ADVICE NOTE: Proliferation of seagrass in Pipe Clay Lagoon: the ecological role, understanding the drivers, and the consequences for oyster growers.

Final Report

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Executive Summary

A seagrass proliferation has been reported in several locations on the east coast of Tasmania in recent years, notably in Pipe Clay Lagoon and Georges Bay. In Pipe Clay Lagoon, the spatial extent and biomass appears unprecedented, and all five commercial oyster producers have reported impacts on oyster production and/or farm operations. This has culminated in a permit application, under the *Living Marine Resources Management Act 1995* to undertake a scientific research trial to determine if cutting the seagrass will restore favourable oyster growing conditions. This document has been prepared to help inform management and support options for businesses being impacted by seagrass proliferation by describing the long-term seagrass dynamics in Pipe Clay Lagoon based on available historical records, the potential causes of the current proliferation, and the impact on oyster farming. This is explored in the context of our current knowledge of seagrass, the species present, their ecological role, and the known drivers of seagrass habitat and extent.

Seagrass species are marine angiosperms meaning they produce fruits, flowers, leaves and stems as part of the aboveground biomass. The belowground biomass has horizontal creeping rhizomes with nodes from which roots and shoots develop. The belowground biomass allows for extension of the local abundance through asexual reproduction (genetic “clones” of the parent plant), while the aboveground fruits and flowers allow for long-distance extension through sexual (genetic material from two parent plants) reproduction. Seagrass habitats provide food, shelter, and essential nursey areas for a range of species, some of which are endangered or critically endangered, and because of this, seagrass habitats are protected under legislation. Seagrass also has well-documented ecosystem services, such as nutrient removal and primary production, which are beneficial to natural ecology and ecosystem health.

There are nine seagrass species found in Tasmania, with *Heterozostera nigricaulis*, also referred to as *Zostera nigricaulis*, the dominant (and possibly only) species in Pipe Clay Lagoon. Historical reports of seagrass in Pipe Clay Lagoon indicate that the presence has been sporadic ranging from forming distinct beds (Guiler, 1950; DPIPWE, 1998) to being virtually absent (Mount et al., 2005). Satellite imagery shows the seagrass habitat has expanded rapidly between November 2017 and January 2022 consistent with the observations of oyster farmers and local residents. The possible cause of this proliferation is difficult to determine, but our analysis suggests the increased abundance is likely to be driven by, but not limited to, large-scale climate factors, especially higher than average rainfall and warmer temperatures (BOM, 2023). This, in combination with the colonising/opportunistic nature and reproductive strategies of *H. nigricaulis*, may have enabled the species to expand its presence in the Lagoon and elsewhere in the State. The role of oyster farms is difficult to determine, but good water clarity associated with the filtering capacity of the oysters together with enrichment of sediments via their pseudo faeces is likely to help facilitate the establishment of seagrass.

The reported impacts of the seagrass proliferation on oyster farming can be categorised into impacts on production (e.g., mortality, reduced growth and difficulties conditioning) and operations (e.g., financial impacts, safety concerns and difficulties accessing lease). The extent to which production and farming operations are impacted is difficult to quantify without production data, but it is likely to be substantial. If a permit is to be issued to trial the removal of above ground biomass in a restricted area, we recommend that this is used to better quantify the impacts of seagrass, and the effectiveness of seagrass above ground biomass removal, on oyster production, seagrass dynamics and other key environmental and ecological parameters.

Background and Need

The Department of Natural Resources and Environment (NRE TAS) has recently become aware of the proliferation of seagrass in Pipe Clay Lagoon that is reported to be impacting on oyster producers. This document has been prepared in response to a request for advice from the NRE TAS.

A proliferation in seagrass has been reported in several locations on the east coast of Tasmania in recent years, notably in Pipe Clay Lagoon and Georges Bay. In Pipe Clay Lagoon, the spatial extent and biomass appears unprecedented, and all five commercial oyster producers have reported impacts on oyster production and/or farm operations. As a response, an oyster farmer has submitted a permit application, under the *Living Marine Resources Management Act 1995* to undertake a scientific research trial to determine if cutting the seagrass will restore favourable oyster growing conditions. There is a clear need to better understand long term seagrass dynamics in Pipe Clay Lagoon based on available historical records, the potential causes of the current proliferation and the impact on oyster farming. This will be explored in the context of our current knowledge of seagrass, the species present, their ecological role, and the known drivers of seagrass habitat and extent. This will help inform management and support options for businesses being impacted by seagrass proliferation.

Objectives

More specifically, the advice note has been written to address:

- the known species of seagrass in Tasmania and their conservation status, including known species reported from Pipe Clay Lagoon.
- the role of seagrass as an ecological community and habitat.
- the available history of seagrass in Pipe Clay Lagoon.
- possible causes of its proliferation
- impacts on oyster farming.
- any recommendations for management and/or research

Section 1: Seagrass Species in Tasmania

There are currently 22 recognised species of seagrass in Australia, although there is ongoing debate as to what constitutes a seagrass species, and how these are classified and grouped (Macreadie et al., 2018). Seagrass span across ~51,000 km^2 of habitat along the entire coast of Australia – New South Wales, Queensland, South Australia, Tasmania, Victoria, Western Australia, and Northern Territory, and together make up the most diverse array of seagrass species in the world (Butler and Jernakoff, 1999). Seagrass occurs in three main habitats: estuarine, coastal, and deep water (Figure 1). However, it mostly occurs in estuarine and coastal habitats where there is enough light and nutrients to support photosynthesis, but its distribution with depth can vary depending on the species and light climate. It is predominately found growing on soft and sandy sediments, but some species are found growing on hard substrates (e.g., rocky reefs).

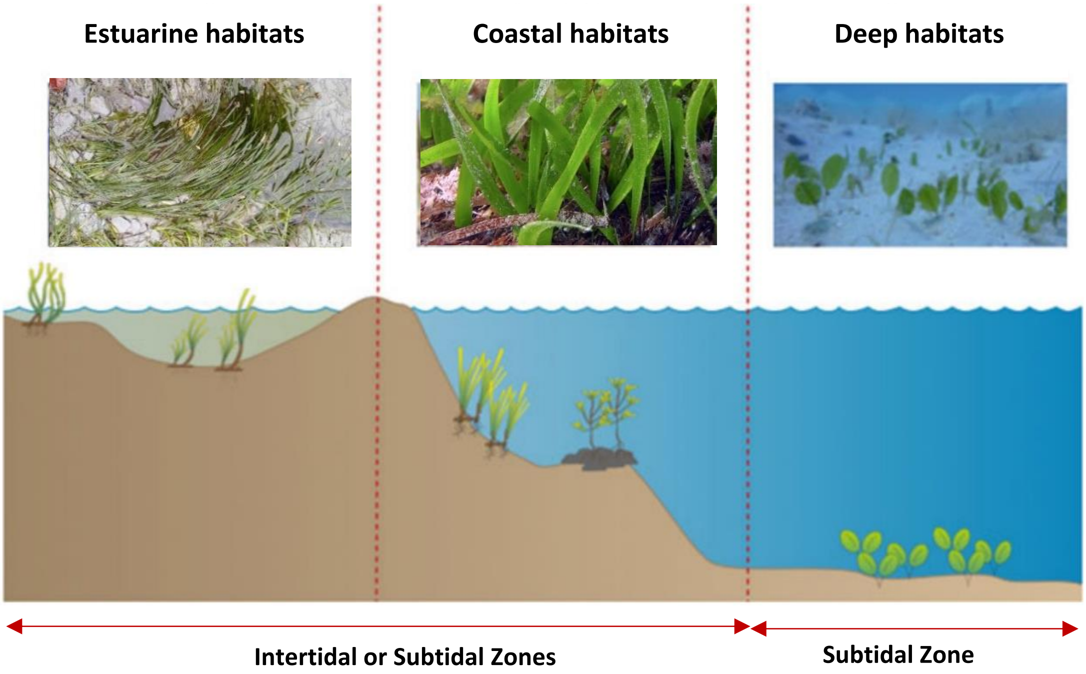


Figure 1: Conceptual diagram showing the main habitats of seagrass in Australia. The majority of seagrass is located within intertidal and shallow subtidal habitats. Modified from Macreadie et al. (2018).

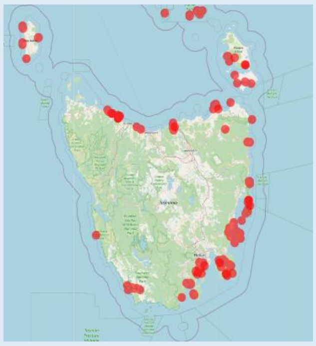
Known Seagrass Species in Tasmania

There are nine seagrass species found in Tasmania. Five of these are relatively well understood species: *Amphibolis antarctica*, *Halophila australis*, *Heterozostera tasmanica*, *Posidonia australis* and *Zostera muelleri*. *H. tasmanica* was originally described as *Z. tasmanica* (Ascherson, 1868), but genetic research does not necessarily support the separation of *Heterozostera* and *Zostera* (Tanaka et al., 2003). *H. tasmanica* was also separated into two species, *H. tasmanica* and *H. nigricaulis* (can also be named as *Z. tasmanica* and *Z. nigricaulis*), relatively recently (Kuo, 2005). *Ruppia maritima*, *R. polycarpa*, and *R. megacarpa* are freshwater macrophytes and not marine plants, but they are salt tolerant and inhabit the brackish inland reaches of lagoons and estuaries. The most abundant species in Tasmania are *H. tasmanica* (which, following the separation into two species, is likely to be *H. nigricaulis*) and *Z. muelleri* (Macreadie et al., 2018). All these species are native to Australia, and none are endemic to Tasmania. All species have a conversation status of “least concern”, except for *P. australis* that has a species conservation status of “near threatened” (IUCN Red List, 2023). *P. australis* meadows of the Manning-Hawksbury ecoregion in New South Wales are also listed as “endangered” under the Environment Protection and Biosecurity Conservation Act 1999 (Department of the Environment, 2023).

Heterozostera tasmanica / Heterozostera nigricaulis

Taxonomic status:	Unaccepted, synonym of the genus Zostera
Common name(s):	Long eelgrass
Main habitat(s) in Tasmania:	Extensive populations in coastal habitats
Conservation status:	Least concern

Prefers fine sand and sheltered bays, but is found in most areas (depth: low tide mark to ≥10m). Intolerance to low salinity. Can colonise disturbed areas and co-habit with other seagrass species. Long and flat leaves, with both species almost identical, but unlike *H. tasmanica*, *H. nigricaulis* has blackened main stems and notched tips.



Recorded observations of both species in Atlas of Living Australia (ala.org.au). Species image (H. nigricaulis) from AlgaeBase (algaebase.org).

Zostera muelleri

Taxonomic status:	Accepted
Common name(s):	Short eelgrass
Main habitat:	Common in estuarine habitats
Conservation status:	Least concern

Tolerates most sediment types and areas, except exposed coasts, channels, straits (depth: intertidal to 2.5m). Does not usually colonise with other seagrass species. Long and flat leaves, similar to *H. nigricaulis*, but has green main stems (*H. tasmanica* has green main stems and rounded tips).

Recorded observations of Z. muelleri in Atlas Living Australia (ala.org.au). Species image from AlgaeBase (algaebase.org).

Amphibolis antarctica

Taxonomic status:	Accepted
Common name(s):	Sea nymph and wire weed
Main habitat(s) in Tasmania:	Lesser species in coastal habitats (mostly north of Maria Island)
Conservation status:	Least concern

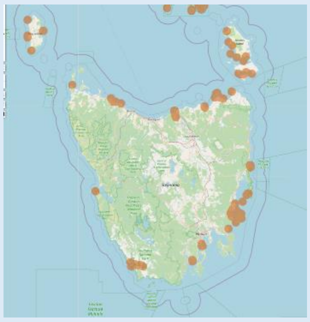
Fine sand of sheltered and semi-sheltered areas (depth: 2.5m to 5m). Not commonly colonised with other seagrass species. Shorter (compared to other seagrass species) and flat leaves that overlap only at the base.

Recorded observations of A. antarctica in Atlas of Living Australia (ala.org.au). Species image from AlgaeBase (algaebase.org).

Posidonia australis

Taxonomic status: Accepted
Common name(s): Strapweed, fibre-ball weed, and broad leaf seagrass
Main habitat(s) in Tasmania: Most abundant species in estuarine habitats
Conservation status (IUCN): **Near threatened**

Favours sheltered to semi-sheltered areas with fine, sandy flat sediments (depth: 2m to 20m). Not commonly colonised with other seagrass species, but can be found at the tidal edge protecting other species in high-energy beds. Long strap-like and bright green leaves that can grow to over 80cm long with rounded ends. Meadows in the Manning-Hawksbury region (NSW) are listed as "endangered" (EPBC).

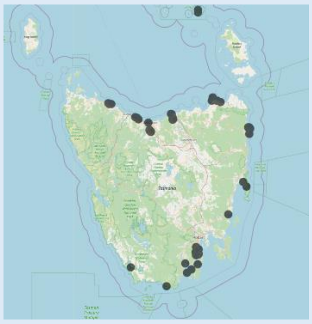


Recorded observations of P. australis in Atlas of Living Australia (ala.org.au). Species image from AlgaeBase (algaebase.org).

Halophila australis

Taxonomic status: Accepted (previously known as *H. ovalis*)
Common name(s): Paddle weed
Main habitat(s) in Tasmania: Costal habitats (lesser on the west coast)
Conservation status: Least concerned

Usually grows in fine sand and sheltered areas, but can tolerate some fine mud and semi-exposure (depth: low tide mark to >20m). Either does not usually colonise with other seagrass species or found with *H. tasmanica*. Paddle-shaped leaves occurring in pairs with noticeable cross-veins on the surface.

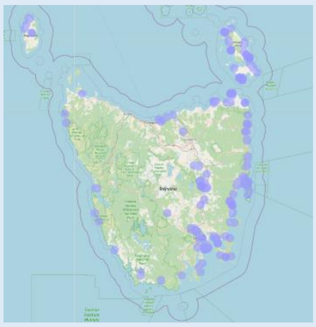


Recorded observations of P. australis in Atlas of Living Australia (ala.org.au). Species image from AlgaeBase (algaebase.org).

Ruppia maritima, R. polycarpa and R. megacarpa

Taxonomic status: All species accepted
Common name(s): Ditch grasses, tassel pondweed, widgeon grasses, widgeon weeds
Main habitat(s) in Tasmania: Estuarine habitats (brackish water)
Conservation status: Least concerned

All species are known to grow inland lagoons and are adapted for brackish water, including previous reports in Great and Little Swanport (Mount et al., 2005). Species information and distribution is limited. Leaves are small to medium-sized, and usually noticeably sympodial (i.e., one branch develops more strongly than the other).



Recorded observations of combined species in Atlas of Living Australia (ala.org.au). Species (R. maritima) image from AlgaeBase (algaebase.org).

Species Records in Pipe Clay Lagoon

Based on historical reports, the presence of seagrass in Pipe Clay Lagoon has been sporadic and descriptions have ranged from the presence of distinct beds (Guiler, 1950) to it being virtually absent (Mount et al., 2005), but there are few reports that identify the species. The first description of a seagrass species in Pipe Clay Lagoon was in 1948, which identified a "*Zostera* zone" described as belt of *Zostera nana* (Guiler, 1950). Although *Z. nana* is no longer an accepted taxonomic name, it is the original taxonomic name (a "synonym") for *Zostera noltei*. *Z. noltei* is a seagrass species of north-western Europe and is not known to be present anywhere in Australia, suggesting that it was likely mis-classified. *Z. noltei* is closely related to *Z. muelleri*, a common species in Tasmania, and the two species are estimated to have genetically diverged about 2.89 million years ago (Les et al. 2003). *Z. muelleri* also has a very similar morphology to *H. tasmanica* and *H. nigricaulis*, and as such, it is difficult to know which of these species was in fact present when first described by Guiler (1950).

In the Marine Farming Development Plan for Pipe Clay Lagoon (DPIPWE, 1998), *H. tasmanica* is reported as the most common species, but the source for this identification is unclear. Despite extensive habitat mapping of the Lagoon in 2004 by Mount et al. (2005), which reported 0.3 hectares of dense seagrass and 0.8 hectares of sparse seagrass along the main channel and near the mouth, the species present was not reported. Records from Atlas of Living Australia show that although all nine species of seagrass found in Tasmania have been identified in areas surrounding Pipe Clay Lagoon, no species were reported for Pipe Clay Lagoon itself (Atlas of Living Australia, 2023; Figure 2). In preparation for this report, the seagrass present in the lagoon was preliminarily identified as *H. nigricaulis* during a field visit in early 2023. The identification was based on the presence of three key features: monopodial growth (i.e., a single main stem, rather than a one branch stronger than another), distinctive black stems and rhizomes, and notched leaves (Figure 3). Although *H. nigricaulis* can co-exist with other seagrass species, no other species were found during this field visit. This suggests that *H. nigricaulis* is the most likely dominant species in Pipe Clay Lagoon, but to confirm this, a detailed ecological survey is required.

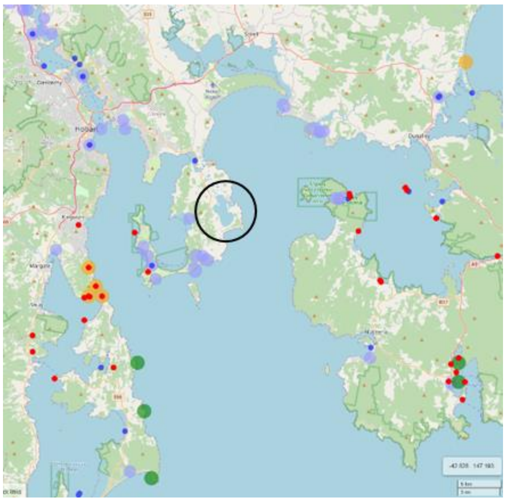


Figure 2: Recorded seagrass species in and around Pipe Clay Lagoon from the Atlas of Living Australia (ala.org.au). All nine species found in Tasmania have been identified in the region: *H. tasmanica and H. nigricaulis* (●), *Z. muelleri* (●), *A. antarctica* (●), *P. australis*, (●), and *R. maritima, R. polycarpa and R. megcarpa* (●). Note: the size of the keys does not indicate abundance.

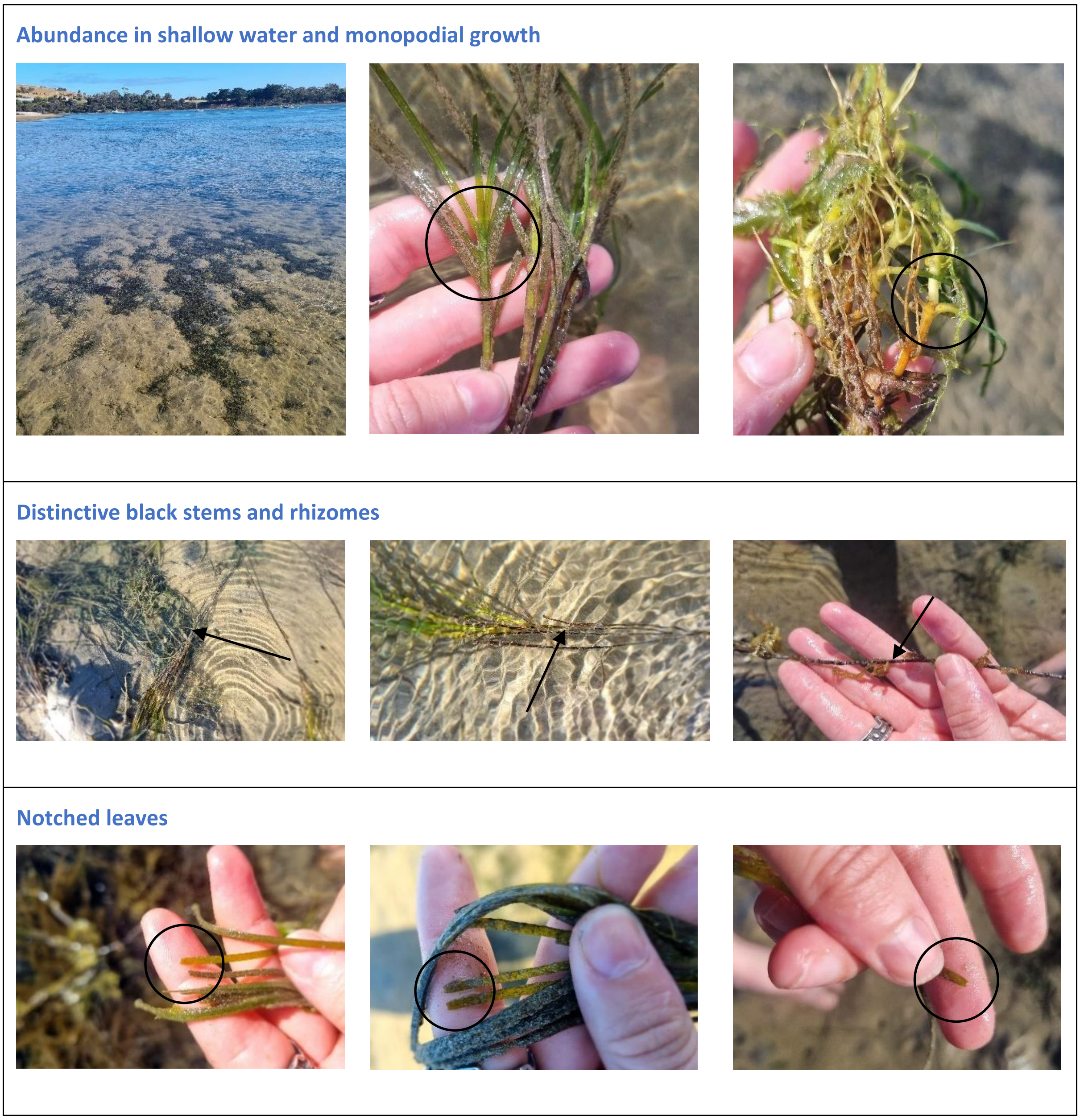


Figure 3: Collection of images from the northern shore along Pipe Clay Esplanade on the spit at low tide showing abundance in shallow water and the key identification features indicating *H. nigricaulis* is the most likely dominant species.

Section 2: Ecological Role of Seagrass

Seagrass Biology: Structure and Reproduction

Seagrass species are marine angiosperms, meaning seagrass is classified as true fruiting and flowering plants. This makes seagrass unique because, unlike other flowering plants, almost all species reproduce completely underwater. Like terrestrial flowering plants, seagrass consists of above and below ground biomass (Kuo and den Hartog, 2006). Beneath the sediment the plant grows horizontally via creeping rhizomes with nodes from which branching and simple roots and shoots develop (Figure 4). The roots penetrate down into the sediment, whereas the shoots grow into the water column and are made up of main stems, leaf sheaths and leaf blades. Variation in anatomic structures between seagrass species, such as leaf blade height and shape, can be used a key identifying features and creates structural diversity within and between seagrass habitats.

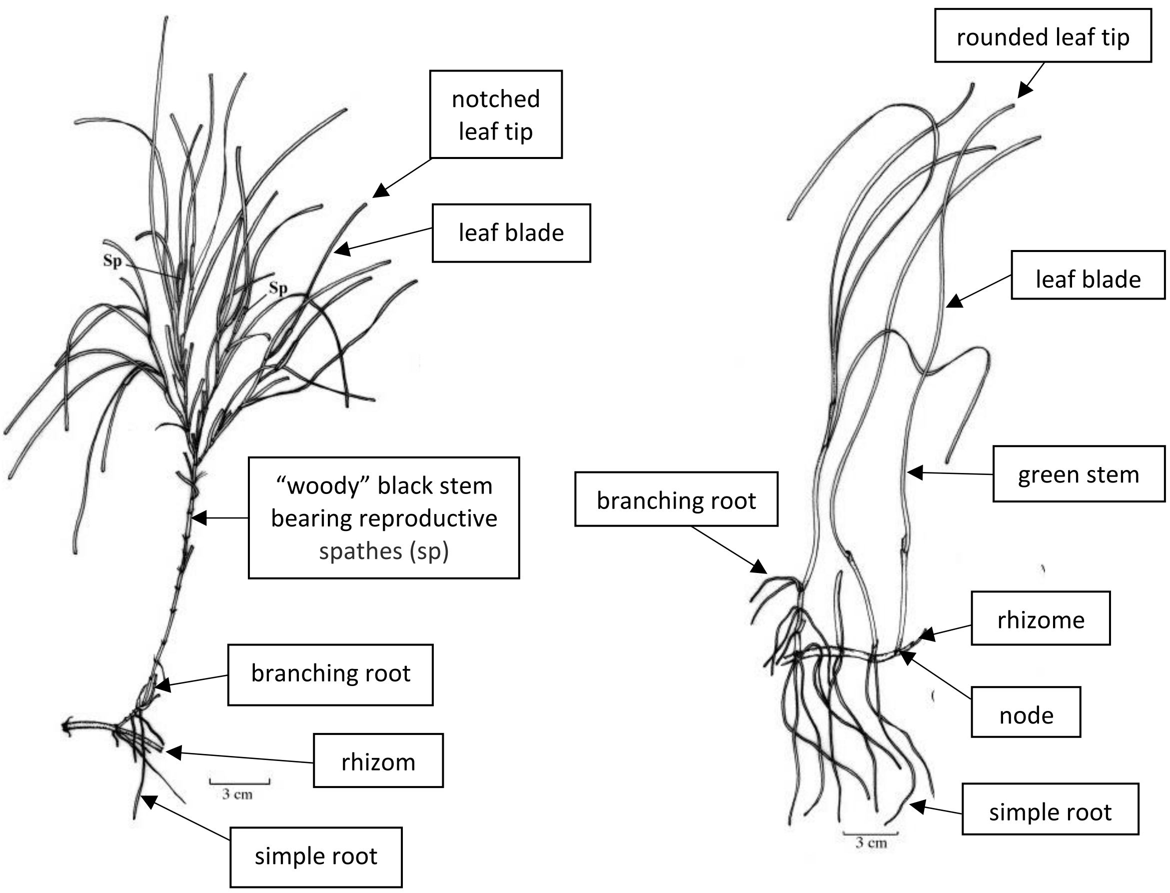


Figure 4: Structural characteristics of *Heterozostera* species found in Tasmania: *H. nigricaulis* (left, thought to be the dominant species currently in Pipe Clay Lagoon) and *H. tasmanica* (right). Modified from Kuo (2005).

Seagrass can reproduce both asexually (i.e., genetic “clones” of parent plant) and sexually (i.e., genetic material from two parent plants, Figure 5). Asexual reproduction is the extension of local abundance through rhizome growth beneath the sediment, from which new shoots can develop (Kuo et al., 2018). Fragments of rhizomes can break off during storms, via herbivore grazing, or with damaging activity (e.g., anchoring) and these can survive drifting in the water column for, in some cases, weeks and then settle and grow into new plants through asexual reproduction in a different location (Thomson et al., 2015). The sexual reproductive organs are the flower sheath known as a spadice (i.e., the leaf “pocket” that houses the flowers), and fruits and seeds. Pollination happens when the pollen from the male flower is carried through the water to fertilise the ovary of the female flower (Wise, 2022). Most seagrass species produce either male or female reproductive organs of a single individual plant, meaning there are separate male and female plants. Flowering usually takes place in winter or early spring. In Port Phillip Bay, Victoria, Smith et al. (2016) reported that flowering *of H. nigricaulis* occurred from August until December, the timing of which was inconsistent between seasons, and peak flowering production occurred in October/November. Observations of seed production of *H. nigricaulis* in the lower Derwent Estuary suggests a similar timing (Ross pers obs). Once seeds are released from the female plants, the seeds are dispersed by water movement or physical relocation where germination can colonise new locations many kilometres away. Depending on factors such as the seagrass species, currents, winds, and temperature, dispersal time can range from 10 to 30 days.

Figure 5: *Heterozostera nigricaulis* sexual reproductive cycle: a) over-mature flowering shoot, b) interior needle-like seed sheathe (spathe), c) maturing ovary, d) small hard seed, e) germinating seed, f) seedling with true leaves, and g) mature vegetative shoot. Sourced from Sullivan (2019).

The dominant reproductive strategy (i.e., asexual or sexual) can depend on if the seagrass is "enduring" or "transitory". Enduring seagrass is when the abundance is continually present for at least two years, while transitory seagrass is when the abundance is not persistent over time; that is, sometimes there will be seagrass present, other times there will be no seagrass present. Importantly, transitory seagrass is not necessarily aligned with annual cycles, but can fluctuate over longer or shorter time scales, for example, be present for months or years before disappearing (Kilminster et al., 2015). This makes the seagrass abundance at Pipe Clay Lagoon most likely transitory. For transitory seagrass, sexual reproduction is normally the most dominant reproductive strategy, but recent research shows the importance of asexual reproduction in maintaining populations once established (Smith et al., 2016; Johnson et al., 2020).

The Generic Seagrass Model categorises seagrass genera based on growth, form, and function as "colonising", "opportunistic", and/or "persistent" (Walker et al., 1999; Kilminster et al., 2015; Figure 6). These categories describe characteristics relating to plant turnover, individual plant persistence, time to reach sexual maturity, and seed dormancy (Kilminster et al., 2015). The seagrass species found in Tasmania are categorised as colonising (*Halophila* and *Ruppia*), colonising/opportunistic (*Zostera* and *Heterozostera*, classed together under *Zostera* according to Walker et al., 1999), or colonising/persistent (*Amphibolis*). This highlights the dynamic nature of *H. nigricaulis* abundance and its capacity to rapidly expand and recover through both asexual (growth of rhizomes or fragments) and sexual (seeds) reproduction.

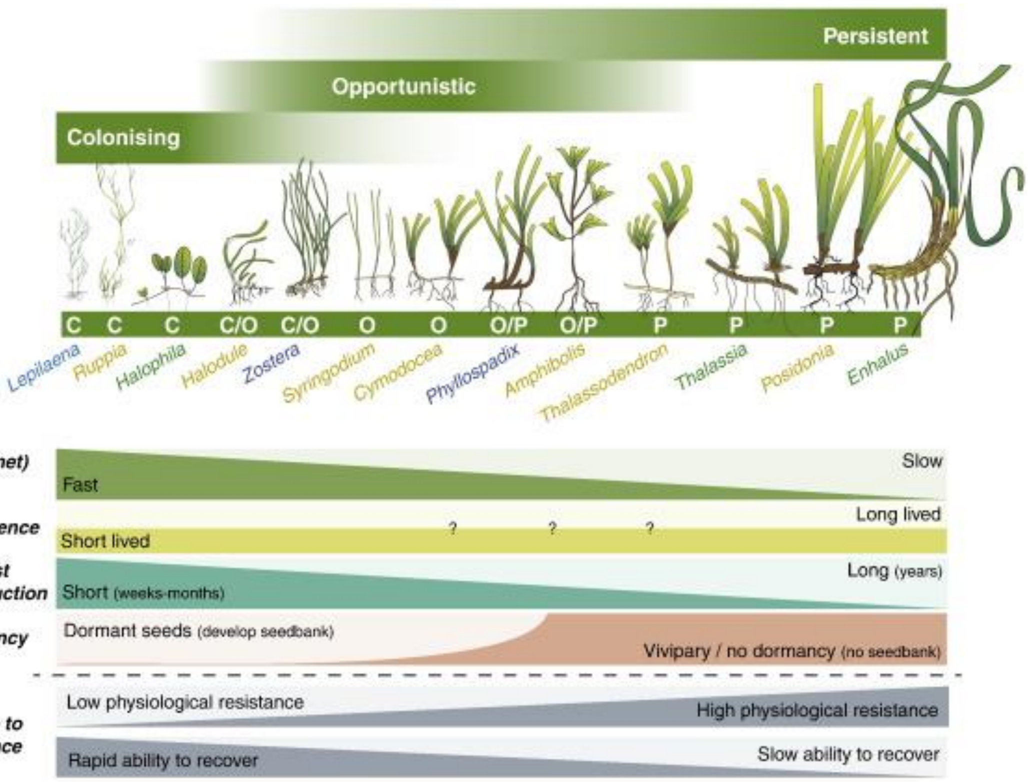


Figure 6: Diagram showing traits along colonising (C), opportunistic (O), and persistent (P) seagrasses with respect to shoot turnover, individual plant ("genet") persistence, time to reach sexual maturity, and seed dormancy. Sourced from Kilminster et al. (2015).

The ability of seagrass seeds to remain viable in sediments or in the water column has attracted recent attention. For *H. nigricaulis* in South Australia, seeds were, in one instance, 41% viable after 12 months (Smith et al., 2022). For germination, *H. nigricaulis* in Victoria was shown to be enhanced with low salinity (25 ppt optimal), low temperatures (< 13 °C optimal), and low sedimentation (fine to medium sand with < 1 cm burial depth; Cumming et al., 2017). This suggests that the *H. nigricaulis* seed viability and germination, which is needed for sexual reproduction, is largely seasonal and likely limited, but not exclusively, by large-scale drivers such as rainfall, temperature, and sedimentation.

Seagrass Ecology: Habitat and Community

Seagrass is an important marine ecosystem that provides food, shelter, and essential nursery areas. In Tasmania, seagrass is thought to be declining (Rees, 1993) and is protected under Division 6 Sections 138 (*Activities Causing Detrimental Effect*) and 139 (*Protection of Marine Plant*) of the *Living Marine Resources Management Act 1995*. There are further protections under Part 4 Section 25 (*Protection of Native Marine Plants Attached to Seabed or Other Substrate*) of the *Fisheries (Marine Plants) Rules 2017*.

Seagrasses are plants that photosynthesise, and the high primary productivity of seagrass habitats support an abundance and diversity of species that live on (epiphytic species) or among the seagrass leaves and in the sediment (benthic species; Hemminga and Duarte, 2000). There are very few herbivores that graze directly on seagrass (e.g., urchins and small arthropods). This is because the leaves contain phenols, have low nitrogen content, and high cellulose content (Bologna and Heck, 1999). Instead, most seagrass-associated herbivores graze on the epiphytic algae, predominantly diatoms, that grow on the seagrass leaves (Bologna and Heck, 1999). Benthic species are largely driven by the sub-structure of seagrass, such as sediment grain size, organic content, and the root and rhizome system (González-Ortiz et al., 2016; Rodil et al. 2021; Boyé et al., 2017).

Seagrass herbivores are a source of food for a range of predatory species. Fish generally reside seagrass habitats in three different ways: small benthic fish that reside almost entirely in the seagrass, pelagic or reef fish that temporarily reside in the seagrass during their juvenile stage, or fish that utilise seagrass on rare occasions, such as adult pelagic or reef species (Gillanders 2006). Seagrass species, structural complexity, and biomass can drive change in fish assemblages, including the fish abundance and diversity (Hori et al., 2009; Park and Kwak 2018; Jones et al., 2021). The structural complexity of seagrass also provides fish with a place to refuge from larger predators (Gillanders 2006).

Seagrass habitats are widely regarded as a nursery area for many species, including recreational and commercial fish. Unfortunately there have been few studies in Tasmania, the most comprehensive was over two decades ago by Jordan et al. (1998) in which they assessed the fish species associated *Heterozostera* beds and nearby unvegetated habitats at three sites across Tasmania; the species with the most separation in abundance between the two habitats are shown in Table 1. Based on evidence from elsewhere in Australia, it is highly likely that seagrass in Tasmania is an important habitat for species such as King George Whiting and Southern Calamari. It is important to recognise that unvegetated habitats, such as the unvegetated sand flats of Pipe Clay Lagoon, are also an important habitat for juvenile fish, especially those that either camouflage or exhibit schooling behaviour (Jordan et al., 1998). For example, juvenile Southern sand flathead prefer unvegetated habitats, while mature Southern sand flathead show no preference between seagrass and unvegetated habitats (Jordan et al., 1998). The Marine Farming Development Plan for Pipe Clay Lagoon (DPIPWE, 1998) reported flathead, as well as flounder, as the most common fish species. In Pipe Clay Lagoon, recent anecdotal evidence might suggest diminishing abundances of flathead and flounder, and the increased presence of both calamari and bream (pers. comm).

Table 1: Top ten species with the most difference in abundance between *Heterozostera* and unvegetated sites at three sites (Georges Bay, Norfolk Bay, and Prosser Bay). Source: Modified from Jordan et al. (1998).

Species	Common Name	Preferred Habitat	Species Interest
Stigmatopora argus	Spotted pipefish	Seagrass	Iconic species
Acanthaluteres spilomelanurus	Bridled leatherjacket	Seagrass	Fishing species
Neoodax balteatus	Little weed whiting	Seagrass	Aquarium traded species
Vanacampus phillipi	Port Phillip pipefish	Seagrass	Iconic species
Cristiceps australis	Crested weedfish	Seagrass	Cryptic species
Vincentia conspersa	Southern cardinalfish	Seagrass	Fishing species
Nesogobius sp. 1	Sandgoby	Unvegetated	Cryptic genus
Gymnapistes marmoratus	Southern Australian cobbler	Seagrass	Venomous
Platycephalus bassensis	Southern sand flathead	Unvegetated	Fishing species
Rhombosolea taparina	Greenback flounder	Unvegetated	Fishing species

Seagrass Ecosystem Services

Seagrass habitats have ecosystem services that provide benefits through the natural ecology and ecosystem health. Recognising these ecosystem services can aid in environmental decision-making, management, and policy, but are often complicated by the conflicting values held by different stakeholders (Kilminster et al., 2015). These ecosystem services are listed in Table 2.

This report only addresses the ecosystem services of the seagrass habitat. It must be acknowledged that all ecosystems, including the extensive unvegetated sand flats that were more present prior to the increased seagrass abundance in Pipe Clay Lagoon, provide valuable ecosystem services as well. As an example, other notable species found in Pipe Clay Lagoon not associated with seagrass habitats include the invasive and commercially valuable *Oratosquilla oratoria* (Japanese mantis shrimp) which prefer unvegetated habitat (3 specimens found; observed by Ugalde in 2018), the native *Ostrea angasi* (native flat oyster) that forms endangered oyster reefs (“mini”-reef found near the hatchery water outlet, ~30cm depth at low tide; observed by Ugalde in 2018), and the vulnerable *Parvulastra vivipara* (Tasmanian live-bearing sea star) found on the wild oyster beds (observed by Strain in 2022). There are also 11 migratory bird species protected under international treaties (DPIPWE, 1998): the Chinese-Australia Migratory Bird Agreement (CAMBA: 6 species) and the Japan-Australia Migratory Bird Agreement (JAMBA: 8 species).

Table 2: Seven ecosystem services which are provided by seagrass. Modified from Kilminster et al. (2015) and adapted from Barbier et al. (2011).

Ecosystem Service	Description of Service	Role of Seagrass
Primary production	Seagrass is a photosynthetic foundation species.	• Most information available is on seagrass conservation, and focuses on persistent seagrass habitats, especially opportunistic and/or persistent seagrass species (Duarte et al., 2010). • Primary production (i.e., the amount of carbon fixed per unit area) is dependent on the photosynthetic rate and the biomass of seagrass present. • Despite the lower biomass of colonising and opportunistic species, which usually form transitory habitats, primary production can still be high (e.g. Kenworthy et al., 1989, Williams, 1988).
Food	Promoting diversity through herbivores directly grazing on the seagrass and herbivores supporting predatory species. This extends beyond the seagrass boundary and includes groups such as land-based species (e.g., birds).	• Colonising and opportunistic seagrass species that form transitory habitats are often a preferred food source of direct grazers of seagrass, such as urchins or birds (Eklöf et al., 2009, Jacobs et al., 1981). • Other iconic direct grazers of seagrass, such as turtles and dugongs, are not found in Tasmania (e.g., Aragones and Marsh, 2000; McMahon, 2005). • Grazers provide food for predators living in or around the seagrass habitat. • Many micro and macro fauna live in the habitats created by the seagrass habitat.
Coastal protection and erosion control	Seagrass provides sediment stabilisation and dissipates waves and water movement. This reduces turbidity and increases light availability in the water column.	• Seagrasses provide coastal protection by stabilising the sediment with their shallow roots and rhizomes and by attenuating currents and wave energy near the sediment water interface (bed shear stress) due to the above ground biomass. • Colonising or opportunistic seagrass species can reduce water velocities (e.g. Heiss et al., 2000) and there tends to be greater attenuation when a larger proportion of the water column is filled by the seagrass canopy (Koch et al., 2006). • Annual seagrass abundance can build up sediment during the growing season, although potentially export it during winter (Bos et al., 2007). • Given the high variability in transitory seagrass abundance (spatially and temporally), the magnitude of this service and importance to coastal ecosystems is not well understood.
Nutrient removal and water purification	Provides nutrient and pollution uptake, and some of these are retained in the seagrass biomass. Dead biomass material can become buried or drift elsewhere, resulting in particle deposition or removal from a given area.	• Transitory seagrass are formed by colonising and opportunistic species (like *H. nigricaulis*) which have higher nutrient content (than persistent species) with proportionally less structural carbon. • Generally faster growth rates of these species mean that these communities have a high potential to convert nutrients into beneficial foodwebs and pathways. • Seagrasses are preferred sources of food for grazers and consumption by birds may provide export of nutrients in estuarine waters (where transitory communities are common). • Other grazers (e.g., sea urchins) may also be important for nutrient export. • Particle deposition within transitory seagrass is less likely to be a dominant process (Mellors et al., 2002) than for persistent communities.

Provision of fish habitat and nursery grounds	Provides a diverse reproductive habitat and nursery for species, and sheltered living space.	• Given the large spatial scale over which seagrass grows, it is likely that the cumulative contribution of them to fisheries production is critical (Coles et al., 1993, Watson et al., 1993), although poorly understood at present. • It has been well documented that extreme environmental conditions that cause a reduction in seagrass habitat and abundance have resulted in subsequent declines in commercially important fisheries (fish, prawn, crab) elsewhere in Australia. • The relative importance of persistent or transitory seagrass has never been documented, but it is likely that transitory seagrass (when present) provide nursery habitat, food and protection for different stages of commercially important species.
Carbon sequestration	Generates biogeochemical activity, sedimentation, and biological productivity.	• High productivity rates of the species that form transitory seagrass habitats and high rates of microbial activity associated in the seagrass rhizosphere, suggest that they could be important contributors to carbon sequestration in the world's oceans. • However, given that seagrass is grazed upon, it is more likely to be consumed or degraded. • The role of transitory habitats in long term carbon sequestration is highly dependent on subsequent transformations and pathways that are still poorly understood (Duarte et al., 2010, Fourqurean et al., 2012, Lavery et al., 2013, Mateo et al., 2006).
Recreation, education, research, and tourism	Provides unique and aesthetic submerged vegetation, and a suitable habitat for diverse flora and fauna with recreational and commercial value.	• The species that form transitory seagrass habitats provide food for threatened and endangered species (e.g. migratory shorebirds), hence providing eco-tourism potentials. • Recreational fishing, snorkelling and diving opportunities may also be associated with transitory habitats. • Other ecosystem services (above) also assist in the maintenance of good water quality and reduced erosion, providing a more aesthetic experience for tourists in many marine or estuarine environments. • A range of interactions between society and seagrass ecosystems are reported in Cullen-Unsworth et al. (2013), however the relative contribution of transitory and persistent habitats to these services is poorly understood.

Section 3: Records of Seagrass in Pipe Clay Lagoon

Seagrass in Pipe Clay Lagoon at present appears to be particularly abundant according to historical records from published reports (see summaries the boxes below), direct observations, and aerial imagery.

Published Reports

The earliest published records are from Guiler (1950) where five beds were mapped in Pipe Clay Lagoon in 1948 and the species as identified as *Z. nana*. In a comprehensive assessment of seagrass in Tasmania, Rees (1993) found no evidence of seagrass from beach searches or aerial imagery in Pipe Clay Lagoon in summer and autumn 1992, although reported that there may be small patches. The Marine Farm Development Plan (1998) reported that seagrass (reported as *H. tasmanica*) coverage increased significantly between 1993 and 1997 based on aerial photos compared to previous years (photos back to 1981) when it was absent or only present in small patches. Between August 2004 and September 2005, habitat mapping of Pipe Clay Lagoon by Mount et al (2004) reported only a small area, with 0.3 hectares of dense seagrass and 0.8 hectares of sparse patchy seagrass.

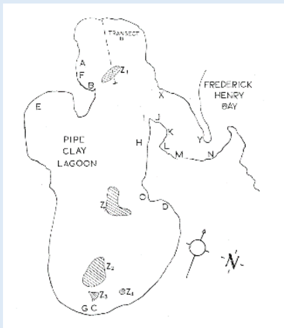
In the last few years, local residents and oyster farmers have reported the rapid increase in seagrass abundance in Pipe Clay Lagoon, with seagrass coverage considered to be unprecedented. Interestingly, the reports are not limited to Pipe Clay Lagoon itself, with local residents also reporting an increased abundance in the seagrass beds along the coastline near Lauderdale, outside Pipe Clay Lagoon. A comparison of satellite images from Google Earth from 2005 to 2022 provides further confirmation of the rapid expansion of seagrass in the lagoon over the last 2-3 years (Figure 8).

1984: A Series of Papers Published on Intertidal Ecology of Tasmania

Reference:	Guiler (1950)
Type of report:	Scientific paper
Purpose:	Intertidal ecology of Pipe Clay Lagoon

- Five seagrass beds were mapped and identified as *Zostera nana*
- Three zones were classified along the sample transect on the northern shore of Pipe Clay Lagoon: *Upper Shore with Arthrocnemon, Supra Zostera, Zostera, Infra Zostera,* and *Lagoon Bottom*
- The *Zostera Zone* was described as a *firmly aggregated mass* that created a shallow "pond" on the inshore side at low tide.

Guiler (1950) identified species associated with the seagrass, but may have been misidentified. Some notable seagrass associated species were mussels, clams, native oysters (*Ostrea*), and crabs.



Detailed map of Pipe Clay Lagoon showing the sampled transect with associated seagrass species and the seagrass (Zostera) beds marked Z_1, Z_2, Z_3, Z_4, and Z_5 (Guiler, 1950)

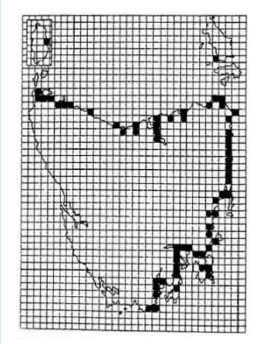
1993: Tasmanian Seagrass Communities

Reference:	Rees (1993)
Type of report:	Thesis
Purpose:	University of Tasmania PhD Thesis

Seagrass abundance in Pipe Clay Lagoon is:

- *Corroborated by an eye witness account by a local resident.*
- *No evidence could be found of seagrass in this tidal arm from beach searches or inspections of recent aerial photographs, although there may be small patches.*

The thesis mapped seagrass abundance of an area of approximately 220 km^2 and reported that between 400 and 500 km^2 of seagrass may occur in Tasmania. The results of the analysis suggested the abundance was in significant decline.



Map of seagrass abundance in Tasmania based on a 10 km^2 grid. No notable abundance was found in Pipe Clay Lagoon.

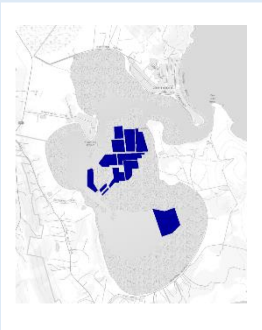
1998: Marine Farming Development Plan

Reference:	DPIPWE (1998)
Type of report:	Government document
Purpose:	Marine Farming Development Plan for Pipe Clay Lagoon

Sections from the plan:

- *Heterozostera tasmanica appears to be the most common species.*
- *Seagrass beds are mostly found in an area inside the lagoon opposite Cremorne spit.*
- *There are also patches and isolated plants scattered through the lagoon.*
- *Aerial photographs show that the larger patches of seagrass south west of the entrance appear to have established in the last few years, the coverage having increased between 1993 and 1997, and been small or nonexistent in earlier photos dating back to 1981*

The plan states that *a detailed scientific study would be necessary to determine the scope of change in seagrass beds and whether changes were caused by natural variation or human activity.*



Map of Pipe Clay Lagoon showing the marine leases covered in the Marine Farming Development Plan (DPIPWE, 1998).

August 2004 – September 2005: Natural Heritage Trust Report

Reference:	Mount et al. (2005)
Type of report:	Final Report
Purpose:	Habitat mapping in the southern NRM region, including other oyster growing areas

Sections from the report:

- *Almost of complete lack of seagrass.*
- *Strong marine influenced waters, caused by the extraordinarily high tidal flushing rate, where almost of the whole volume of the lagoon is exchanged each tidal cycle, coupled with verry low freshwater inputs.*
- *Extensive areas of intertidal, flats and subtidal shallows.*
- *The most diverse habitats are along the main channel near the mouth.*

There is no significant seagrass in Pipe Clay Lagoon, though there are a few small beds lining the main entrance channel, dense near the mouth and sparser where the channel turns easterly around the spit. Similarly, there is a low-profile reef and cobble habitat in the main entrance area.

Mount et al. (2005) also reported the greatest amount of seagrass in Greater and Little Swanport (identified as *H. tasmanica*, *Z. muelleri*, and *Ruppia* sp.), followed by Pitt Water. The seagrass species in Pipe Clay was not identified.

Aerial image (dated March 2004) and habitat map of Pipe Clay Lagoon (Mount et al., 2005)

Aerial Imagery

Google Earth Pro has 50 historic satellite images of Pipe Clay Lagoon from May 2005 to January 2022 (inclusive). Some of these images are of duplicate days, obscured by cloud cover, or have reduced image quality. Nonetheless, these images show a clear shift in available habitat, particularly between November 2017 (predominantly sand flats) to January 2022 (increased greenery, presumed to be seagrass), keeping in mind that the information gained from these images are limited because ground-truthing has not been performed. This timing in habitat shift aligns with published reports (see Section 3.2) and on-ground observations made by local residents and other sources (see Section 3.3). Before November 2017, some images appear to show alternative habitats to sand flats, which may be small patches of seagrass, wild oyster beds (which are known to be extensive, Figure 7), or other habitat. A selection of 12 images is shown in Figure 8 from October 2013 to January 2022.

Figure 7: Pipe Clay Lagoon map in 2018 showing three ground-truthed (photo insert) wild oyster (*Crassostrea gigas*) beds in red, an approximate location of a small patch of native oysters (*Ostrea angasi*) in black, and marine leases in blue (Crawford and Ugalde, 2019). The native oysters cannot be seen from the satellite image.

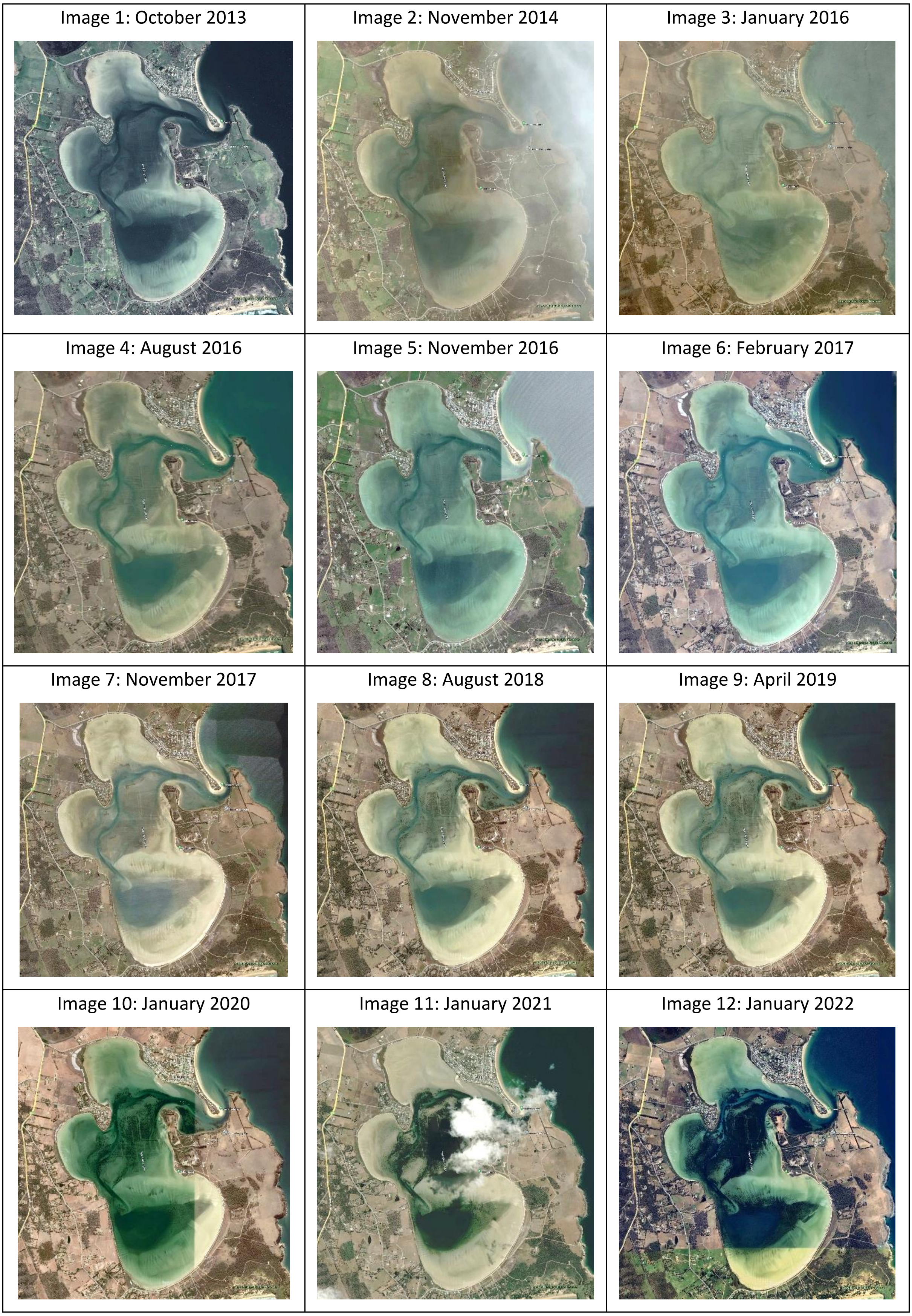


Figure 8: Selection of historic satellite images of Pipe Clay Lagoon from October 2013 to January 2022 showing the increased extension of seagrass in Pipe Clay Lagoon. All images have been corrected for brightness +20%.

Section 4: Possible Causes for the Increase in Seagrass Abundance

The presence of seagrass is typically considered indicative of a heathy ecosystem (Orth and Moore, 1983). Seagrass is often found at the land-sea interface, encountering runoff and land-derived inputs of nutrient and sediments (Short et al., 2006). Under normal conditions, seagrass can thrive, absorbing the excess nutrients and filtering out fine sediments from the water column, but when inputs become excessive, other more opportunistic rapid growing algae outcompete seagrass for nutrients and light, leading to a decline in seagrass health and reduction in cover (Dennison et al., 1993; Kirkman 1997; Boudouresque et al., 2000; Green and Short 2003). Seagrass loss in Australia and elsewhere in the world has been shown to be linked to shoreline development, industrial and residential pollution, and damaging fishery and aquaculture practices (Short et al., 2006).

The possible causes for the increase in seagrass abundance in Pipe Clay Lagoon are explored using a Likelihood Impact Matrix (Table 3). This matrix helps to consider two intersecting factors, each ranked 1 (low) to 3 (high): the likelihood that a potential cause has occurred in Pipe Clay Lagoon, and the magnitude of impact that potential cause could have on seagrass abundance. The potential causes for the increase in seagrass abundance have been listed from available literature (often relating to seagrass decline both in Australia and elsewhere) and personal communications with experts. The matrix also ranks the scale of the change derived from the potential cause (either large-scale or small-scale), and the level of uncertainty that describes the satisfaction with the amount of information that is available for accurate rankings. These factors are important because the increase in seagrass abundance is not contained to Pipe Clay Lagoon.

The Likelihood Impact Matrix suggests that the increase in seagrass abundance in Pipe Clay Lagoon is predominantly driven by, but not limited to, large-scale climate factors, particularly higher than average rainfall and warm temperatures (Table 4), that has occurred in the last few years. These climate drivers are likely to have increased nutrients in Pipe Clay Lagoon, either through land-based runoff or leaching from the water table, and at critical times, potentially reduced the salinity for optimal germination. These conditions may have enabled the seagrass to become established, and now, coupled with the lack of flushing, reduced turbidity and sedimentation (these are “positive feedbacks” provided by the seagrass itself), and the colonising/opportunistic ecology of *H. nigricaulis*, populations are being maintained through a combination of sexual and asexual reproduction. Although farmed and wild oysters may not have contributed to the initial increase in seagrass abundance, oysters are filter feeders that influence water clarity and increase light available for benthic primary produces, such as seagrass. The release of oyster faeces and pseudofaeces (i.e., undigested waste from large particles that cannot be digested or excess food) may also support the establishment of seagrass beds by providing optimal nutrient conditions for asexual reproduction.

Table 3: A Likelihood Impact Matrix considering the intersecting factors of likelihood (ranked 1 to 3) and impact (ranked 1 to 3) for the potential causes of the increase in seagrass abundance. The residual likelihood (ranked 1 to 9) indicates the causes most likely to be driving the increase in seagrass abundance in Pipe Clay Lagoon.

Potential Cause of Seagrass Growth: Environmental, Physical, Ecological	Likelihood (1 – 3)	Change Driven by the Potential Cause	Scale of Change	Impact (1 – 3)	Uncertainty (Low – High)	Residual Likelihood (1 – 9)
Environmental Causes of Increase Seagrass Abundance in Pipe Clay Lagoon						
Optimal nutrients (increase nutrient loads or decreased eutrophication)	3	Depending on the prior nutrient levels, a nutrient increase (perhaps through increased land-based runoff, leaching from the high water table, or oyster depositing faeces or pseudofaeces) or decrease (improve land management) in the seawater may now be optimal for seagrass growth (Githaiga et al., 2019).	• Large scale: climatic changes • Small scale: local management	3	**High** No recent nutrient data is available	9
Increased rainfall	3	The high rainfall events over the past couple of years may have contributed to optimal conditions for seagrass growth through increased freshwater inputs (salinity decrease), increased land-based runoff or water table leaching (nutrient increase), and negative impacts on oyster physiology (reduced nutrient extraction and assimilation). Normally, Pipe Clay Lagoon is characterised by low freshwater inputs (DPIPWE, 1998).	• Large scale: climatic changes	3	**Low** Climate records are available	9
Decreased flushing	3	Pipe Clay Lagoon has exceptionally high tidal exchange estimated at 1.36 tidal cycles with a high water volume of ~7,000 ML (DPIPWE, 1998). A decrease in this exchange may support seagrass establishment and growth by reducing the flushing of seeds and reproductive material and reducing the hydrology impact on individual plants or small patches that exhibit a high boundary to area ratio (Githaiga et al., 2019).	• Large scale: climatic changes	2	**Medium** Satellite data, maps, and observations are available	6
Decreased turbidity	2	A decrease in turbidity caused by suspended sediment, organic matter, or other light-scattering particles (e.g., phytoplankton) would increase the light availability required for seagrass growth (Githaiga et al., 2019). The hydrology can stir up and suspend particles more easily than some other habitats (e.g., sandflats).	• Large scale: climatic changes • Small scale: local management	2	**Medium** Satellite data is available	4
Optimal water temperature	3	Depending on prior water temperatures, a temperature shift may now be optimal for seagrass growth (Githaiga et al., 2019). Pipe Clay Lagoon has unusual temperature properties influenced by large areas of sand exposed at low tide (especially at the back of the bay) that can influence the thermal properties of the surround water with the changing tide.	• Large scale: climatic changes	3	**Low** Climate records are available	9

Decreased sedimentation	2	Sediments in Pipe Clay Lagoon are known to be dynamic with a history of considerable movement of sediments (especially at the mouth of the lagoon; DPIPWE, 1998). Sedimentation changes can influence the hydrology (and flushing) and decreased sedimentation could prevent the smothering of young seagrass which may enable populations to become established (Githaiga et al., 2019).	• Large scale: climatic changes • Small scale: local management	2	**Medium** Satellite data and maps are available	4
Physical Causes of Increase Seagrass Abundance in Pipe Clay Lagoon						
Reduced dredging or weeding (seagrass removal)	1	Reducing the physical removal of seagrass or burial/smothering of plants, either intentionally or unintentionally, might increase survival and enable reproductive populations to become rapidly established (Tuggerah Lakes Entrance Management Study, 2022). There is some history of dredging in Pipe Clay Lagoon (i.e., opening the gutters; pers. comm) and no history of intentional weeding.	• Small scale: local activities	2	**Low** No records or reports of removal	2
Reduced damaging activities (industry or recreation)	1	Pipe Clay Lagoon has multiple users: industry (oyster farming) and recreation (e.g., boating, swimming, windsurfing, fishing/floundering and onshore activities; DPIPWE, 1998). Improved practices or use of the area might have reduced damaging activities, such as anchoring, propelling, hauling, and enabled reproductive populations to become rapidly established (Tuggerah Lakes Entrance Management Study, 2022).	• Small scale: local activities	2	**Medium** No records or reports of removal, but many activities are carried out in the area	2
Ecological Causes of Increased Seagrass Abundance in Pipe Clay Lagoon						
Decreased competition	1	Other photosynthetic organisms (e.g., phytoplankton, seaweeds) compete with seagrass for light, nutrients, and space. A decrease in these organisms, including by oyster filter feeding, might increase seagrass survival and enable reproductive populations to become rapidly established.	• Large scale: climatic changes • Small scale: local activities	2	**High** Only historic data is available	2
Decreased herbivory species	1	There are a few species that graze directly on seagrass (e.g., urchins and, elsewhere, turtles; Heithaus et al., 2014; Rose et al., 1999). A reduction in these herbivorous species, particularly urchins, might reduce the leaf loss and play a critical role in determining spatial abundance (Bourque and Fourqurean, 2013).	• Large scale: climatic changes • Small scale: local activities	2	**High** Only historic data is available	2
Decreased predatory species	1	Decreasing the abundance of predatory species, such as larger fish through overfishing and/or habitat shifts, might reduce the abundance of herbivorous species that graze on the seagrass (Atwood et al., 2015; Coverdale et al., 2014).	• Large scale: climatic changes • Small scale: local activities	2	**High** Only historic data is available	2
Increased colonising/opportu	3	According to the Generic Seagrass Model, *Heterozostera* spp. has rapid re-seeding, broad seed distribution ranges, high turnover of individual plant, and mostly sexual reproduction (Walker et al., 1999; Kilminster et al., 2015). Seeds can also be viable for over 12 months (Smith et al., 2022). These characteristics could give the genus a	• Small scale: local activities	3	**Low** *Heterozostera* is well understood	9

nistic ecology of *Heterozostera* sp.		"boom or bust" type of growth, where if conditions are optional, growth and reproduction (including seed banks in the water column or sediment) could be higher in comparison to other genera.			and a common genus	
Optimal abundance of oysters	2	The farmed and wild oysters (*C. gigas*) in Pipe Clay Lagoon will contribute to increased seagrass abundance through indirect environmental causes, such as oyster filter feeding reducing turbidity (i.e., removed phytoplankton from the water column), increasing light availability (i.e., reduced phytoplankton reduces competition for light) and increasing nutrients (i.e., increased amount of faeces and psedofaeces in the sediment and the water column) and contribute to decreased seagrass abundance through direct physical causes, such as damaging activities, such as propelling, wading, and physical removal. It is uncertain if the amount of farmed and wild oysters in Pipe Lagoon has increased, and if the potential timing of this is aligned with the increase in seagrass abundance.	• Small scale: local activities	3	**High** Recent farming records are not available	6

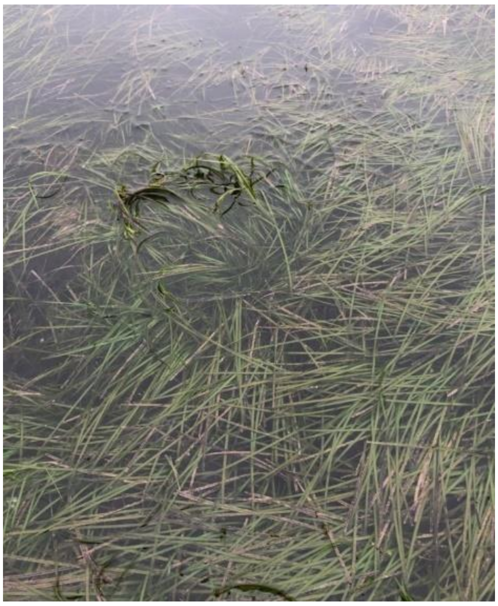
Table 4: Monthly total rainfall (mm) and monthly average maximum (i.e., the average of all available daily maxima for the month) temperature (°C) and recorded by the Bureau of Meteorology (BOM) from the Hobart (Ellerslie Road) Station from 2014 and 2022. Monthly averages are calculated from historic data available from 1882 to 2023 (when available). Available at Climate Data Online (BOM, 2023) at: www.bom.gov.au/climate/data/index.shtml.

Monthly total rainfall (mm)														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Average**	**Annual +/- Compared to Historic Average**
2014	16.2	27.6	23.4	42	30.6	20.6	95.8	46.2	19.4	49.6	34.8	78	40.4	-10.8
2015	121.6	21.6	51.2	12.4	75.8	44.2	23	63.8	25	14.4	40.4	35	44.0	-7.1
2016	40.2	21.8	17	8.8	96	115.4	79.2	15.8	94.2	83.4	65.2	56.6	57.8	6.7
2017	60	10.4	37	21.6	28.4	6.6	37.2	65	46.2	33.4	46.4	101	41.1	-10.0
2018	22.2	35.2	38.6	30	146.2	34.2	55.2	53.4	17.4	30.2	61.6	61	48.8	-2.3
2019	0.4	35.4	18.2	32.4	23.4	19.4	46.6	100.2	34.6	17.6	40.8	16	32.1	-19.0
2020	33.6	15.8	72	78	15.8	84.2	11.6	103.8	35	122	12.2	72.2	54.7	3.6
2021	28.8	52	59.6	23.8		59.8	14.2	50.6	71.6	160.4	90	40.8	59.2	8.1
2022	54.4	5.4	30.6	21	134.6	58.2	25.4	67	59	90.2	78.6	75.6	58.3	7.2
Historic Average	46.7	39.1	44.6	49.8	47.6	53.8	51.6	54.3	52.9	62.1	54.3	56.4	51.1	
Monthly average maximum temperature (°C)														
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Average**	**Annual +/- Compared to Historic Average**
2014	23.5	23.1	22	18.3	15.6	13.3	13.4	14.6	17.9	18.1	19.4	20.3	18.3	1.3
2015	21.5	22.5	20.3	16.7	14.6	12.9	12.1	12.4	16.2	19.7	20.5	22.5	17.7	0.7
2016	22.5	23.8	21.6	20.4	15.6	13.5	13.2	14.3	16.2	17.2	18.6	22	18.2	1.2
2017	23	22.9	22.4	19.2	14.7	13.9	12.2	13.3	15.1	20	22.4	22.5	18.5	1.5
2018	24.4	21.7	21.4	18.8	15.8	12.8	13.4	13.9	16.3	18.3	19.5	22.3	18.2	1.2
2019	25.9	22.9	21.5	19.6	15.8	13.6	13.5	13.7	16.7	18.8	20.2	21.8	18.7	1.7
2020	24.3	20.8	20	17.3	15.5	12.8	12.5	13.6	16.8	16	22.3	20.7	17.7	0.7
2021	22.5	22.5	21.2	18.5	15.7	13.4	13	14.4	15.8	16.5	18.3	21.1	17.7	0.7
2022	22.1	22.5	21.5	19	15.1	12.5	12.8	14.6	15.3	16.9	18.5	19.8	17.6	0.6
Historic Average	21.8	21.7	20.2	17.4	14.5	12	11.8	13.1	15.2	17	18.8	20.4	17.0	

Section 5: Impacts on Oyster Farming

All five commercial oyster farm operators in Pipe Clay Lagoon have reported seagrass impacts on oyster production and/or farm operations. The most wide-spread impacts are reduced oyster growth and conditioning, financial impacts, and safety concerns accessing oysters (Table 5, pers. comm.). Other observations of change in the lagoon made by oyster farm operations include a reduction in the presence of small or juvenile fish, changes to sandbars forming in the entrance, silt build-up in the presence of seagrass, and reduced water flow where seagrass is abundant.

Table 5: Reported observations made by oyster farmers in Pipe Clay Lagoon relating to oyster production and farming operations (photo: S. Calvert).

Seagrass impacts on oyster production	Seagrass impacts on farming operations
• Oyster mortality • Oyster reduced growth • Sediment changes (softer sediment) • Water flow changes • Difficulties conditioning and fattening • Changes in oyster meat colour (meat is darker and not preference by the market)	• Farmers experiencing financial impacts • Farmers experiencing safety concerns • Farmers experiencing stress • Difficulties accessing lease • Difficulties wading through seagrass • Propellor entanglement
	

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