DARWINWATERFRONT

RECREATION LAGOON

WATER QUALITY MONITORING PROGRAM

April 2020

Disclaimer

This document provides information of a general nature and is specific to the Darwin Waterfront Recreation Lagoon. Readers should refer to the National Health and Medical Research Council's and their relevant state environmental health department guidelines in relation to managing risk in recreational waters. Neither the Darwin Waterfront Corporation or the author give any assurances in relation to the content herein.

Preface

This document is intended to provide information of a general nature in relation to the recreational water quality program implemented by Darwin Waterfront Corporation Operations to ensure the Recreation Lagoon remains a safe and enjoyable recreation facility for use by general public for aquatic recreation activities.

The Lagoon is a 4.5Ha man-made saltwater body of water that is replenished with natural seawater from Darwin Harbour, and since its completion in 2009 the Lagoon has sustained a diverse ecosystem of marine flora and fauna, including fish, molluscs, invertebrates, and marine algae, all of which needs to be managed to ensure the primary contact classification is maintained.

First published 2020
Version 0

Author: J. Kassaras (BEng, MProjMgt)

Executive Summary

The Recreation Lagoon at Darwin Waterfront is a dominant feature of the development. The Lagoon waterbody is physically separate from the adjoining Darwin harbour, and was created to establish a permanent, non-tidal 'waterfront' to counteract the large tidal range of Darwin harbour and provide a safe swimming facility for locals and visiting tourists.

Completely isolated from the harbour by a 750m long seawall, the water in the Lagoon is replenished at the rate of approximately 27,500cu.m per week. This ensures the water in the Lagoon is maintained at a high standard, and ensures sufficient circulation to prevent stagnation and anaerobic (lack of oxygen) conditions from developing within the water column.

The Darwin Waterfront Corporation is responsible for the ongoing management of the Recreation Lagoon and ensuring the Lagoon continues to meet stringent recreational water quality guidelines, preserving its primary contact classification; necessary for swimming.

National Health and Medical Research Council (NHMRC), Department of Health (DOH) and best practice guidelines developed by other states provide the overarching framework used to develop and implement site specific management practices that underpin a risk based approach to the Corporation's water quality management in the Lagoon.

A major aspect of the Corporation's approach is routine microbiological testing of the water to monitor the presence of faecal contamination. Testing for the presence of intestinal enterococci is considered the preferred indicator by NHMRC and DOH, and although not considered a pathogen of concern, its presence can indicated the presence of other, more severe pathogens like protozoa and viruses, which can lead to gastrointestinal illness (GII) and/or acute febrile respiratory illness (AFRI).

The Recreation Lagoon Water Quality Management Program ensures closure of the Lagoon due to adverse water conditions are rare, and that when required, appropriate corrective action is implemented in a timely manner to protect users and restore water quality as quickly as possible.

Introduction

The Darwin Waterfront Recreation Lagoon Water Quality Management Program ensures the Corporation meets its obligation to maintain the highest standard of water quality in the Lagoon so it meets stringent National guidelines for primary contact, and maximises opportunities for aquatic recreation in Darwin while limiting exposure to endemic marine dangers like box jellyfish, crocodiles and sharks, which are prevalent in Top End marine waters.

The Darwin Waterfront Recreation Lagoon is a man-made, sea water lagoon that adjoins the Darwin harbour. Construction of the Lagoon commenced in 2004 and was completed in 2009, and it comprises an earthen embankment seawall and a mechanical flushing system, which replenishes the lagoon water by pumping in fresh sea water from the harbour.

With a total approximate volume equivalent to 11 Olympic sized swimming pools, the flushing system pumps in the equivalent volume of the lagoon over 7 days with fresh sea water from the harbour. Fine mesh screens with apertures of 500microns prevent uptake of marine life and flotsam.

It is a central feature of the Darwin Waterfront precinct, providing approximately 4.5Ha (45,000sq.m) of 'artificial', non-tidal marine aquatic recreation space, making it the safest 'beach' in the Top End to swim.

The National Health and Medical Research Council and Department of Health guidelines provide the overarching framework under which the water quality management program has been developed to mitigate risks associated with poor water quality, primarily from enteric viruses and protozoa[1]. Taking into account the unique characteristics of the Lagoon, the Corporation has implemented site specific processes and procedures that ensure compliance with recommended best practice; fundamental to its risk based approach to water quality management.

The program aims to address two key components of water quality; microbial conditions, and the presence of box jellyfish and other dangerous aquatic organisms, which are considered the two main threats to safety in the Recreation Lagoon.

Microbial monitoring comprises routine sampling and testing of the water for the presence of intestinal enterococci, as an indicator for the presence of pathogens like E. Coli and cryptosporidium which are known to cause gastrointestinal illness (GII) and/or acute febrile respiratory illness (AFRI).

Jellyfish and other marine life like stonefish and blue ringed octopus are some of the most venomous creatures in the World, and as a marine waterbody, the Recreation Lagoon is susceptible to the presence of these marine stingers. The deadly Chironex fleckeri (box jellyfish) and Gerongia rifkinae (Irukandji) are prevalent in local seas and the program includes actively monitoring the presence of jellyfish to manage these risks.

Overall the program aims to significantly reduce the latent risk to the health and wellbeing of the Recreation Lagoon users by actively managing those vectors considered the most likely to pose a threat; microbial and marine stingers, while remaining cognisant of other water-based, relatively low risk threats like cyanobacteria.

[1] Enteric viruses and protozoa refers to those pathogens that originate in the gut of mammals, are otherwise not present naturally, and are recognised as contamination originating from faecal sources.

Recreational Water Quality Framework

National Health and Medical Research Council (NHMRC) Guidelines

The NHMRC guidelines were published in 2008, and until now remains the benchmark guideline for managing recreation water risks throughout Australia. It is referred to as the overarching framework for the program.

Chapter 5 of the guidelines address the microbial assessment of recreational waters and defines the risk based approach to sanitary inspection and assessment, including the principle of testing for the presence of enterococci as an indicator for pathogenic viruses (e.g. Rotaviruses, Hepatitis etc), bacteria(e.g. Salmonella) and protozoa (Cryptosporidium, Giardia etc.).

Management of dangerous aquatic organisms is discussed in Chapter 8 of the guidelines, including venomous and non-venomous species.

Department of Health (NT) Guidelines

The Department of Health (DOH) revised its Draft Guidance Notes for Recreational Water Quality in the Northern Territory in 2020 in response to the need for more focussed guidance in the Northern Territory, and the need to supplement the overarching framework of the NHMRC's guidelines to assist managers of recreational water facilities to develop and implement appropriate water quality management practices.

The DOH guidance notes solely focus on the microbial aspects of water quality and define a preferred methodology for assigning sanitary inspection categories to NT recreational waters, including trigger levels for action in response to elevated microbial test results.

Risk Assessment and Management

The Corporation adopts a qualitative based approach to water quality management of the lagoon, considered the most practical method of managing the risks, and consistent with the NHMRC and DOH guidelines.

The Corporation's risk management framework underpins its risk management approach to water quality management.

Lagoon Characteristics

The lagoon is a man-made marine waterbody constructed as part of the Darwin City Waterfront Redevelopment project, stage one of which was completed in 2009. The lagoon is physically isolated from the adjoining Darwin harbour by a 650m long seawall which prevents large predatory or dangerous marine species from entering the lagoon. This ensures the lagoon is the safest place to swim in the 'sea' in Darwin.

The lagoon has a total volume of 27,500cu.m, or 27.5 million litres and to ensure the lagoon water is kept to a high standard, it is replenished with fresh sea water from Darwin Harbour continuously by three large pumps at the pumping station on Stokes Hill Wharf. Stainless steel screens with apertures of 500 micron (0.5mm) prevent take-up of marine fauna and flotsam from the harbour, and to date have prevented the ingress of box jellyfish and other dangerous aquatic organisms.

The layout and design of drainage systems throughout the public domain protect the lagoon water quality. A defined catchment ensures that only rainfall within the lagoon's protected catchment enters the lagoon during storms. All other stormwater runoff is diverted away from the lagoon to prevent poor quality waters (e.g. roadway runoff) entering the lagoon.

This 'protection' from poor quality water ingress, combined with an effective turnover of the total volume of the lagoon over 7 days through pumping in of fresh sea water ensures water quality is maintained at a high level.

Microbial Water Quality Assessment & Classification

Sanitary Inspection and Assessment

The DOH guidance notes suggest the preferred approach to sanitary inspection and assessment of recreational waters is that used by NSW Beachwatch in New South Wales.

The screening approach used by NSW Beachwatch is a qualitative risk based approach to assessing the sanitary classification taking into account the likelihood and consequence of faecal sources. The approach is consistent with the NHMRC guidelines.

With reference to the DOH guidance notes and the NSW Beachwatch as the preferred approach, Darwin Waterfront Corporation has developed a site specific DWC Microbial Assessment Tool to use for classifying the Recreation Lagoon.

The DWC Microbial Assessment Tool is used to identify potential sources of faecal contamination specific to the Darwin Waterfront Recreation Lagoon, and assess the likelihood of these sources impacting on the water quality using qualitative risk assessment principles, resulting in an overall classification.

The DWC Microbial Assessment Tool was used to determine the Lagoon's classification in accordance with NHMRC guidelines.

The Darwin Waterfront Recreation Lagoon's sanitary classification has been assessed as **Very Low**.

Microbial Indicator

Intestinal enterococci (enterococci) is the preferred indicator organism for testing microbial quality of water. Pruss (1998) showed that the presence of intestinal enterococci (and other indicator bacteria) is a reliable indicator of the presence of other pathogenic organisms consistent with faecal contamination.

Enterococci is persistent in saltwater and therefore the preferred indicator species for testing the microbial properties of recreational waters, and it is used by the Corporation to monitor microbial quality of the Recreation Lagoon.

Intestinal enterococci itself is considered non-pathogenic. It originates from the gut and is excreted from the body through passing of faeces, along with pathogens of concern, including parasitic protozoa (cryptosporidium) and viruses like Rotaviruses, Hepatitis etc.

Microbial Assessment and Categorisation

Section 5.3.3 of the NHMRC guideline relates to the microbial assessment of marine waters. The Lagoon is a marine water body, sustained by continuous delivery of fresh sea water from the harbour into the lagoon using the flushing system and therefore falls within the scope of this section.

Microbial classification provides clear guidance on the risk levels associated with varying levels of enterococci counts based on the 95th percentile calculation method using the Enterotester developed by the Department of Health in Western Australia.

The categorisation system comprises four (4) categories, representing levels of risk that have been developed through extensive epidemiological studies (NHMRC, 2008). These are defined in Table 5.7 of the NHMRC guidelines.

NHMRC Table 5.7, replicated below, provides clear guidance on the microbial assessment category based on the tested water quality of the Lagoon, which over time has been determined to be Category A.

Table 1 Microbial Water Quality Assessment Categories

Category	95th Percentile value for intestinal enterococci/100mL	Estimation of probability	
A	≤40	GII risks: < 1%	AFRI risk: < 0.3%
B	41-200	GII risk: < 1-5%	AFRI risk: < 0.3-1.9%
C	201-500	GII risk: < 5-10%	AFRI risk: < 1.9-3.9%
D	>500	GII risk: > 10%	AFRI risk: > 3.9%

The microbial water quality assessment has determined the lagoon to be **Category A** (< 40 counts/100mL)

Initial Classification

The initial microbial assessment of a recreational water body is determined by comparing two unique characteristics of the lagoon:

- The sanitary inspection classification, and
- The microbial assessment category.

The results of the sanitary inspection and microbial assessment category of the lagoon have been used to determine the initial microbial water quality classification of the lagoon using the matrix shown in Table 5.13 in the NHMRC guidelines, reproduced in Table 2 below.

Table 2 Classification matrix for faecal pollution of recreational water

		Microbial water quality assessment category (95th percentiles – intestinal enterococci/100mL)				Exceptional Circumstances
		A ≤ 40	B 41 - 200	C 201 - 500	D > 500	
Sanitary inspection category (Susceptibility to faecal influence)	Very Low	Very good	Very good	Follow up	Follow up	ACTION
	Low	Very good	Good	Follow up	Follow up	
	Moderate	Good	Good	Poor	Poor	
	High	Good	Fair	Poor	Very poor	
	Very High	Follow up	Fair	Poor	Very poor	
	Exceptional circumstances	ACTION				

Initial classification of lagoon has been determined to be **Very Good**.

Monitoring and Testing

Since sampling and testing commenced in 2009, the Lagoon has consistently exhibited very good water quality, although incidents of elevated intestinal enterococci counts has been recorded almost annually since 2010.

Routine testing by the Corporation is used to evaluate the microbial conditions (enterococci count) present in the water at the time of testing to determine if intervention is required to address changes to the water quality.

The results of routine testing inform the Corporation's Operations team to make decision about the suitability of the lagoon as a primary contact recreation water body throughout the year, and in some cases the need to close the facility to swimming.

The frequency of the testing during normal operating conditions (i.e. < 40 counts/mL) is monthly, however this can change from time to time in response to environmental and other factors. This exceeds the minimum requirements of the NHMRC guidelines based on sanitary classification.

Sampling of Water

Currently, the Corporation samples from five (5) different locations around the lagoon perimeter to ensure spatial variation of sample sites is significant (NHMRC, 2008). Locations include sites off the sea wall and inside the beach inlet, which has significantly higher bather loads than the rest of the lagoon.

Routine testing of the lagoon is conducted once a month across five different locations around the perimeter of the lagoon during normal operating conditions i.e. where count is < 40 per millilitre

Sampling and testing frequency and number may be increased during periods of heightened microbial risk anecdotally coinciding with periods of monsoon weather. This is because the inflows from runoff and the usually heavy overcast conditions combined with warm temperatures present ideal conditions for 'blooming'.

Factors Affecting Microbial Water Quality

The Recreation Lagoon has been open to the public as a primary contact recreation waterbody since 2009. During this time the Corporation has continuously undertaken routine sampling and testing of the water quality in accordance with the NHMRC and DOH guidelines using independent environmental consultants.

Since opening, the lagoon has had to be closed on nine (9) occasions due to elevated levels of intestinal enterococci counts, and each incident has coincided with periods of monsoonal weather where heavily overcast and frequent intense rainfall conditions prevail. Combined with elevated temperatures during the Wet Season and low ultra-violet sun light penetration, it creates ideal conditions for the potential growth of pathogenic bacteria and viruses in the lagoon.

Anecdotally, the persistence of these pathogens in salt water is short-lived, however the significant runoff entering the lagoon from the precinct parklands can temporarily result in stratification due to the less dense fresh water overlying more dense sea water prior to natural mixing, creating more favourable conditions for the pathogens to persist and flourish.

Response to Poor Microbial Water Quality

The Corporation has developed a water quality response plan, to ensure immediate action is taken in response to testing that indicates poor quality water conditions in the lagoon. The process is summarised below in Figure 1.

The response plan provides pre-defined actions based on the latest test results, and uses a traffic light system to classify the water quality, based on monthly test results.

The criteria have been adopted from National Health and Medical Research Council Guidelines 2008 – Table 5.7, and is presented in a more user friendly table format, shown below in Table 3.

Figure 1 Procedure for Closure, Monitoring and Restoration of Recreation Lagoon Water Quality

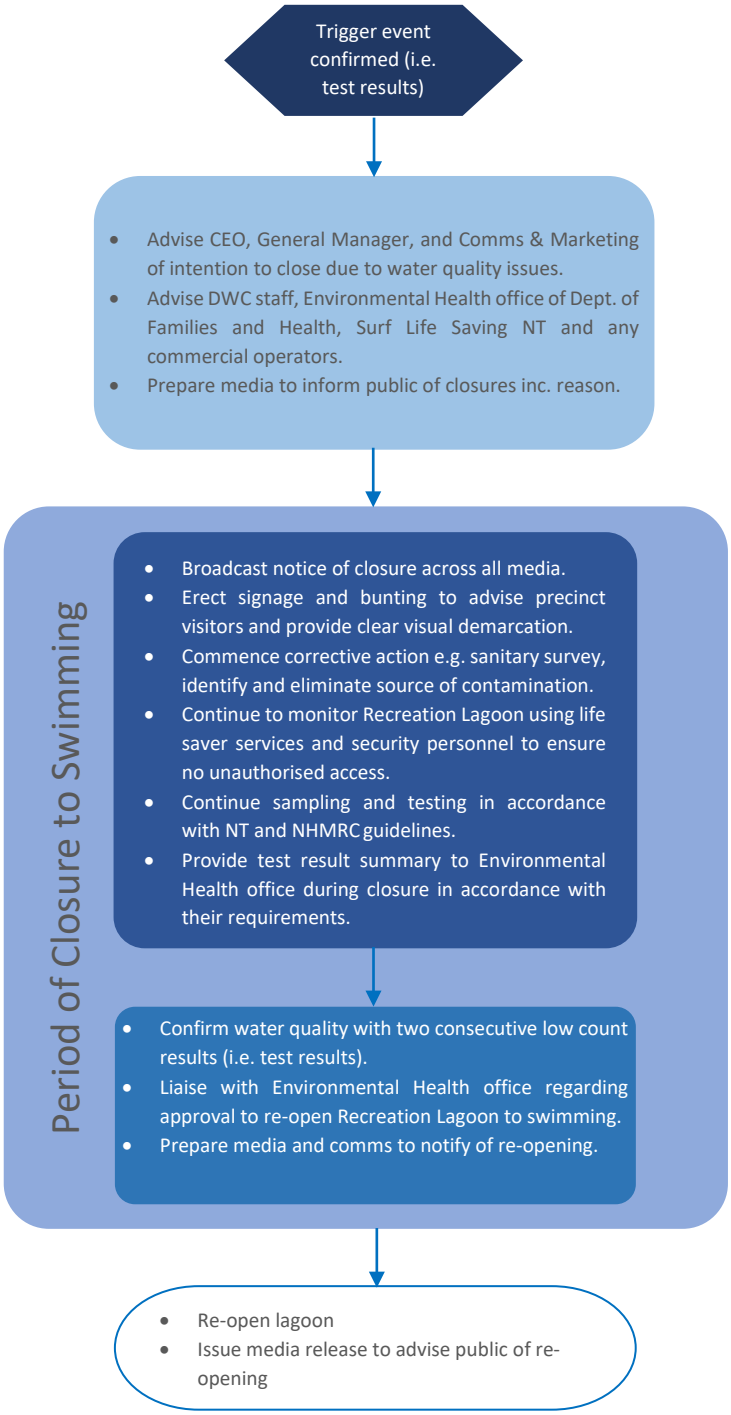


Table 3 Traffic Light System for Water Quality Classification

GREEN MODE

Status	Criteria	Action
Surveillance/Open for Swimming	All samples: ≤40 Enterococci/100mL[1] **OR** ≤200 E.Coli/100mL **and** <10 pathogenic protozoans/100mL[2]	Continue routine sampling[3]

AMBER MODE

Status	Criteria	Action
Alert/Open for Swimming	All samples: Between 41 and 200 Enterococci/100mL[1] **OR** >200 E.Coli/100mL **and** <10 pathogenic protozoans/100mL[2]	• Increase sampling rates to daily[4] • Confirm poor water quality with replicate sampling • Undertake a sanitary survey (NHMRC 2006) and identify sources of contamination

RED MODE

Status	Criteria	Action
Closed for Swimming	Two samples: >201 Enterococci/100mL within 24 hrs[1] **OR** Single sample: >500 E.Coli/100mL **and** >10 pathogenic protozoans/100mL[2]	• Erect warning signs to inform public near affected areas and access points • Inform public through media that a public health problem exists • Increase sampling rates to daily[4] • Confirm poor water quality with replicate sampling • Undertake a sanitary survey (NHMRC 2005) and identify sources of contamination

Note 1: Microbiological indicator
Enterococci is the preferred indicator, however until a robust enterococci data base is established in the Northern Territory, the use of E.coli is acceptable.

Note 2: Pathogenic protozoans
There is no generic test for pathogenic protozoans, however there may need to be specific testing for the following protozoans depending on the outcomes of a specific risk assessment process:

- Naegleria fowleri (*preferred testing organism in fresh waters*)
- Acanthamoeba spp
- Entamoeba spp
- Cryptosporidium

Note 3: Frequency of routine sampling – Green Mode
The frequency of routine sampling for both marine and fresh waters is relative to the daily use of the water body. The following criteria applies:

Sampling Frequency	Frequency of Daily Use	
Weekly	High	> 100 people
Monthly	Medium	10 – 100 people
Monthly or greater*	Low	< 10 people

**Sampling frequency of monthly or greater can be applied if data history shows high reliability good water quality*

Note 4: Frequency of sampling – Amber and Red Modes
The declaration of Red and Amber Modes demands daily water sampling, which may pose logistical issues in regional and remote areas. The viability of daily sampling needs to be considered in any specific risk assessment process.

Water Treatment

The presence of marine flora and fauna has flourished since the lagoon was constructed, with large populations of fish, molluscs and other marine organisms. The prevalence of these species in the lagoon demonstrates a healthy marine ecosystem has been created. This restricts the use of traditional treatment options like chlorination to maintain water quality.

During times of elevated microbial activity, the options for treatment are therefore limited, and depending on prevailing weather and other factors, the lagoon may be subject to closures for long periods.

The safest and most practical way of addressing the microbial water quality issues, without adversely impacting the natural marine ecosystem in the lagoon, is to basically take a passive approach by allowing nature to take the lead.

Pathogenic organisms are susceptible to ultra-violet (UV) radiation. There is clear correlation between the level of UV and the incidents of increased microbial activity in the lagoon. That is, every incident of elevated intestinal enterococci in the lagoon has coincided with periods of monsoonal weather conditions, where there has been significant rainfall and heavy cloud cover. The dense clouds associated with monsoon weather conditions prevent high levels of UV from reaching the lagoon surface. This, combined with high ambient temperatures and dilution of the sea water due to the influx of run-off, creates ideal conditions for proliferation of bacteria and other pathogens.

When the lagoon is again exposed to extended periods of high UV, intestinal enterococci counts reduce very quickly.

This scenario occurs during the hotter, wetter months of the Wet Season, which is the off-peak season and therefore the lagoon experiences significantly reduced bather loads. During the Dry Season, activity in the lagoon ramps up significantly, and despite the increased bather loads during this time, the constant exposure to high UV (very few clouds during the Dry Season) has ensured the microbial water quality has been maintained.

Circulation and Aeration

The lagoon pumping system has been designed to ensure adequate circulation of water throughout the lagoon to prevent stagnation and the development of anaerobic conditions over time. This is achieved in three ways:

- Three separate pump inlets in the lagoon ensure fresh sea water is delivered directly at the northern, or ‘up-stream’ end of the lagoon. The water then ‘flows’ down-stream to the outlet weir.
- The inlets are located at different levels within the water column ensuring fresh sea water is delivered at deep, mid-depth and surface levels.
- A weir at the southern end of the lagoon promotes the ‘flow’ of water from the northern end to the southern end while controlling the volume of water out flowing out of the lagoon.

The non-tidal nature of the lagoon means that anaerobic conditions are present in the beach sand. This results in discolouration of the beach sand at depth, which when disturbed can increase turbidity. While this affects the clarity of the water, it does not present a risk to swimmers. The discolouration fades relatively quickly once the sand has been exposed to air..

Pets

The Corporation does not permit pets in the Recreation Lagoon under any circumstances.

This is to ensure water quality is maintained at a high level, and to prevent incidental instances of faecal contamination originating from pets and their excrement.

In relation to the Recreation Lagoon, it is possible for these dangerous aquatic organisms to be present and the risk needs to be managed accordingly.

It is known that no sharks or crocodiles are presently in the lagoon, and the most likely threat comes from marine stingers like box jellyfish and irukandji. Consequently, the Corporation in consultation with jellyfish experts from James Cook University, CSIRO, and the Australian Marine Stinger Advisory Service has identified the need to actively monitor and manage the presence of box jellyfish, namely the Chironex fleckeri and Gerongia rifkinae; the box jelly and irukandji respectively – refer to Table 4 below.

To date there has been no confirmed cases of Chironex fleckeri and only one suspected case of Gerongia rifkinae in the Recreation Lagoon. A juvenile stonefish has also been removed from the lagoon.

The lagoon is a natural marine ecosystem and as such there is never assurance that dangerous aquatic organisms won't pose a risk. However the Corporation has developed procedures to minimise the risk of encounters of dangerous aquatic organisms with humans.

Jellyfish

Box Jellyfish (Chironex fleckeri)

As the name suggests the box jellyfish is easily identified by the box shape, and the characteristic clusters of tentacles at the bottom of each corner of the body. Considered the most venomous animal in the World, the box jelly fish can grow up to 30 centimetres across, and its tentacles can extend over three (3) metres from the body.

Although rare, stings from box jellyfish can result in massive envenomation (NHMRC, 2008) and death. Fatalities from box jellyfish stings have been recorded in WA, QLD and the NT. The warm tropical waters of the north Australia coast (Broome WA to Gladstone QLD) during the Wet Season provide the perfect breeding ground for box jellyfish, which are primarily an estuarine and inshore species.

Box jellyfish are not known to currently inhabit the recreation lagoon, however their absence must be verified constantly through regular scans to minimise risks to swimmers.

Sea Wasp (Chironpsalmus quadrigatus)

Despite being much smaller than the box jellyfish, sea wasp exhibits similar characteristics but are much less lethal due to reduced venom output if stinging occurs. Measuring up to 70mm across the body it too exhibits clusters of tentacles on each corner of the body, and whilst stinging in the Northern Territory is common, there have been no recorded fatalities in the NT (NHMRC, 2008).

For the purpose of the water quality management program, sea wasp are managed as per box jellyfish.

Irukandji (Gerongia rifkinae)

The relatively tiny size of irukandji jellyfish, and its distinctive and severe symptoms makes it one of the more difficult to manage. Averaging only 20mm in size across the body, it is easily characterised by four single tentacles on each corner of the body. While the tentacle reach of the Irukandji is significantly shorter, the whole organism is covered in nematocysts i.e. not only on its tentacles, but also its bell.

Victims of stings may not even realise they've been stung due to the relatively mild initial effect, and only realise they've been stung once symptoms have developed, usually over approximately 30 minutes. Irukandji syndrome follows with symptoms including severe back pain, chest and abdominal pain, nausea, vomiting, sweating and headaches. In rare cases victims may suffer from pulmonary oedema (Little and Mulchany, 1998).

Cassiopeia (Upside down) Jellyfish

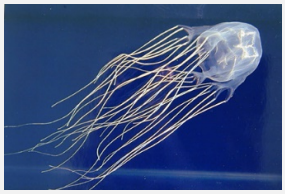
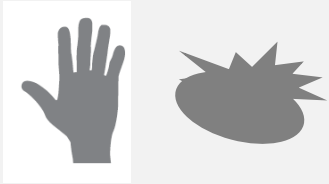
Cassiopeia jellyfish are endemic to the lagoon, and the relatively shallow, calm waters provide the ideal habitat for this jellyfish, which is considered a nuisance species by the Corporation.

Also known as the upside down jellyfish, the Cassiopeia species in the Recreation Lagoon is thought to be an as yet unclassified species. Unlike some other jellyfish species, the Cassiopeia species is not predatory. It feeds on marine algae that naturally grows on its 'tentacles'.

They lay, upside down and immobile in shallower waters on the seabed, in filtered sunlight, and this promotes the growth of the marine algae on their 'underside', which resembles a cauliflower. The cauliflower texture is thought to increase the surface area, allowing more algae to grow on the jellyfish, which it then consumes.

When disturbed, Cassiopeia release a 'toxic' mucous as a defence mechanism. The mucous can cause varying degrees of irritation to humans, ranging from mild tingling to severe itchiness and a mild burning sensation in extreme cases.

Table 4 Marine Stingers of Concern

STINGER	IDENTIFICATION	SIGN AND SYMPTOMS
Box Jellyfish/Sea Wasp  Size relative to human		Intense pain – possible death. Tentacles and sting site is clearly visible. Generally large, easily visible sting site with numerous tentacles.
Irukandji Jellyfish  Size relative to human		Pain is moderate to start but intensifies over time (approx. 30mins). Tentacles and/or sting site can be difficult to identify initially. Irukandji syndrome – nausea, vomiting, sweating, difficulty breathing, cramps, limb spasms, coughing, anxiety.
Cassiopeia Jellyfish  Size relative to human		Mild to medium skin irritation. Itchy skin, tingling, 'pins 'n' needles', and redness. On rare occasions symptoms can include stinging sensation, usually in children.

Other Venomous Species

Stonefish and hydroids have previously been removed from the lagoon, and the Corporation attempts to remove these and any other venomous species when they've been identified.

Non Venomous Species

Non venomous species like sharks and crocodiles are unable to enter the lagoon. There has never been any confirmed sightings or encounters that would indicate the presence of a shark or crocodile and the physical characteristics of the lagoon mean the risk associated with ingress of these species in negligible. The only exception would be if these species were introduced by human intervention.

Other non-venomous species known to inhabit the lagoon include bristle worms. These are physically removed when encountered.

Box Jellyfish Management

Lagoon Population

There have never been any confirmed sightings of Chironex Fleckeri (box jellyfish) in the Lagoon, although there has been one confirmed case of Gerongia rifkinae. This is considered an isolated occurrence, since no other populations are known to be present in the lagoon[2].

Uptake Prevention

The lagoon is constantly receiving fresh sea water from Darwin Harbour, pumped in by the flushing system. The pumping system comprises three large volume pumps located at Stokes Hill Wharf that constantly replenish the lagoon and provide oxygen rich water from the harbour.

Several large rivers discharge into Darwin Harbour and therefore the harbour provides ideal breeding and habitat for box jellyfish. To prevent the uptake of jellyfish (and other marine species and flotsam) the pump intakes are fitted with fine mesh screens with apertures no greater than 500 microns.

While this prevents the uptake of adult jellyfish, it does not prevent the uptake of jellyfish polyps which can be a small as 200 microns in diameter. Therefore jellyfish management is still necessary to ensure the lagoon remains stinger free to the extent practicable.

Night Scanning

The Recreation Lagoon has a surface area of approximately 4.5Ha and varies in depth from 0m to more than 10m. This presents challenges when scanning for the presence of jellyfish like the box jellyfish.

Box jellyfish are predatory and actively hunt prey as part of their feeding cycle. In consultation with experts from James Cook University, the Corporation has developed a jellyfish scanning procedure to help detect the presence of predatory box jellyfish like the Chironex fleckeri and Gerongia rifkinae.

The procedure involves night time scanning using a submersible prawn light. Submerging a prawn light in the lagoon at night attracts small fish, on which box jellyfish feed. Box jellyfish know this and are attracted to light. As capable swimmers, particularly in the calm water of the lagoon, it would take a box jellyfish approximately 15 minutes to swim to the light.

The Darwin Waterfront Corporation conducts night scanning weekly during the box jellyfish season (Oct through May), at several locations around the perimeter of the lagoon.

Irukandji

The modus operandi of the Gerongia rifkinae is similar to that of box jellyfish; both are cubozoids. Night scanning performed as part of box jellyfish management is also used to scan for Irukandji, however, its much smaller scale necessitates additional measures to minimise the presence of this species in the lagoon and prevent encounters with lagoon users.

Cassiopeia Jellyfish Management

The Recreation Lagoon provides an ideal environment for Cassiopeia jellyfish, due to the lack of tidal movement and strong currents. The shallow areas around the perimeter allow the jellyfish to settle in areas with good sunlight penetration.

This is particularly evident within the beach inlet area, where the water is relatively shallow and clear. This tends to promote the migration of the Cassiopeia from deeper areas of the lagoon into the beach inlet, and higher bather loads in this area result in increased opportunity for encounters with lagoon users.

[2] This cannot be confirmed, however the lack of incidents involving jellyfish stings suggests there is no sustained presence of these organisms in the lagoon and therefore considered an isolated case.

To address this, lifeguards periodically undertake sweeps of the beach area seabed to collect and remove Cassiopeia from the lagoon. Removing all Cassiopeia is not practical, however proliferation is effectively controlled through the removal of larger, more easily collect 'mature' specimens (i.e. >200mm diameter). This ensures the numbers of mature jellyfish, capable of breeding, are kept under control.

The Darwin Waterfront Corporation routinely removes larger, breeder Cassiopeia jellyfish as a means of minimising their impact and controlling their numbers in the lagoon.

Other dangerous organisms

From time to time the presence of other dangerous species is identified (e.g. stonefish). Where the species can be identified and located, the Corporation removes it from the lagoon. This may be achieved by netting, baiting, or use of lures to catch the organism.

REFERENCES

Darwin Waterfront Corporation, 2020, 'Recreation Lagoon Water Quality Response Plan', Darwin NT.

Northern Territory Government Department of Health, 2020, 'Draft Guidance Notes for Recreational Water Quality in the Northern Territory', Darwin NT.

Australian Government National Health and Medical Research Council, 2008 'Guidelines for Managing Risks in Recreational Water', Canberra ACT.

Stingeradvisor.com, 2011 *Australian Marine Stinger Advisory Services,* [online] Available at: http://www.stingeradvisor.com/index.htm [Accessed 24 April 2020].

DARWINWATERFRONT

DARWIN WATERFRONT CORPORATION
DARWIN, NORTHERN TERRITORY.

Published 2020