) Medium density *Zostera* dominated seagrass within *Zostera* / *Halophila* beds adjoining a low density patch of *P. australis*, c) low density *Halophila* with heavy epiphytic fouling and d) Medium density *Zostera* dominated seagrass within *Zostera / Halophila* bed in shallow areas close to the proposal footprint, e) reduced *Halophila* density in summer 2022 (HZ-K07).

Appendix 1: Monitoring site locations

Site	Location	Purpose	Easting (GDA94 MGA56)	Northing (GDA94 MGA56)
***Halophila / Zostera* monitoring (drop camera)**				
HZ-LP01	La Perouse	Potential impact	336429.98	6237907.4
HZ-LP02	La Perouse	Potential impact	336516.36	6237871.92
HZ-LP03	La Perouse	Control	336438.35	6238037.7
HZ-LP04	La Perouse	Control	336317.97	6238009.92
HZ-K05	Kurnell	Potential impact	335274.25	6236137.09
HZ-K06	Kurnell	Potential impact	335344.73	6236180.62
HZ-K07	Kurnell	Control	335437.75	6236230.96
HZ-K08	Kurnell	Control	335164.51	6236149.72
HZ-K09	Kurnell	Potential impact	335310.06	6236050.64
HZ-K10	Kurnell	Potential impact	335383.27	6236105.94
***Posidonia* bed monitoring (ADAS scientific divers)**				
PB-K01	Kurnell	Potential impact	335263.13	6236095.86
PB-K02	Kurnell	Potential impact	335234.62	6236085.28
PB-K03	Kurnell	Potential impact, possible control	335189.91	6236071.11
PB-K04	Kurnell	Potential impact, possible control	335127.2	6236041.22
PB-K05	Kurnell	Potential impact	335315.43	6236006.55
PB-K06	Kurnell	Potential impact	335287.92	6235986.41
PB-K07	Kurnell	Potential impact, possible control	335250.49	6235967.27
PB-K08	Kurnell	Potential impact, possible control	335173.89	6235927.58
PB-K09	Kurnell	Potential impact	335326.24	6236087.61
PB-K10	Kurnell	Potential impact, possible control	335417.71	6236193.76
PB-LP11	La Perouse	Potential impact	336545.65	6237861.53
PB-LP12	La Perouse	Control	336578.02	6238082.55
***Posidonia* patch monitoring (ADAS scientific divers)**				
PP-LP01	La Perouse	Potential impact	336506.15	6237863.79
PP-LP02	La Perouse	Potential impact	336533.9	6237847.83
PP-K03	Kurnell	Potential impact	335367.57	6236122.05
PP-K04	Kurnell	Potential impact	335346.18	6236109.77
PP-K07	Kurnell	Potential impact	335340.22	6236069.58
PP-K08	Kurnell	Potential impact	335355.6	6236062.17
PP-K09	Kurnell	Potential impact	335366.1	6236071.99
PP-K11	Kurnell	Potential impact	335370.57	6236060.62

Appendix 2: Epiphyte Loading Scale





Appendix 3: Seagrass mapping results Baseline 1 - Baseline 3

Baseline 1 - Baseline 3: seagrass mapping results

Area (m^2)	Baseline 1 (winter 2021)			Baseline 2 (summer 2022)			Baseline 3 (winter 2022)		
	Kurnell	La Perouse	Total	Kurnell	La Perouse	Total	Kurnell	La Perouse	Total
Project Boundary									
Posidonia	2864	0	2864	3555	0	3555	19	137	156
Posidonia / Halophila	843	170	1013	838	0	838	3175	0	3175
Posidonia / Zostera	0	0	0	0	0	0	85	0	85
Posidonia Mixed	772	0	772	484	132	616	1083	0	1083
Zostera	199	0	199	0	0	0	247	135	382
Zostera / Halophila	27243	6417	33660	2246	7704	9951	7728	295	8023
Halophila	1874	25340	27214	19258	17252	36510	5880	9073	14952
Rock / Rubble / Reef	-	-	-	-	-	-	5959	9463	15421
Sand or silt	-	-	-	-	-	-	22140	42777	64917
Subtotal Posidonia combined	*4479*	*170*	*4649*	*4877*	*132*	*5009*	*4362*	*137*	*4499*
Subtotal Zostera combined	*27442*	*6417*	*33859*	*2246*	*7704*	*9951*	*7975*	*430*	*8405*
Subtotal Halophila combined	*29117*	*31757*	*60874*	*21504*	*24956*	*46461*	*13607*	*9368*	*22976*
Total seagrass combined	*33795*	*31927*	*65722*	*26381*	*25089*	*51469*	*18217*	*9640*	*27857*
Construction Footprint									
Posidonia	4	0	4	0	0	0	0.00	0.00	0.00
Posidonia / Halophila	16	0	16	14	0	14	5.11	0.00	5.11
Posidonia / Zostera	0	0	0	0	0	0	0.00	0.00	0.00
Posidonia Mixed	0	0	0	0	0	0	0.00	0.00	0.00
Zostera	52	0	52	0	0	0	17.86	0.00	17.86
Zostera / Halophila	867	0	867	42	0	42	365.41	0.00	365.41
Halophila	57	991	1048	985	676	1661	435.07	0.00	435.07

Area (m^2)	Baseline 1 (winter 2021)			Baseline 2 (summer 2022)			Baseline 3 (winter 2022)		
	Kurnell	La Perouse	Total	Kurnell	La Perouse	Total	Kurnell	La Perouse	Total
Rock / Rubble / Reef	-	-	-	-	-	-	228.59	518.80	747.39
Sand or silt	-	-	-	-	-	-	273.65	1035.43	1309.08
Subtotal Posidonia combined	*20*	*0*	*20*	*14*	*0*	*14*	*5*	*0*	*5*
Subtotal Zostera combined	*919*	*0*	*919*	*42*	*0*	*42*	*383*	*0*	*383*
Subtotal Halophila combined	*924*	*991*	*1915*	*1027*	*676*	*1703*	*800*	*0*	*800*
Total seagrass combined	*996*	*991*	*1987*	*1042*	*676*	*1718*	*823*	*0*	*823*
Buffer area									
Posidonia	70	0	70	106	0	106	6.28	0.00	6.28
Posidonia / Halophila	22	0	22	23	0	23	65.26	0.00	65.26
Posidonia / Zostera	0	0	0	0	0	0	48.97	0.00	48.97
Posidonia Mixed	136	0	136	91	0	91	142.60	0.00	142.60
Zostera	146	0	146	0	0	0	22.13	0.00	22.13
Zostera / Halophila	3745	52	3797	7	0	7	1690.77	0.00	1690.77
Halophila	84	3474	3558	4358	2499	6858	1884.08	77.55	1961.63
Rock / Rubble / Reef	-	-	-	-	-	-	1695.96	1626.12	3322.08
Sand or silt	-	-	-	-	-	-	1635.59	3736.03	5371.62
Subtotal Posidonia combined	*228*	*0*	*228*	*220*	*0*	*220*	*263*	*0*	*263*
Subtotal Zostera combined	*3891*	*52*	*3943*	*7*	*0*	*7*	*1713*	*0*	*1713*
Subtotal Halophila combined	*3829*	*3526*	*7355*	*4365*	*2499*	*6865*	*3575*	*78*	*3652*
Total seagrass combined	*4203*	*3526*	*7729*	*4585*	*2499*	*7085*	*3860*	*78*	*3938*

Appendix 4: Summary drop camera survey results collected during Baseline 3

Baseline 3: drop camera survey results (winter 2022)

Site	MACROALGAE (MA)		SEAGRASS (S)		SUBSTRATE (SU)		*Posidonia australis* (PA)		*Zostera capricorni* (ZC)		*Halophila* sp. (HS)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
HZ-LP01	0.11	0.02	0.00	0.00	99.56	18.18	0.00	0.00	0.00	0.00	0.00	0.00
HZ-LP02	0.45	0.08	0.11	0.02	99.33	18.14	0.00	0.00	0.00	0.00	0.11	0.02
HZ-LP03	0.11	0.02	1.56	0.28	98.00	17.89	0.00	0.00	0.11	0.02	1.45	0.26
HZ-LP04	0.33	0.06	0.11	0.02	99.11	18.10	0.00	0.00	0.00	0.00	0.11	0.02
HZ-K05	0.55	0.10	0.22	0.04	97.93	17.88	0.00	0.00	0.00	0.00	0.22	0.04
HZ-K06	0.55	0.10	0.22	0.04	97.93	17.88	0.00	0.00	0.00	0.00	0.22	0.04
HZ-K07	0.33	0.06	0.11	0.02	99.56	18.18	0.00	0.00	0.00	0.00	0.11	0.02
HZ-K08	3.13	0.57	0.22	0.04	96.43	17.61	0.00	0.00	0.22	0.04	0.00	0.00
HZ-K09	2.23	0.41	3.46	0.63	93.76	17.12	0.00	0.00	2.90	0.53	0.56	0.10
HZ-K10	0.67	0.12	2.91	0.53	96.31	17.58	0.00	0.00	2.01	0.37	0.89	0.16

Site	Epiphytic Algae (EA)		Turfing Algae (TA)		Sand Silt (SS)	
	Mean	SE	Mean	SE	Mean	SE
HZ-LP01	0.00	0.00	0.33	0.06	85.43	15.60
HZ-LP02	0.00	0.00	0.11	0.02	93.30	17.03
HZ-LP03	0.00	0.00	0.33	0.06	92.65	16.92
HZ-LP04	0.00	0.00	0.44	0.08	82.78	15.11
HZ-K05	0.00	0.00	1.31	0.24	90.40	16.51
HZ-K06	0.00	0.00	1.31	0.24	90.40	16.51
HZ-K07	0.00	0.00	0.00	0.00	99.33	18.14
HZ-K08	0.00	0.00	0.22	0.04	95.87	17.50
HZ-K09	0.45	0.08	0.11	0.02	90.75	16.57
HZ-K10	0.11	0.02	0.00	0.00	92.40	16.87

Appendix 5: Summary *Posidonia* bed and patch monitoring data

Baseline 1 - Baseline 3: Average shoot density results (0.25 m^2)

Survey	Baseline 1 (winter 2021)			Baseline 2 (summer 2022)			Baseline 3 (winter 2022)		
Species	*Halophila*	*Zostera*	*Posidonia*	*Halophila*	*Zostera*	*Posidonia*	*Halophila*	*Zostera*	*Posidonia*
PB-K01	15.2	15.8	15.8	124.8	0.8	16.8	45.2	2.2	10.8
PB-K02	35.2	109.6	13.2	335.2	0.0	16.2	20.2	0.8	12.4
PB-K03	19.2	24.8	39.6	113.6	78.4	19.6	19.8	33.6	17.2
PB-K04	43.2	68.8	15.0	145.6	76.0	21.2	10.2	24	13.6
PB-K05	56.0	42.4	37.4	217.6	137.6	21.0	1.2	23.4	9.8
PB-K06	24.8	19.2	30.8	112.8	62.4	26.0	1.8	0.4	25.2
PB-K07	2.4	12.0	7.8	139.2	33.6	50.4	2.6	0	35.6
PB-K08	12.0	37.6	8.8	58.4	20.8	46.8	0.8	11.6	36.2
PB-K09	19.2	62.4	11.2	164.8	0.8	14.8	14.8	6.4	10.6
PB-K10	34.4	24.0	20.8	108.8	2.4	12.2	1	0	11.4
PB-LP11	44.0	4.8	22.0	96.0	0.0	29.8	0	0	11
PB-LP12	5.6	4.0	29.0	28.8	6.4	33.2	0	0	21.4
PP-K03	32.8	32.8	17.4	428.0	4.8	12.4	8.6	2.6	7.4
PP-K04	83.2	62.4	13.0	230.4	4.0	12.8	1.4	0.2	14.0
PP-K07	155.0	146.0	6.5	322.0	7.0	16.0	2.2	15.0	9.8
PP-K08	50.7	104.0	13.0	220.0	12.0	14.3	6.4	71.0	5.8
PP-K09	24.0	71.0	13.0	110.0	52.0	15.3	6.8	13.0	11.0
PP-K11	42.0	76.0	17.3	184.0	22.0	20.0	15.8	53.6	17.4
PP-LP01	140.0	4.0	12.0	152.0	0.0	13.0	0.0	0.0	7.8
PP-LP02	97.3	13.3	15.3	128.0	0.0	24.7	0.0	0.0	11.8

Baseline 1 - Baseline 3: Average leaf length, epiphytic cover and visible sheaf results (0.25 m²)

Season	Baseline 1 (winter 2021)						Baseline 2 (summer 2022)						Baseline 3 (winter 2022)						
Average	Leaf length (cm)		Epiphytic cover score			Sheaf visible (%)	Leaf length (cm)		Epiphytic cover score			Sheaf visible (%)	Leaf length (cm)			Epiphytic cover score			Sheaf visible (%)
Species	*Posidonia*	*Zostera*	*Halophila*	*Zostera*	*Posidonia*	*Posidonia*	*Posidonia*	*Zostera*	*Halophila*	*Zostera*	*Posidonia*	*Posidonia*	*Halophila*	*Zostera*	*Posidonia*	*Halophila*	*Zostera*	*Posidonia*	*Posidonia*
PB-K01	25.3	5.3	2.2	2.7	2	46	34.2	16	2.8	4	4.1	34	2.26	5.31	21.40	2.08	2.00	3.58	0.00
PB-K02	33.6	8.7	2.6	1.7	3	43	28.5	N.D.	2.2	N.D.	3.3	12	2.38	8.50	19.93	2.44	3.00	3.45	25.11
PB-K03	11.7	30.6	2.5	3.3	2	42	31	11.3	2.7	3	4.3	28	2.20	10.88	25.26	1.98	1.86	3.54	0.00
PB-K04	16.9	29.1	3	3	3.3	0	31.7	13.6	2.3	2.5	3.8	12	1.45	9.68	21.34	1.76	1.88	3.56	26.00
PB-K05	38.4	5.5	2.6	1.3	3	68	32.5	9.1	2.7	2.6	3.9	18	2.19	8.04	22.60	1.00	1.64	3.63	14.00
PB-K06	31.3	9.2	3.1	1.5	3.7	44	33.2	7.5	3.2	2.6	4.4	34	2.54	5.00	27.00	1.70	1.00	3.40	12.00
PB-K07	30.5	10.5	4	1.7	3.6	41	30.7	10.4	2.8	2.1	4.2	30	0.98	0.00	21.16	1.61	0.00	3.68	0.00
PB-K08	30.8	10.4	3.6	1.9	3.8	47	32.3	16.1	2.5	3.6	4.4	88	1.50	5.00	17.92	1.20	1.55	3.52	30.00
PB-K09	38.6	15.2	2.5	2.1	3.8	4	36.3	12.6	2.6	2.4	4.1	24	2.18	7.33	21.34	2.95	2.59	3.48	0.00
PB-K10	27	4.2	3.9	2.9	3.8	55	31.9	14.7	2.6	2.1	4.4	6	1.92	0.00	20.24	2.33	N.D.	3.68	0.00
PB-LP11	38.6	4.4	2.3	1.7	2.2	6	46.2	N.D.	3.3	N.D.	3	50	N.D.	N.D.	19.98	N.D.	N.D.	3.02	14.89
PB-LP12	34.6	4.6	2.9	2.8	3.9	50	42.4	12.2	1.9	1.7	2.9	28	N.D.	N.D.	25.34	N.D.	N.D.	4.56	0.00
PP-K03	36.9	6.2	4.1	N.D.	4.2	46	27.8	N.D.	2.3	N.D.	3.7	10	2.38	8.75	25.58	2.72	N.D.	2.66	0.00
PP-K04	27.7	8.7	3.4	N.D.	4.1	N.D.	38.4	N.D.	2.9	N.D.	4.2	32	2.50	12.33	21.52	2.30	N.D.	2.68	4.00
PP-K07	34.8	9.9	2.1	N.D.	2.2	15	30.6	N.D.	2.4	N.D.	3.6	35	2.15	7.89	21.39	2.70	N.D.	3.78	0.00
PP-K08	37	11.9	3	N.D.	4.1	0	37	N.D.	2.6	N.D.	4.2	46	2.12	6.60	22.88	2.32	N.D.	3.44	0.00
PP-K09	37.1	11.7	3.7	N.D.	4	68	33	N.D.	2.3	N.D.	3.7	73	1.67	7.86	24.39	2.09	N.D.	3.73	0.00
PP-K11	58.5	10.1	2.6	N.D.	3	25	42	N.D.	2.3	N.D.	4.3	15	0.00	0.00	32.16	1.81	N.D.	4.30	0.00
PP-LP01	32.7	13.9	1.7	2	2.3	31	35.8	N.D.	3.1	N.D.	3.5	75	N.D.	N.D.	21.45	N.D.	N.D.	3.00	2.50
PP-LP02	27.2	2.1	1.8	N.D.	1.9	3	39	0	3.4	0	3	40	N.D.	N.D.	21.60	N.D.	N.D.	4.19	0.00

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Heritage management
Aboriginal heritage
Historical heritage
Conservation management
Community consultation
Archaeological, built and landscape values

Environmental management and approvals
Impact assessments
Development and activity approvals
Rehabilitation
Stakeholder consultation and facilitation
Project management

Environmental offsetting
Offset strategy and assessment (NSW, QLD, Commonwealth)
Accredited BAM assessors (NSW)
Biodiversity Stewardship Site Agreements (NSW)
Offset site establishment and management
Offset brokerage
Advanced Offset establishment (QLD)