Seagrass Distribution

Cook Island Aquatic Reserve, November 2024

Prepared for: Transport for New South Wales

Prepared by Ecological Service Professionals Pty Ltd

January 2025

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Document Control

Report Title: Seagrass Distribution: Cook Island Aquatic Reserve, November 2024

Project Reference: 2440

Client: Transport for New South Wales

Client Contact: Sarah Dobe

Report Status	Version Number	Date Submitted	Authored By	Reviewed By	Issued By	Comment
Draft	2440.001V1	17/01/2025	S Walker L West	L West	L West	Draft for client review
Final	2440.001V2	31/01/2025	L West	S Walker	S Walker	Final report

Acknowledgement of Country: In the spirit of reconciliation Ecological Service Professionals acknowledges the Kombumerri and Minjungbal peoples, the Traditional Custodians of country where we have worked, and we recognise their connection to land, sea and community. We pay our respect to their Elders past and present and extend that respect to all Aboriginal and Torres Strait Islander peoples through our scientific work on country.

File Name: 2440.001V2_CI_Seagrass.docx

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Executive Summary

Ecological Service Professionals Pty Ltd (ESP) was commissioned by Transport for New South Wales (NSW) to complete a field survey to quantify the extent and coverage of seagrass around Cook Island. To do this, a benthic survey using remote techniques was completed on 8 November 2024 to map the distribution, coverage and condition of seagrass around Cook Island.

Seagrass has historically been recorded on the north-western side of Cook Island since 2020, with the distribution first mapped in November 2023. Based on qualitative survey data collected between 2020 and 2023, seagrass on the north-western side of Cook Island was dominated by *Halophila ovalis,* with the extent and coverage varying over time. In July 2020 and May 2021, the seagrass on the north-western side of Cook Island covered approximately 30% to 50% of the sediment within each small patch. In June 2021 and May 2023, while seagrass patches were still present in this area, the coverage had declined to approximately 10% or less.

The benthic survey in November 2024, recorded seagrass on the north-western and south-western sides of Cook Island (in approximately 7 to 9 m water depth). It covered a total area of 1,633 m^2, which was much larger than measured in November 2023 (958 m^2). Communities were also typically denser and more continuous in November 2024 compared to November 2023. The overall condition of seagrass was generally good, with the patches likely to persist over time despite variations in the overall extent and coverage.

On the north-western side of Cook Island, seagrass was recorded in patches between macroalgae, rock and rubble on sand habitats. The community was dominated by *H. ovalis* in fair to good condition, with coverage of patches ranging between 10% and 60%. On the south-western side of Cook Island, seagrass was more continuous and had a much greater extent than on the north-western side. The community was typically dominated by a mixed community of *H. ovalis*, *Zostera muelleri* and / or *Halodule uninervis* (Figure 3.5), with smaller areas were *H. ovalis* occurred alone. Coverage of seagrass on the south-western side of Cook Island was moderate to dense (20 – 80% coverage), with the greatest density occurring along the fringe of the rocky reef, creating a distinct band between the seagrass and bare sand in some areas.

Changes in the extent and coverage of seagrass may be due to natural variation (e.g. from catchment runoff and associated changes in light and water quality) as well as human activity (e.g. from deposition of dredge spoil, coastal development, shoreline modification, pollution, boating and incidental anchoring). Given the spatial variability in the extent and coverage of seagrass over time and limited suitability of comparative sites (as offshore seagrass in the region is scarce), ongoing annual monitoring (ideally in the month of November) to confirm the extent and coverage of seagrass around Cook Island is recommended.

1 Introduction

1.1 Background

The Tweed Sand Bypassing (TSB) project is a joint initiative of the New South Wales (NSW) and Queensland State Governments, with the objectives to establish and maintain the entrance to the Tweed River, and to restore and maintain coastal sand drift to the Southern Gold Coast beaches. Part of the TSB project is achieved via a fixed sand bypass system that pumps sand from a jetty on the southern side of the Tweed River, under the river through a series of buried pipelines, to four outlets on the northern side of the river. Supplementary dredging to clear the Tweed River entrance is also commissioned by TSB when required.

When dredging occurs, the dredge deposits sand in approved placement areas along the Tweed Coast and Southern Gold Coast (Figure 1.1). In 2019, additional placement areas at Fingal and Dreamtime were approved to provide greater flexibility in TSB operations. These areas are located near the Cook Island Aquatic Reserve, which is managed under the *Marine Estate Management Act 2014* to protect marine biodiversity and to support marine science, recreation and education. Prior to approval of the Dreamtime and Letitia deposition areas, a Review of Environmental Factors (REF) completed in 2019 stated *the habitat in the proposal area and adjacent habitats is a high energy coastal area of open beach that is not suitable for the establishment of seagrass* (APP 2019). However, since the REF, seagrass has been observed on the north-western side of Cook Island by local divers and by Ecological Service Professionals Pty Ltd (ESP) during the TSB Reef Monitoring Program (ESP 2020; ESP 2021; ESP 2022; ESP 2023; ESP 2024). As such, the extent and distribution of seagrass was mapped in November 2023.

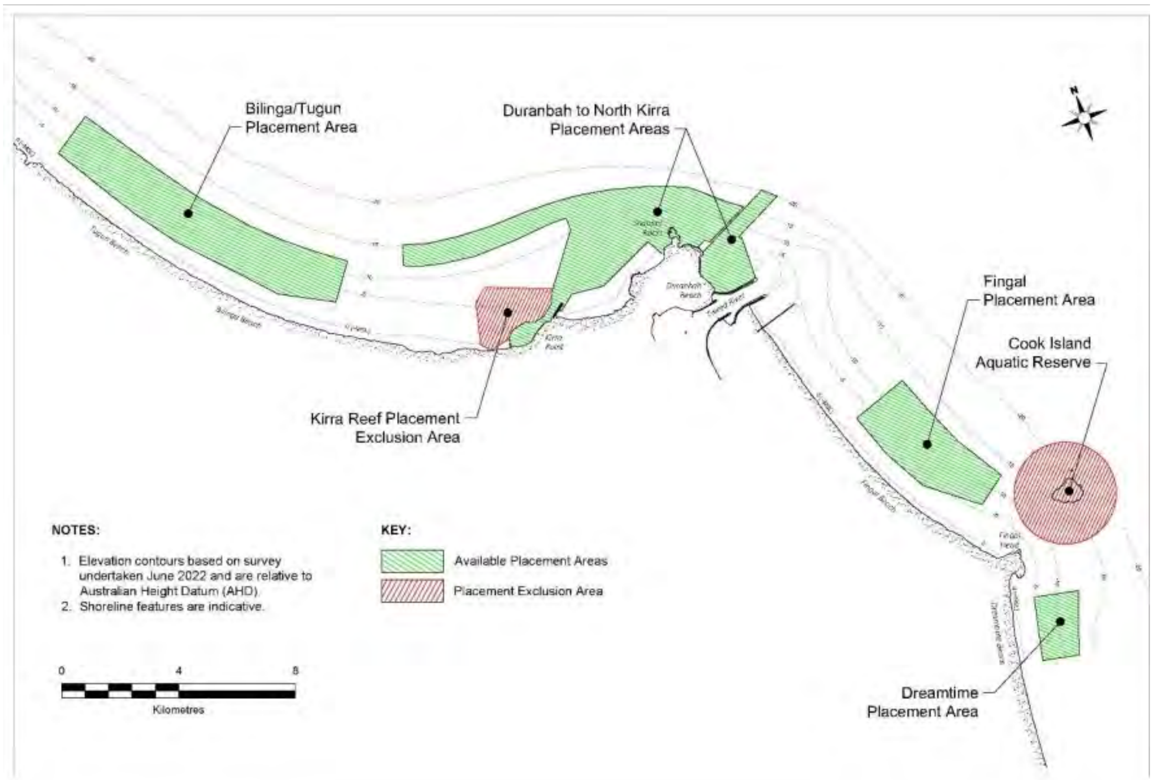

Figure 1.1 Approved placement areas for disposing dredged sand (TSB 2023)

1.2 Seagrass at Cook Island

Seagrass are a marine plant protected under the *NSW Fisheries Management Act 1994*. Seagrass have a broadly important ecological function, including (but not limited to) fisheries habitat, nursery habitat, protection from predators, contributing to food webs, controlling sediment runoff and processing nutrients (Nagelkerken et al. 2008; McKenzie et al. 2021). Seagrass habitats have high ecological value, and provide connectivity between inshore and offshore ecosystems, which is vital for the maintenance and regeneration of numerous fish and invertebrate populations (Waycott et al. 2009; Waycott et al. 2011). They provide food and shelter for a diverse range of marine fauna; and support benthic macroinvertebrate communities, which in turn provide a food resource for many larger species of crustacean, mollusc and finfish, including commercially important species (Coles et al. 1993; Carruthers et al. 2002). Several threatened species, including sea turtles, also rely on seagrass as a foraging habitat.

Seagrass has historically been recorded on the north-western side of Cook Island since 2020, with the distribution first mapped in November 2023. The extent and coverage of seagrass around Cook Island varies over time. In July 2020, the seagrass on the north-western side of Cook Island had moderate to dense coverage of approximately 30% to 50% (between macroalgae, rock and rubble on sand) where it was present (ESP 2020; Figure 1.2a). This moderate to dense patch of seagrass was also present in May 2021, with the coverage consistent with July 2020 (i.e. approximately 30% to 50% of the space where it was present) (ESP 2021; Figure 1.2b). In June 2021, the coverage had declined to approximately 10% of patches where it normally occurred (ESP 2022; Figure 1.2). Similarly, in May 2023, the cover of seagrass in this area remained less than 10% of the patches where seagrass was present (ESP 2023; Figure 1.2d).

a) b)

c) d)

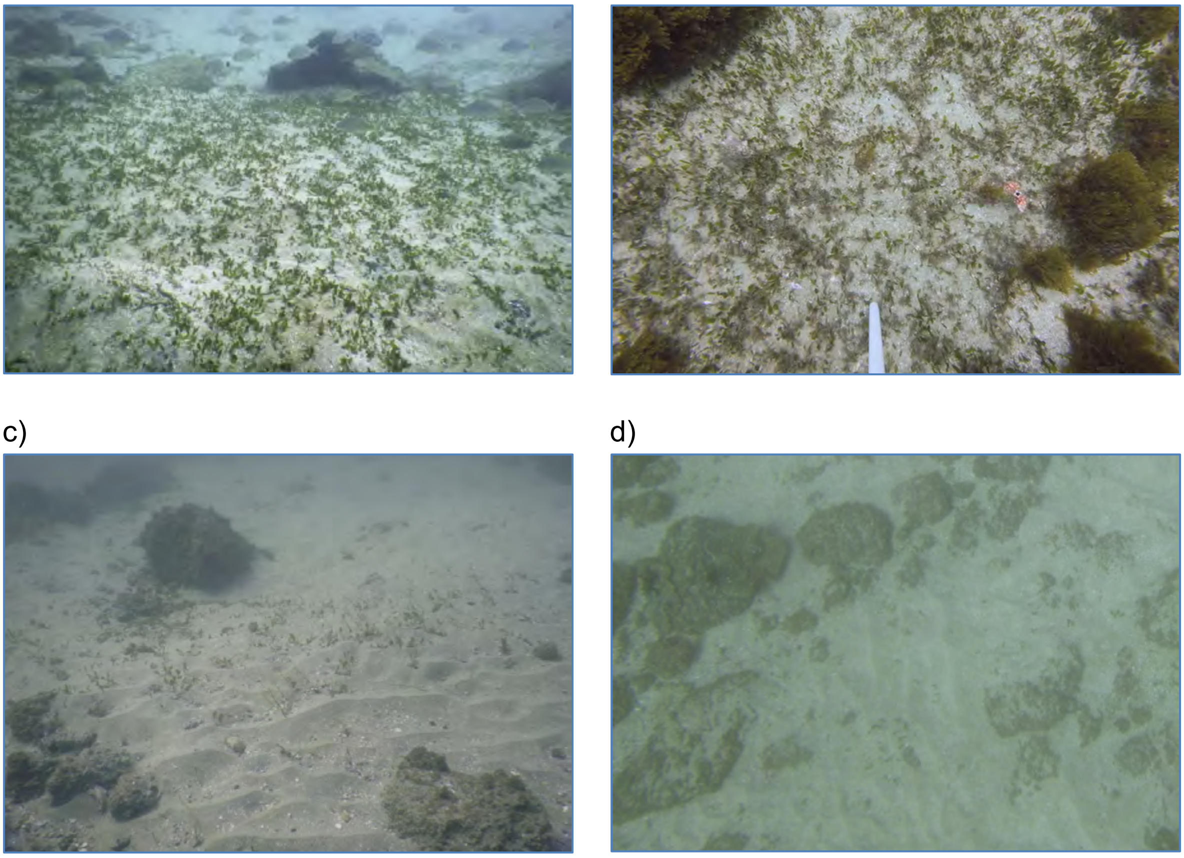

Figure 1.2 Seagrass *Halophila ovalis* on the north-western side of Cook Island in a) July 2020 b) May 2021 c) June 2022 and c) May 2023

In November 2023, seagrass was recorded on the north-western and south-western sides of Cook Island and covered a total area of 958 m^2 (ESP 2024). On the north-western side of Cook Island, seagrass had a discontinuous extent, recorded in patches between macroalgae, rock and rubble on sand habitats. The community was dominated by *Halophila ovalis*, with coverage of patches ranging from approximately 15% to 50% (Figure 1.2a,b). On the south-western side of Cook Island, seagrass was more continuous and had a much greater extent. The community was typically dominated by *H. ovalis* often growing amongst various foliose macroalgae (Figure 1.2c), with a patch of mixed seagrass (*H. ovalis* and *Zostera muelleri*) also present (Figure 1.2d). Coverage of seagrass on the south-western side of Cook Island was dense (>60% coverage) on the fringe of the rocky reef and decreased as the patches extended out over bare sand further away from the rocky reef (ESP 2024).

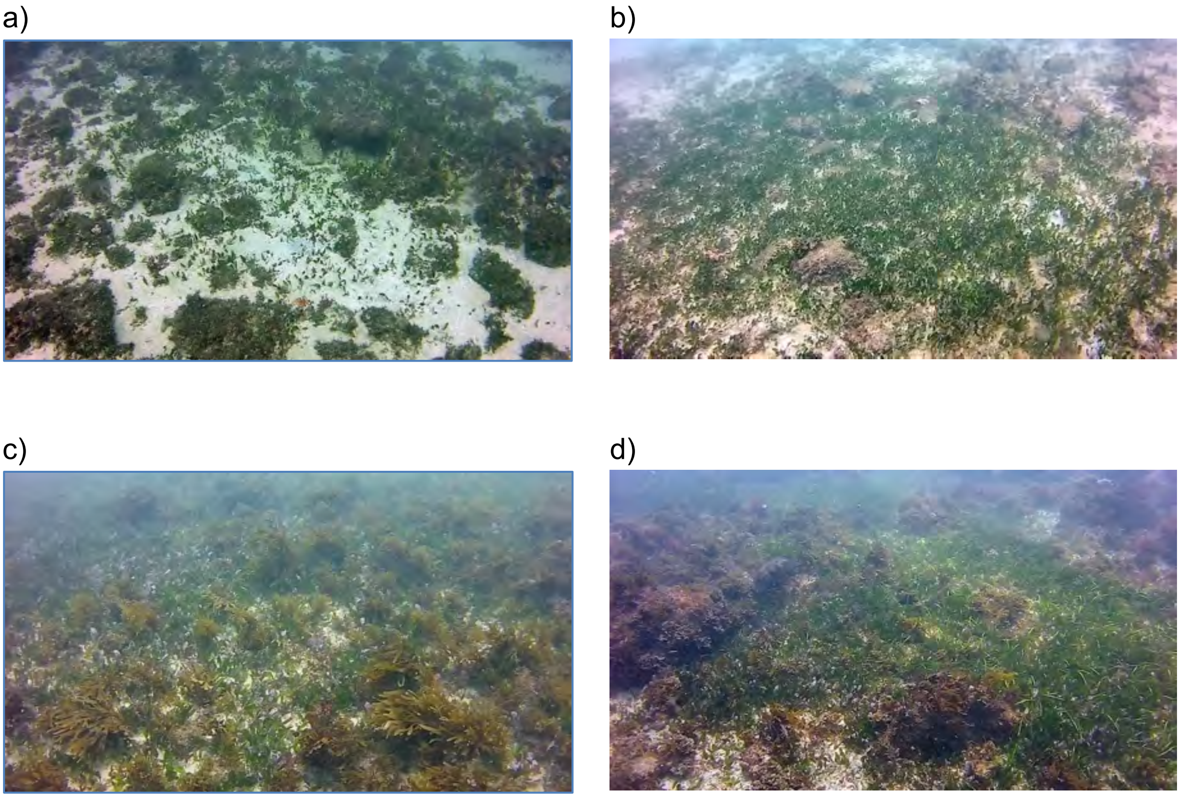

Figure 1.3 Seagrass on the north-western side of Cook Island including a) a small patch and b) dense seagrass of *Halophila ovalis*; c) seagrass on the south western side of Cook Island including c) a dense patch of seagrass and macroalgae and d) a mixed seagrass community (*H. ovalis* & *Zostera muelleri*)

1.3 Sand Placement Activity

The Cook Island Aquatic Reserve is an exclusion zone for placement activities (Figure 1.1) and as such direct disposal of dredge material over the seagrass beds does not occur. Sand from TSB activities (including disposal) has the potential to smother or burry seagrass where it is placed near seagrass and is transported (e.g. by natural drift) to adjacent seagrass beds. Since they were approved in 2019, a total of 130,183 m^3 and 19,061 m^3 of sand has been deposited at the Fingal and Dreamtime placement areas, respectively (

Table 1.1; TSB 2023). Sand placed in these areas is predicted to move predominantly in a northerly direction. Any sand placed at Dreamtime (up to 20,000 m^3 per year) is likely to move with the natural transport pathway around Fingal Head to the west of Cook Island in water depths less than 4 m (Jacobs 2017; Figure 1.4). The movement of sand around the headland is expected to occur during suitable conditions in episodic ‘slugs’ or sand waves of relatively large quantities of sand over a short period of time (Jacobs 2017).

Table 1.1 Volumes of sand (m^3) deposited at the Fingal and Dreamtime placement areas between 2019 and 2024 (TSB 2023)

Date	Fingal	Dreamtime
August 2019	31,366	–
August 2020	24,750	–
September 2021	7,345	–
August 2022	–	8,626
June 2023	31,084	–
September / October 2023	–	10,975
August 2024	35,638	–
Total	**130,183**	**19,601**

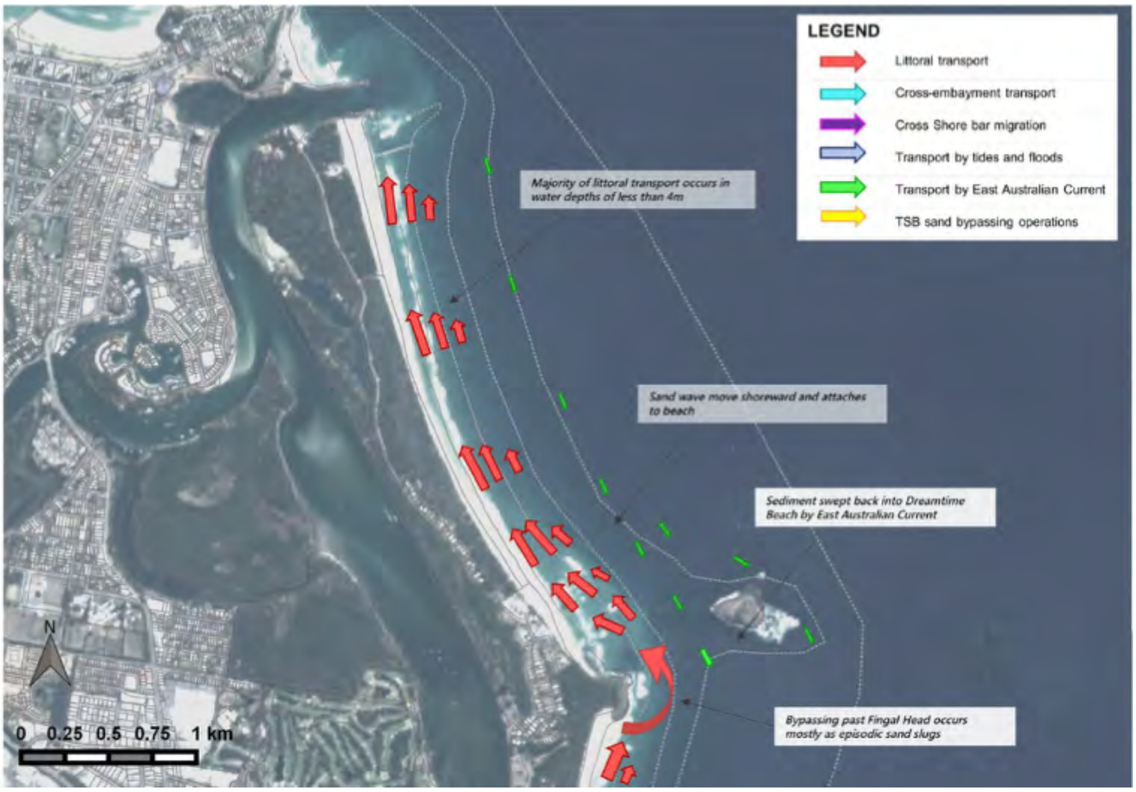

Figure 1.4 Sand transport pathways (Jacobs 2018)

1.4 Scope of Works

ESP was commissioned by Transport for NSW to complete a field survey to quantify the extent and coverage of seagrass around Cook Island. This information was required to monitor changes to the extent, coverage and condition of seagrass at Cook Island, and to assess any potential changes from TSB activity.

2 Methods

2.1 Field Survey

A benthic survey was completed to map the distribution, coverage and condition of seagrass around Cook Island. The survey was completed on 8 November 2024 at a time of year when seagrass is likely to be at the maximum extent (i.e. towards the end of the peak growing season and prior to the wet season, which can result in greater freshwater, turbidity, reducing light penetration for photosynthesis).

The survey was completed using remote techniques from a commercial vessel operated by a suitably qualified skipper. The species composition, percent coverage and condition of seagrass was assessed qualitatively, based on expert assessment of georeferenced imagery (video and photos) at more than 1000 points across the surveyed area. Methods were adapted from Roelfsema & Phinn (2009) where a GPS unit was towed along the water surface with the type of substrate recorded using imagery from an underwater remotely operated vehicle (ROV) (Figure 2.1). Broad seagrass coverage categories were either determined directly from imagery or in the laboratory using georeferenced imagery.

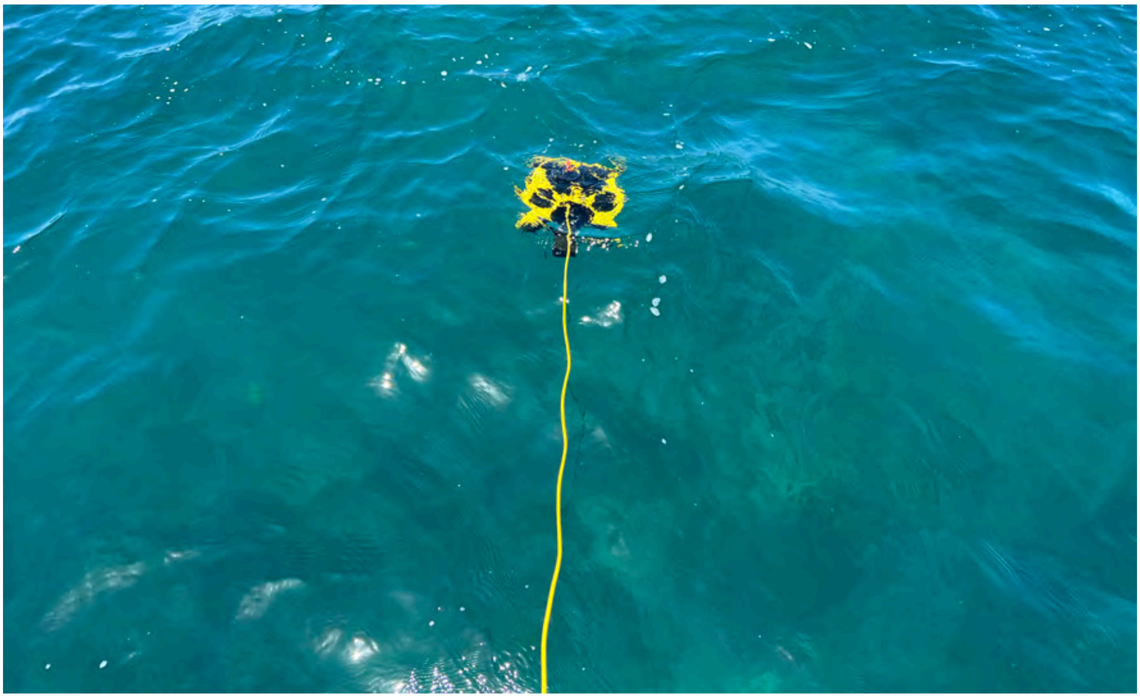

Figure 2.1 ROV used to assess seagrass

2.1.1 Seagrass Condition

Based on field survey results, the condition of seagrass was assessed for each patch based on the criteria adapted by ESP from the Wetland Assessment Manual (Price et al. 2007) and a review of the available fisheries literature[1] linking habitat features with fisheries productivity as outlined in Appendix A. Patches of seagrass were scored based on the presence of various criteria and the total summed across each criteria to determine whether the area of seagrass habitat that was poor, fair, good or very good condition (Appendix A).

2.2 GIS Mapping

A map based on the field data showing the extent of seagrass habitat present around Cook Island was produced using ESRI ArcGIS Pro. The total area for each patch of seagrass was calculated using ESRI ArcGIS Pro.

[1] Bell & Westoby 1986a, b; Edgar & Robertson 1992; Short & Wyllie-Echeverria 1996; Boström & Bonsdorff 1997; Heck et al. 1995; Webster et al 1998; Skilleter et al. 2005; Vanderklift & Jacoby 2003; Pittman et al. 2004; Boström et al. 2006; Jelbart et al. 2007; Price et al. 2007; Shoji et al. 2007

3 Results

3.1 Field Survey

In November 2024, seagrass was recorded on the north-western and south-western sides of Cook Island (Figure 3.1). The total area of seagrass measured was 1,633 m^2, which was 70% larger than measured in November 2023 (958 m^2).

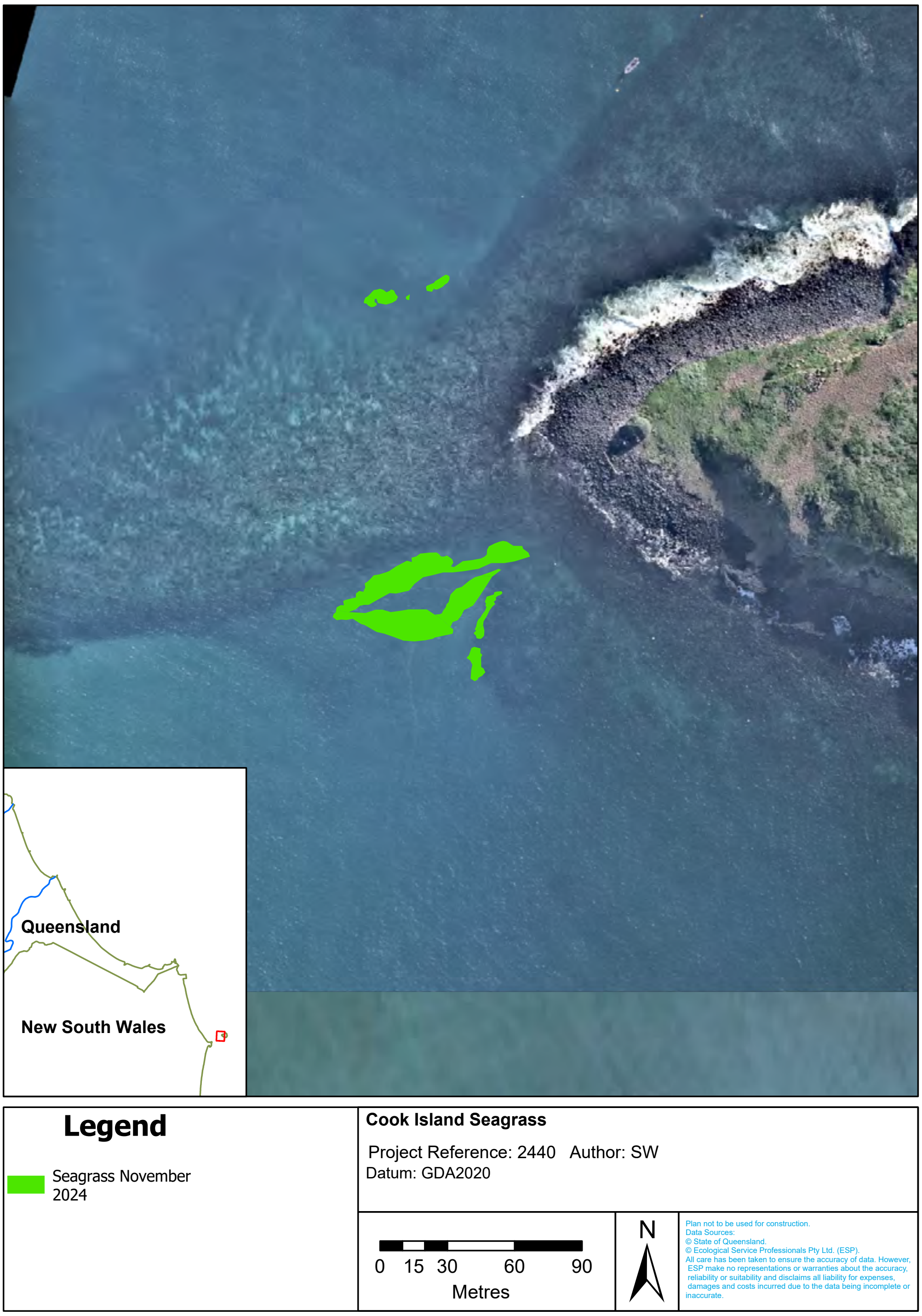

Figure 3.1 Seagrass distribution at Cook Island in November 2024

The seagrass present on the north-western side of Cook Island was recorded in patches of up to 15 m in diameter, with sparse to dense coverage of *H. ovalis* (Figure 3.2). The total area among patches in this location was 118 m^2. The seagrass was growing on sandy patches between rock covered with turf algae or macroalgae at approximately 7 to 9 m depth (Figure 3.3). The percent coverage was 10 to 60% within the patches. Seagrass on the north-western side of Cook Island was in fair to good condition. While the patches remained relatively small, they were more continuous and generally had a higher cover compared to November 2023.

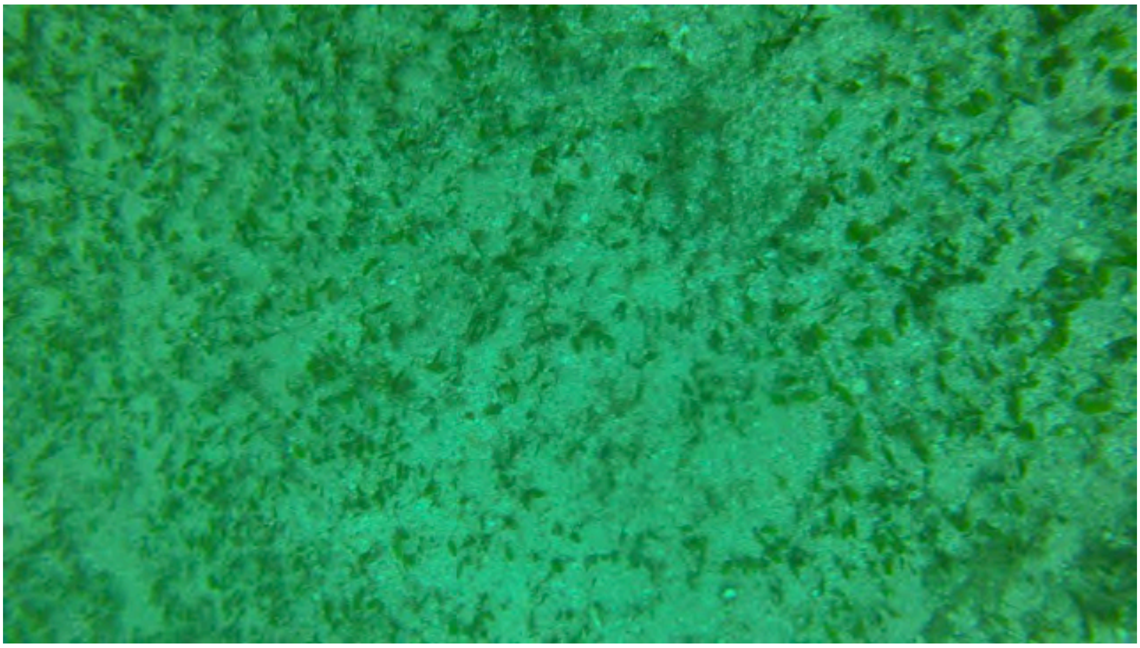

Figure 3.2 Patch of moderate seagrass (*H. ovalis*) on the north-western side of Cook Island

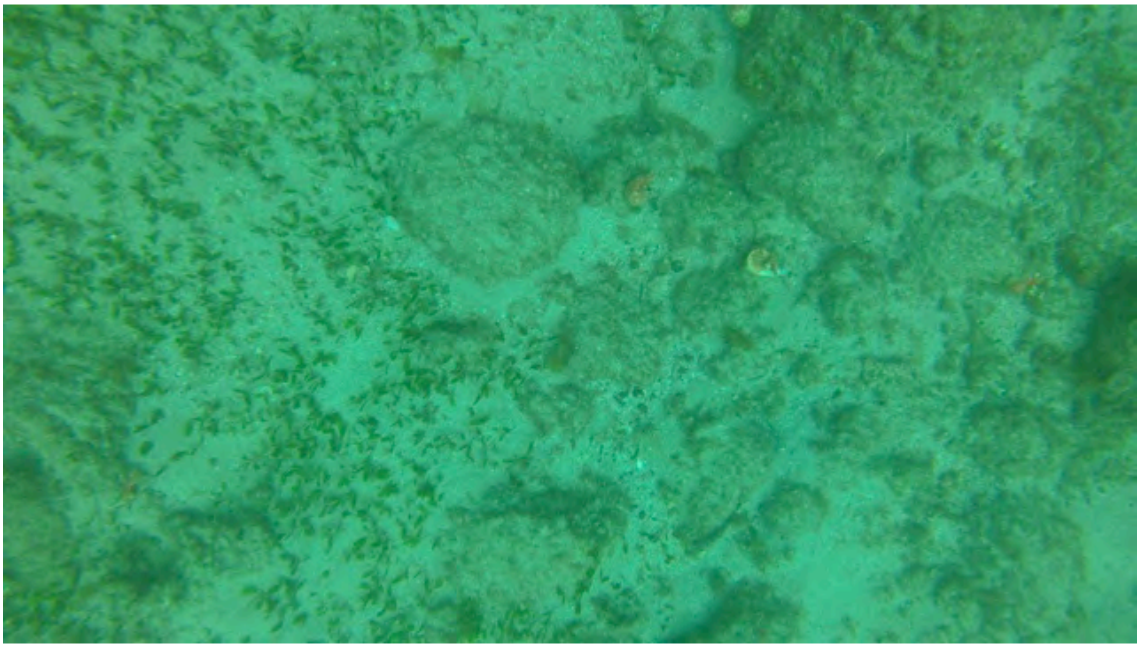

Figure 3.3 Seagrass (*H. ovalis*) between sand and rock habitat on the north-western side of Cook Island

Seagrass grew at a similar depth on the south-western side of the island, although typically had a higher coverage (20 – 80%) and much greater extent than on the north-western side (Figure 3.1). The total area among patches in this location was 1515 m^2.The seagrass was most dense on the fringe of the rocky reef and decreased in coverage as the patches extended out over bare sand. There was a distinct edge between the seagrass and bare sand in some areas (Figure 3.4). The seagrass on the south-western side of the island was dominated by a mixed community of *H. ovalis*, *Zostera muelleri* and / or *Halodule uninervis* (Figure 3.5), with smaller areas dominated by *H. ovalis*. Seagrass was often growing with various foliose macroalgae (*Dictyota* sp.) on sand or rubble (Figure 3.6). The seagrass transitioned to sparse macroalgae and rocky rubble habitat further west. Seagrass on the south-western side of Cook Island was in good to very good condition. The extent of seagrass was much larger and more continuous in November 2024 compared to November 2023. The area of mixed community was also larger in November 2024 (1,144 m^2) compared to November 2023 (268 m^2).

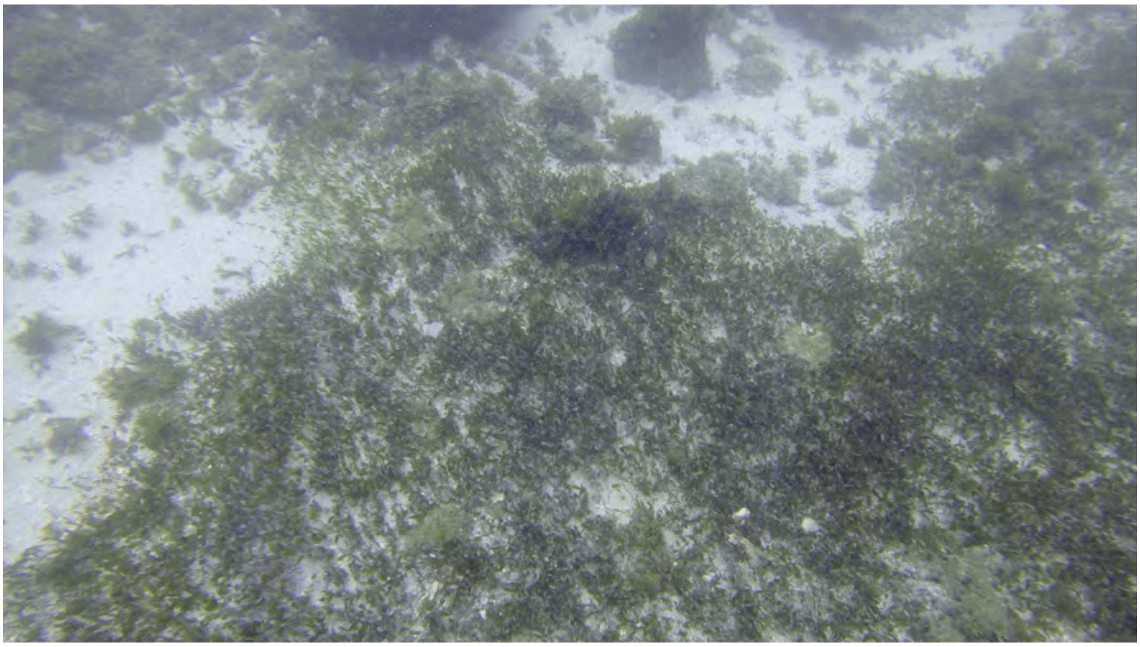

Figure 3.4 Edge of seagrass and bare sand / rock on the south western side of Cook Island

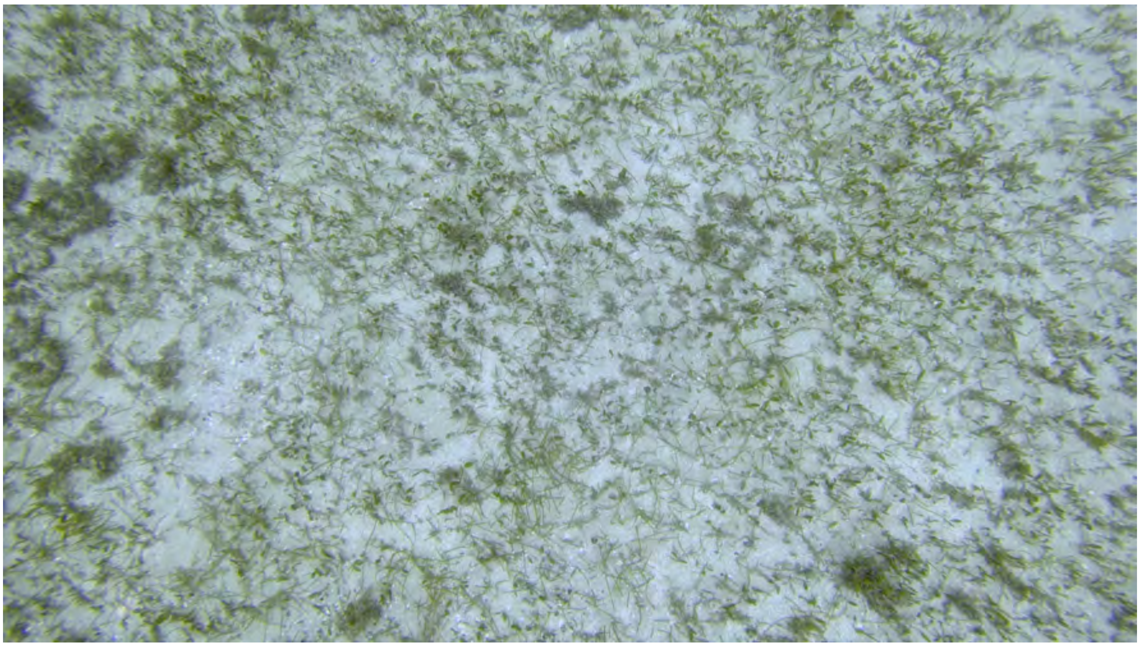

Figure 3.5 Mixed seagrass community on the south western side of Cook Island

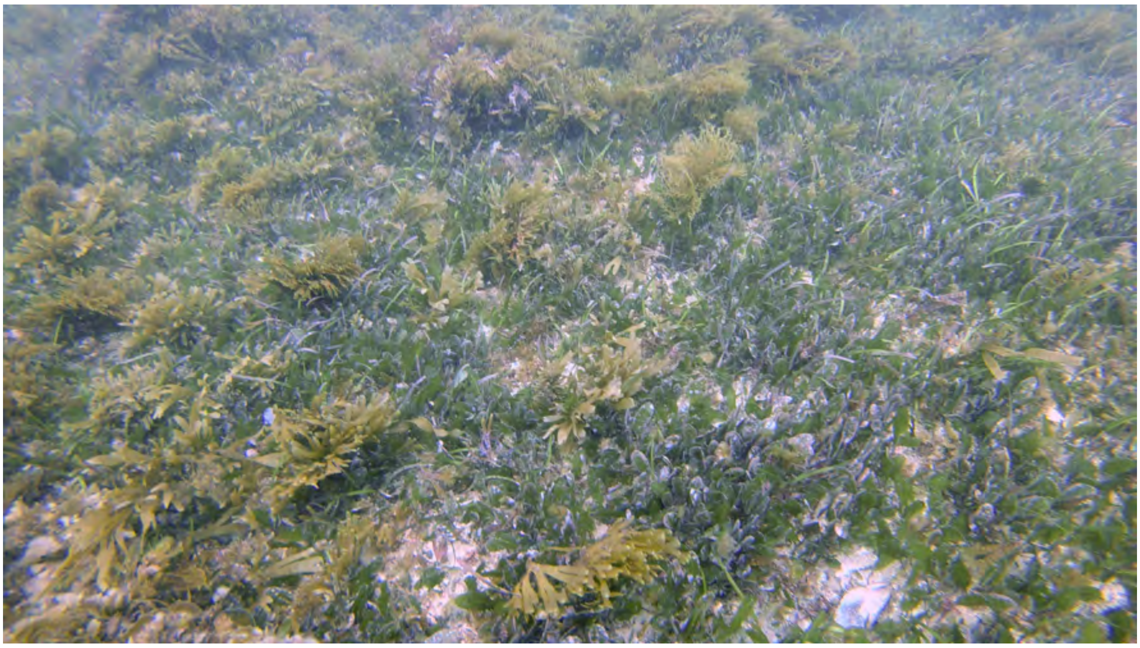

Figure 3.6 Dense seagrass and macroalgae on the south western side of Cook Island

4 Discussion & Recommendations

Seagrass has been recorded historically on the north-western side of Cook Island, with the distribution first mapped in November 2023. Based on qualitative data, the extent and coverage of seagrass around Cook Island has changed over time. In July 2020 and May 2021, the seagrass on the north-western side of Cook Island was moderate to dense, covering approximately 30% to 50% of the area where present. In June 2021 and May 2023, while seagrass was still present in this area, the coverage had declined, covering approximately 10% or less where it was present.

In November 2024, seagrass was recorded on the north-western and south-western sides of Cook Island (in approximately 7 to 9 m water depth) and covered a total area of 1,633 m^2. While the area of seagrass had expanded since November 2023 (958 m^2), the total area of seagrass is relatively small compared with the extent of rocky reef, macroalgae and coral that dominant habitat around Cook Island. The condition of seagrass was generally good in November 2024, with the patches likely to persist over time despite some changes in the overall area covered.

On the north-western side of Cook Island, seagrass had a discontinuous extent, recorded in patches between macroalgae, rock and rubble on sand habitats. The community was dominated by *H. ovalis* in fair to good condition, with coverage of patches ranging between 10% and 60%. On the south-western side of Cook Island, seagrass was more continuous and had a much greater extent than on the north-western side. Seagrass was typically dominated by a mixed community of *H. ovalis*, *Zostera muelleri* and / or *Halodule uninervis* (Figure 3.5), with smaller areas dominated by *H. ovalis*. Coverage of seagrass on the south-western side of Cook Island was dense (20 – 80% coverage), particularly on the fringe of the rocky reef, with a distinct edge between the seagrass and bare sand in some areas.

Seagrasses are sensitive to disturbances and changes in environmental conditions (Short & Wyllie-Echeverria 1996; Heck et al. 2008). Physical factors can influence seagrass cover and extent, including light availability, sedimentation, water quality (particularly turbidity, nutrient levels, temperature, and salinity), current / wave action and water depth. Seagrass (particularly opportunistic species such as *Halophila ovalis)* are highly dynamic, and large interannual changes in the extent of seagrass habitats and community structure resulting from natural disturbances (e.g. flood events, changes in rainfall) have been documented (Lyons et al. 2015; Preen et al. 1995; Campbell & McKenzie 2004). Seagrass are also sensitive to human activities, such as dredging and disposal of sediment, reclamation, coastal development, shoreline modification, boating, anchoring and pollution.

Given the spatial variability in the extent and cover of seagrass over time and limited suitability of comparative sites (as offshore seagrass in the region is scarce), ongoing annual monitoring (ideally in the month of November) to confirm the extent and coverage of seagrass around Cook Island is recommended to monitor any change in the extent and condition of seagrass over time.

5 References

APP 2019. Tweed Sand Bypassing – Back-passing by Dredge: Review of Environmental Factors. Report prepared by Ardill Payne & Partners on behalf of the Department of Industry – Crown Lands.

Bell JD. & Westoby M. 1986a. Abundance of macrofauna in dense seagrass is due to habitat preference, not predation. *Oecologia, 68:* 205-209.

Bell JD. & Westoby M. 1986b. Variation in seagrass height and density over a wide spatial scale: effects on common fish and decapods. *Journal of Experimental Marine Biology and Ecology 104:* 275-295.

Boström C. & Bonsdorff E. 1997. Community structure and spatial variation of benthic invertebrates associated with *Zostera marina* (L.) beds in the northern Baltic Sea. *Journal of Sea Research*, *37:* 153-166.

Boström C, Jackson EL. & Simenstad CA. 2006. Seagrass landscapes and their effects on associated fauna: a review. *Estuarine, Coastal and shelf science*, *68*(3-4), 383-403.

Campbell SJ. & McKenzie LJ. 2004. Flood related loss and recovery of intertidal seagrass meadows in southern Queensland, Australia. *Estuarine, Coastal and Shelf Science* 60: 477-490.

Carruthers TJB, Dennison WC, Longstaff BJ, Waycott M, Abal EG, McKenzie LJ. & Lee Long WJ. 2002. Seagrass habitats of north east Australia: models of key processes and controls. *Bulletin of Marine Science,* 71(3):1153-1169.

Coles RG, Lee Long WJ, Watson RA. & Derbyshire KJ. 1993. Distribution of seagrasses, and their fish and penaeid prawn communities, in Cairns Harbour, a tropical estuary, northern Queensland, Australia. *Australian Journal of Marine and Freshwater Research,* 44:193-210.

Edgar GJ. & Robertson AI. 1992. The influence of seagrass structure on the distribution and abundance of mobile epifauna: Pattern and process in a Western Australian *Amphibolis* bed, *Journal of Experimental Marine Biology and Ecology,* 160:13-31

ESP 2020. Tweed Sand Bypassing Project. Reef Biota Monitoring 2020, report prepared for Queensland Department of Environment and Science and Transport for NSW.

ESP 2021. Tweed Sand Bypassing Project. Reef Biota Monitoring 2021, report prepared for Queensland Department of Environment and Science and Transport for NSW.

ESP 2022. Tweed Sand Bypassing Project. Reef Biota Monitoring 2022, report prepared for Queensland Department of Environment and Science and Transport for NSW.

ESP 2023. Tweed Sand Bypassing Project. Reef Biota Monitoring 2023, report prepared for Queensland Department of Environment and Science and Transport for NSW.

ESP 2024. Seagrass Distribution: Cook Island Aquatic Reserve November 2023, report prepared for Queensland Department of Environment and Science and Transport for NSW.

Heck KL, Able KW, Roman CT. & Fahay MP. 1995. Composition, abundance, biomass, and production of macrofauna in a New England Estuary: Comparisons among eelgrass meadows and other nursery habitats, *Estuaries,* 18:379-389.

Heck KLJ, Carruthers TJB, Duarte CM, Hughes AR, Kendrick G, Orth RJ. & Williams WS. 2008. Trophic transfers from seagrass meadows subsidize diverse marine and terrestrial consumers, *Ecosystems,* 11(7):1198-1210.

Jacobs 2017. Tweed Quantified Conceptual Sediment Transport Model. Report prepared for Tweed Sand Bypassing. December 2017.

Jelbart JE, Ross PM. & Connolly RM. 2007. Patterns of small fish distributions in seagrass beds in a temperate Australian estuary. *Journal of the Marine Biological Association of the United Kingdom,* 87:1297-1307.

Kendrick GA, Nowicki RJ, Olsen YS, Strydom S, Fraser MW, Sinclair EA, Statton J, Hovey RK, Thomson JA, Burkholder DA, McMahon KM, Kilminster K, Hetsel Y, Fourqurean JW, Heithaus MR. & Orth RJ. 2019. A systematic review of how multiple stressors from an extreme event drove ecosystem-wide loss of resilience in an iconic seagrass community. *Frontiers in Marine Science*, *6*: 455.

Lyons M, Roelfsema C, Kovacs E, Samper-Villarreal J, Saunders M, Maxwell P. & Phinn S. 2015. Rapid monitoring of seagrass biomass using a simple linear modelling approach, in the field and from space. *Marine Ecology Progress Series*, 530: 1-14.

McKenzie L, Smith N, Johns L, Yoshida R. & Coles R. 2014. *Development of Wet Tropics WQIP elements – seagrass monitoring,* A report to Terrain NRM, Innisfail, Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) report 14/37, James Cook University, Cairns.

McKenzie LJ, Yoshida RL, Aini JW, Andréfouet S, Colin PL, Cullen-Unsworth LC, Hughes AT, Payri CE, Rota M, Shaw C, Tsuda RT, Vuki VC. & Unsworth RK. 2021. Seagrass ecosystem contributions to people's quality of life in the Pacific Island Countries and Territories. *Marine Pollution Bulletin*, *167*:112307.

Nagelkerken I, Blaber SJM, Bouillon S, Green P, Haywood M, Kirton LG, Meynecke JO, Pawlik J, Penrose HM, Sasekumar A. & Somerfield PJ. 2008. The habitat function of mangroves for terrestrial and marine fauna: A review, *Aquatic Botany,* 89: 155-185.

Pittman SJ, McAlpine CA. & Pittman KM. 2004. Linking fish and prawns to their environment: a hierarchical landscape approach. *Marine Ecology Progress Series,* 283: 233-254.

Price C, Gosling A, Golus C. & Weslake M. 2007. *Wetland Assessment Techniques Manual for Australian Wetlands,* WetlandCare Australia, Ballina.

Preen AR, Long WL. & Coles RG. 1995. Flood and cyclone related loss, and partial recovery, of more than 1000 km2 of seagrass in Hervey Bay, Queensland, Australia. *Aquatic Botany*, *52*(1-2): 3-17.

Roelfsema CM. & Phinn SR. 2009. *A manual for conducting georeferenced photo transect surveys to assess the benthos of coral reef and seagrass habitats version 3.0,* Centre for Remote Sensing and Spatial Information Science, The University of Queensland, Brisbane.

Shoji J, Sakiyama K, Hori M, Yoshida G. & Hamaguchi M. 2007. Seagrass habitat reduces vulnerability of red sea bream *Pagrus major* juveniles to piscivorous fish predator. *Fisheries Science*, *73*(6):1281-1285.

Short FT. & Wyllie-Echeverria S. 1996. Natural and human-induced disturbance of seagrasses. *Environmental conservation*, *23*(1): 17-27.

Skilleter GA, Olds A, Loneragan NR. & Zharikov Y. 2005. The value of patches of intertidal seagrass to prawns depends on their proximity to mangroves. *Marine Biology*, *147*(2): 353-365.

TSB 2023. Tweed Sand Bypassing. Available at: https://www.tweedsandbypass.nsw.gov.au/operations/sand-delivery, accessed December 2023.

Vanderklift MA. & Jacoby CA. 2003. Patterns in fish assemblages 25 years after major seagrass loss. *Marine Ecology Progress Series*, *247*: 225-235.

Waycott M, Duarte CM, Carruthers TJ, Orth RJ, Dennison WC, Olyarnik S, Calladine A, Fourqurean JW, Heck Jr KL, Hughes AR, Kendrick GA, Kenworthy WJ , Short FT. & Williams SL. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the national academy of sciences*, *106*(30): 12377-12381.

Waycott M, McKenzie LJ, Mellors JE, Ellison JC, Sheaves MT, Collier C, Schwartz A–M, Webb A, Johnson J. & Payri CE. 2011. *Vulnerability of mangroves, seagrasses and intertidal flats in the tropical Pacific to climate change* in: Bell, J. D., Johnson, J. E. and Hobday, A. J. (eds.), *Vulnerability of fisheries and aquaculture in the Pacific to climate change,* Secretariat of the Pacific Community, Noumea.

Webster PJ, Rowden AA. & Attrill MJ. 1998. Effect of Shoot Density on the infaunal macro-invertebrate community within a *Zostera marina* seagrass bed. *Estuarine, Coastal and Shelf Science*, *47*(3): 351-357.

Appendix A Seagrass Condition Criteria

Table A1 Seagrass condition index criteria

Seagrass Condition Index	**Criteria Score**			
Score	1	2	3	4
Structural Complexity	Low structural complexity (i.e. max length of seagrass blades <10cm, depending on dominant species present)	Moderate structural complexity (i.e. max length of seagrass blades 10 to 20 cm; depending on dominant species present)	High structural complexity (i.e. max length of seagrass blades 20 to 30 cm depending on dominant species present)	High structural complexity (i.e. max length of seagrass blades >40cm depending on dominant species present)
Coverage of epiphytic algae	Low or very high cover of epiphytic algae (<20% or >80%)	High cover of epiphytic algae >60% of seagrass blades OR low cover of epiphytic (<20%)	Moderate cover of epiphytic algae (20-30%)	Moderate cover of epiphytic algae (30-40%)
Presence of cyanobacterial mats	Presence of dense cyanobacterial mats (Lyngbya).	Sparse coverage of cyanobacterial mats (Lyngbya).	Cyanobacterial mats such as Lyngbya absent	
Coverage of seagrass	Sparse coverage of seagrass (<10%)	Sparse coverage of seagrass (10 to 30%)	Moderately dense coverage of seagrass (30-60%)	Dense coverage of seagrass (>60%)
Seagrass Condition Index (as defined by the metrics below)	**Poor**	**Fair**	**Good**	**Very Good**
Total Condition Index Score	**<4**	**5 to 8**	**9 to 13**	**14 to 16**