GOVERNMENT OF
WESTERN AUSTRALIA

Summary of Cockburn Sound monitoring and research programs 2018

Cockburn Sound Management Council

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This publication is available at the Cockburn Sound Management Council's website:
www.der.wa.gov.au/about-us/cockburn-sound-management-council

For people with special needs, the report can be made available in alternative formats such as audio, large print or braille.

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Abbreviations

Abbreviation	Full term
CHRMAP	Coastal Hazard Risk Management and Adaptation Plan
CSMC	Cockburn Sound Management Council
DoD	Department of Defence
DPIRD	Department of Primary Industries and Regional Development
DWER	Department of Water and Environmental Regulation
EPA Act	*Environmental Protection Act 1986* (WA)
MAFRL	Marine and Freshwater Research Laboratory (Murdoch University)
NATA	National Association of Testing Authorities
SOFAR	Status Reports of the Fisheries and Aquatic Resources of WA
UWA	The University of Western Australia
WA	Western Australia
WAMSI	Western Australian Marine Science Institution

1. Introduction

The Cockburn Sound Management Council (CSMC) is an advisory council to the Minister for Environment established under s.25 of the *Environmental Protection Act 1986* (EP Act). Under its terms of reference, the CSMC is responsible for the oversight and coordination of environmental monitoring and research/investigative studies in Cockburn Sound.

In 2016 the CSMC initiated a project to compile available metadata information on:

- monitoring that is currently being undertaken within the Cockburn Sound marine area; and
- current and recent (previous three years) research and investigative studies being undertaken within the Cockburn Sound marine area.

This information was collated into the report *Summary of Cockburn Sound monitoring and research programs 2016* (Cockburn Sound Management 2016). The CSMC will regularly review and update the information included in the report.

The updated information provided by stakeholders and which is collated in this report includes:

- a summary of the monitoring programs currently being undertaken in the Cockburn Sound marine area (s.2.1);
- metadata provided by individual organisations on the monitoring programs being undertaken in the Cockburn Sound marine area (s.2.2);
- a summary of research and investigative studies currently or recently undertaken in the Cockburn Sound marine area (s.3.1); and
- metadata provided by individual organisations on research and investigative studies in the Cockburn Sound marine area (s.3.2).

2. Monitoring programs in the Cockburn Sound marine area

2.1 Summary of monitoring programs in the Cockburn Sound marine area

The monitoring that is currently being undertaken in the Cockburn Sound marine area and the organisations responsible for that monitoring are summarised in Tables 1a and 1b. The locations of the monitoring sites are shown in Figure 1 (nutrient and chlorophyll *a* concentrations), Figure 2 (physical–chemical parameters), Figure 3 (contaminants in marine waters), Figure 4 (sediment quality), Figure 5 (bathing beach microbiological quality), Figure 6 (seafood quality) and Figure 7 (seagrass health).

For further information on the monitoring programs refer to the metadata in s.2.2.

Table 1a. Summary of monitoring currently being undertaken in the Cockburn Sound marine area.

Agency/Organisation undertaking/funding the monitoring (X) or overseeing the monitoring (X)	Water quality								Phyto-plankton	Sediment quality		Seafood quality			Seagrass health		Seagrass/benthic habitat mapping	Benthic communities	Benthic habitat	Crabs (abundance/catch-effort)	Octopus (abundance/ catch-effort)	Fish		Shark hazard monitoring	Birds		
	Nutrients	Chlorophyll/Phytoplankton	Physical–chemical parameters	Chemical contaminants	Microbiological (enterococci)	Microbiological (total coliforms, thermotolerant coliforms, *E. coli)*	Intake water	Continuous monitoring (temperature)	Phytoplankton (biotoxins)	Physical–chemical parameters	Chemical contaminants	Microbiological	Biotoxins	Chemical contaminants	Shoot density	Lower depth limit						Abundance/catch/effort	Distribution		Little penguins (health and ecology)	Caspian and bridled tern ecology/population dynamics	Exposure to metal contamination (little penguins, Caspian terns)
Cockburn Sound Management Council (CSMC)/Department of Water and Environmental Regulation (DWER)	X	X	X												X	X	X										
Department of Primary Industries and Regional Development (DPIRD)			X					X												X	X	X	X	X			
Department of Health					X	X			X			X	X	X													
City of Cockburn					X																						
City of Rockingham					X																				X		
City of Kwinana					X																						
Australian Department of Defence (DoD)																									X		
Water Corporation			X				X																				
Fremantle Ports	X	X	X	X							X			X			X										
Kwinana Industries Council																	X										
Tronox Management Pty Ltd										X	X																
Conservation Council WA																										X	X
The University of Western Australia (UWA)															X	X	X								X		
Murdoch University																											
Department of Transport																											

Table 1b. Summary of monitoring currently being undertaken in the Cockburn Sound marine area.

Agency/Organisation undertaking/funding the monitoring (X) or overseeing the monitoring (X)	Coastal geomorphology					Introduced marine pests
	Beach profiles	Multibeam/LIDAR	Aerial imagery	Coastline movements	CHRMAP performance	
Cockburn Sound Management Council/DWER						
DPIRD						X
Department of Health						
City of Cockburn	X	X				
City of Rockingham	X				X	
City of Kwinana			X			
Department of Defence (DoD)						X
Water Corporation						
Fremantle Ports						X
Kwinana Industries Council						
Tronox Management Pty Ltd						
Conservation Council WA						
The University of Western Australia						
Murdoch University						
Department of Transport				X		

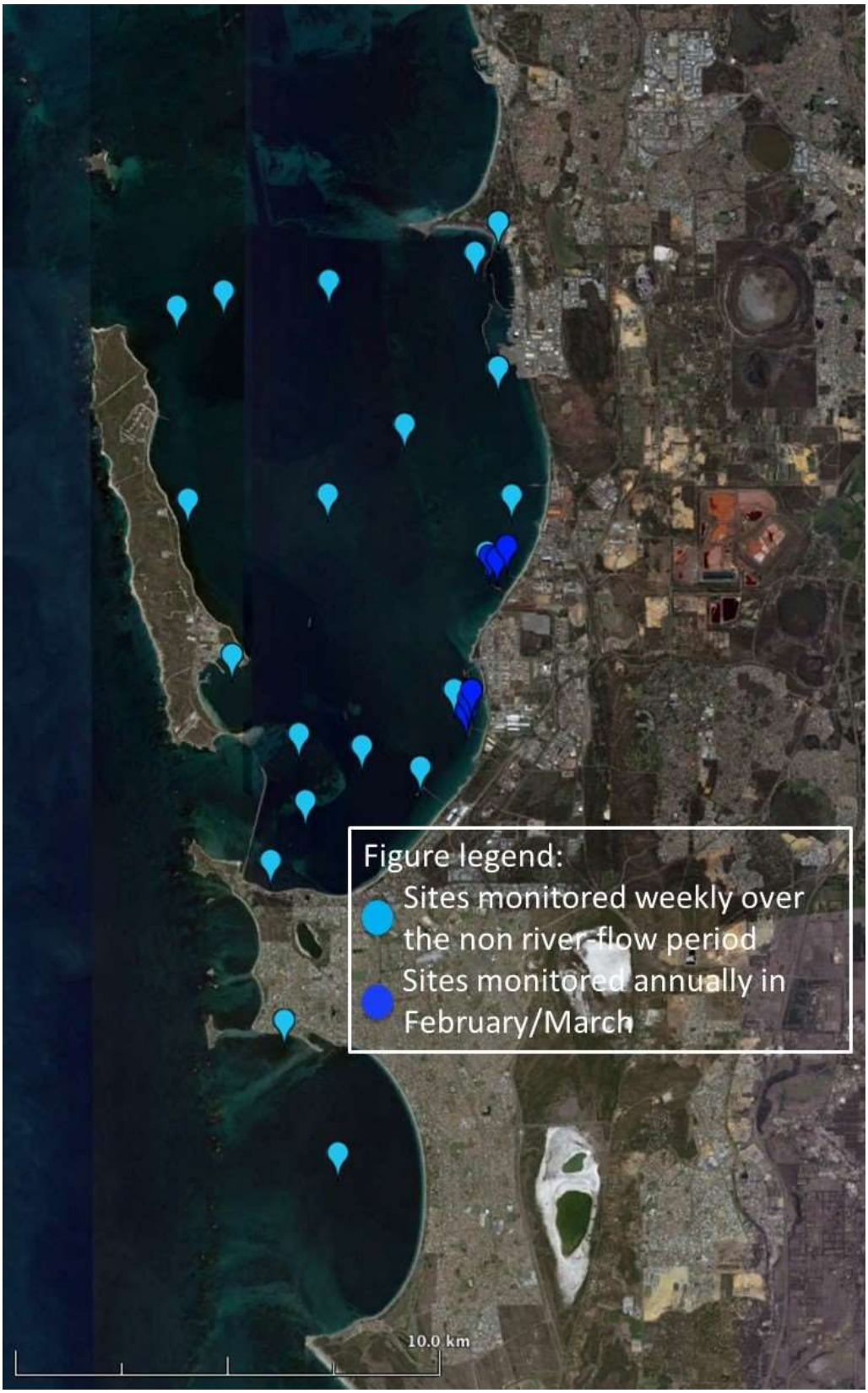


Figure 1. Location of nutrient and chlorophyll *a* water quality monitoring sites.

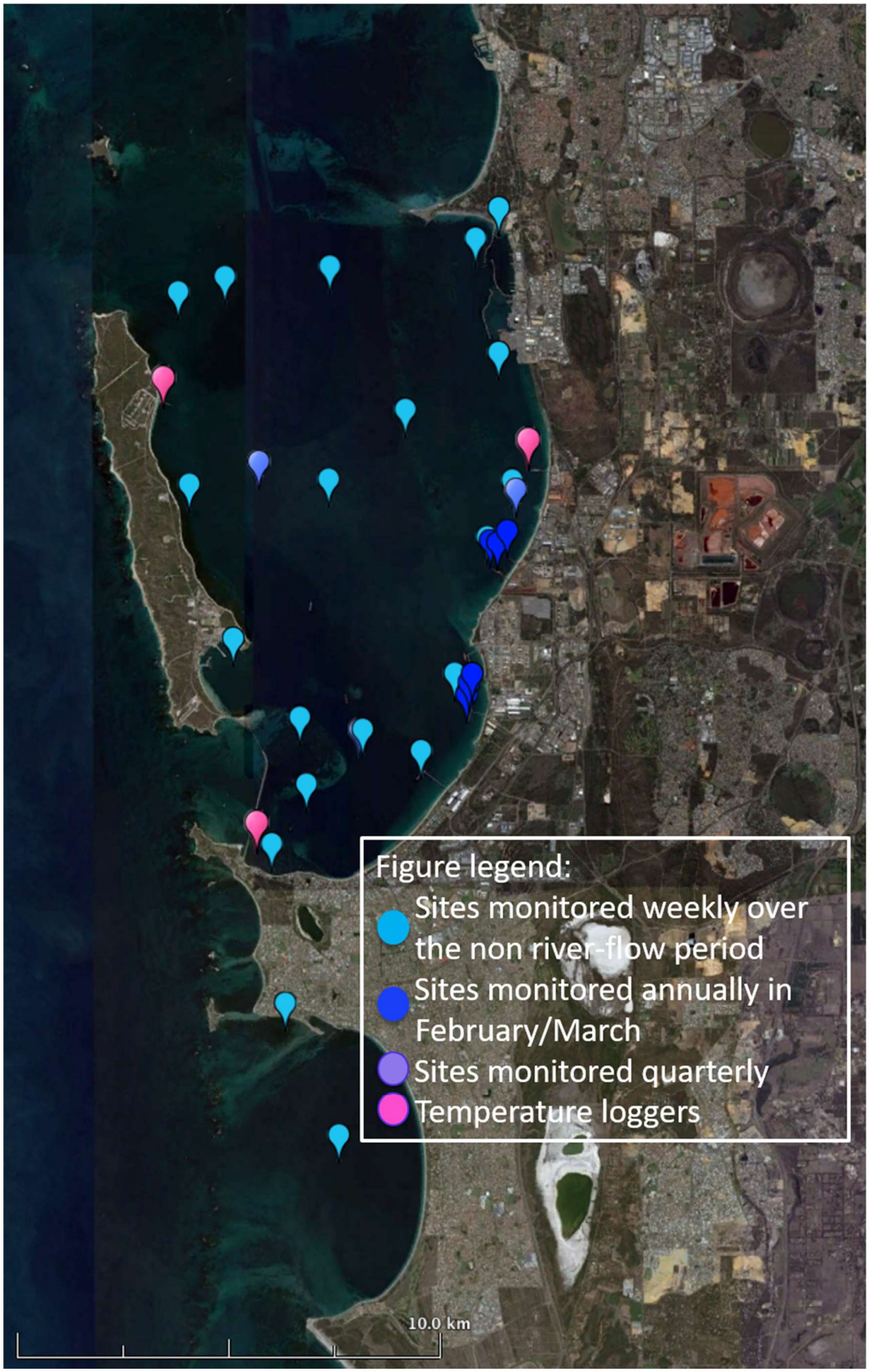


Figure 2. Location of physical–chemical water quality monitoring sites.

Figure 3. Location of contaminants in marine waters monitoring sites.

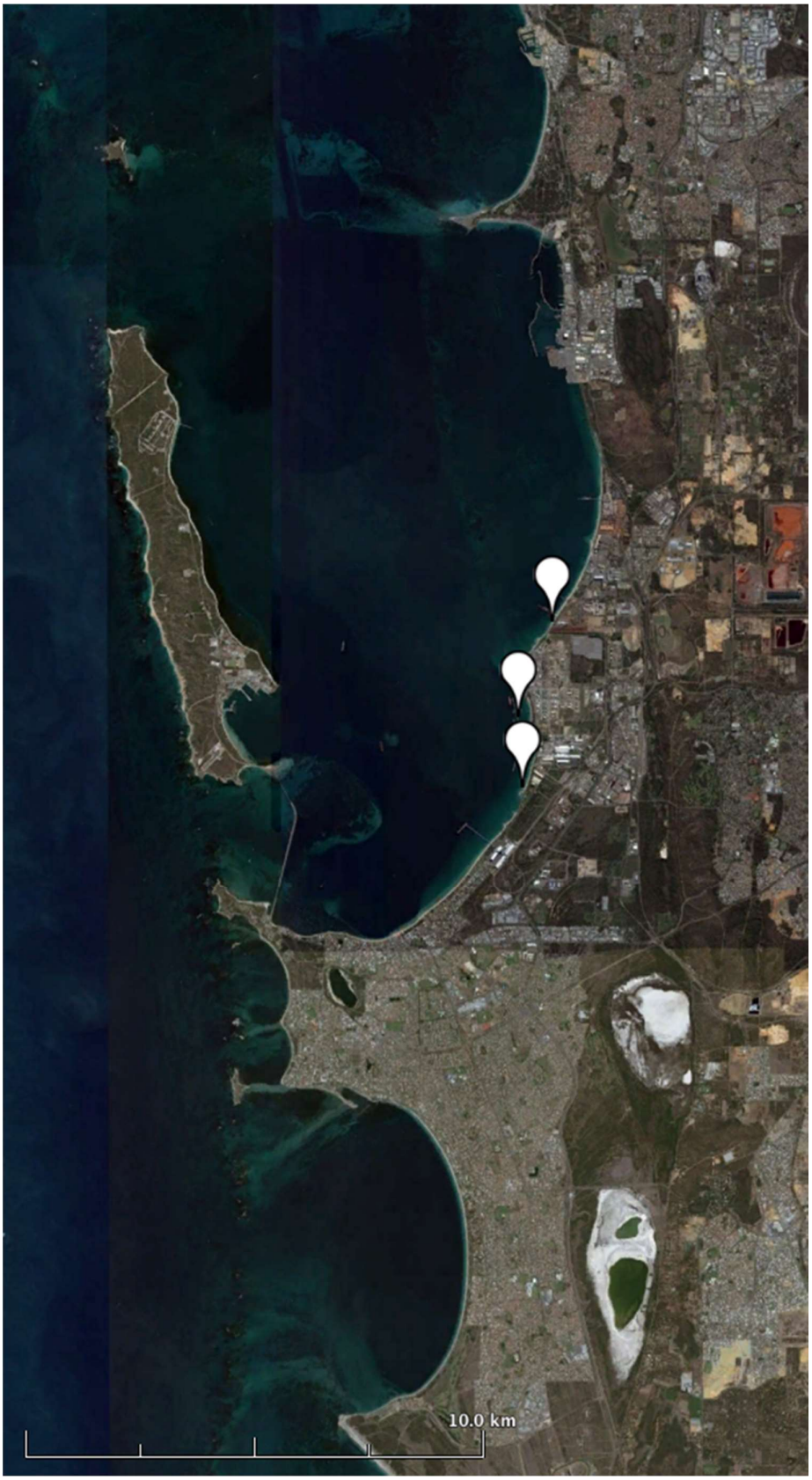


Figure 4. Location of sediment quality monitoring sites.

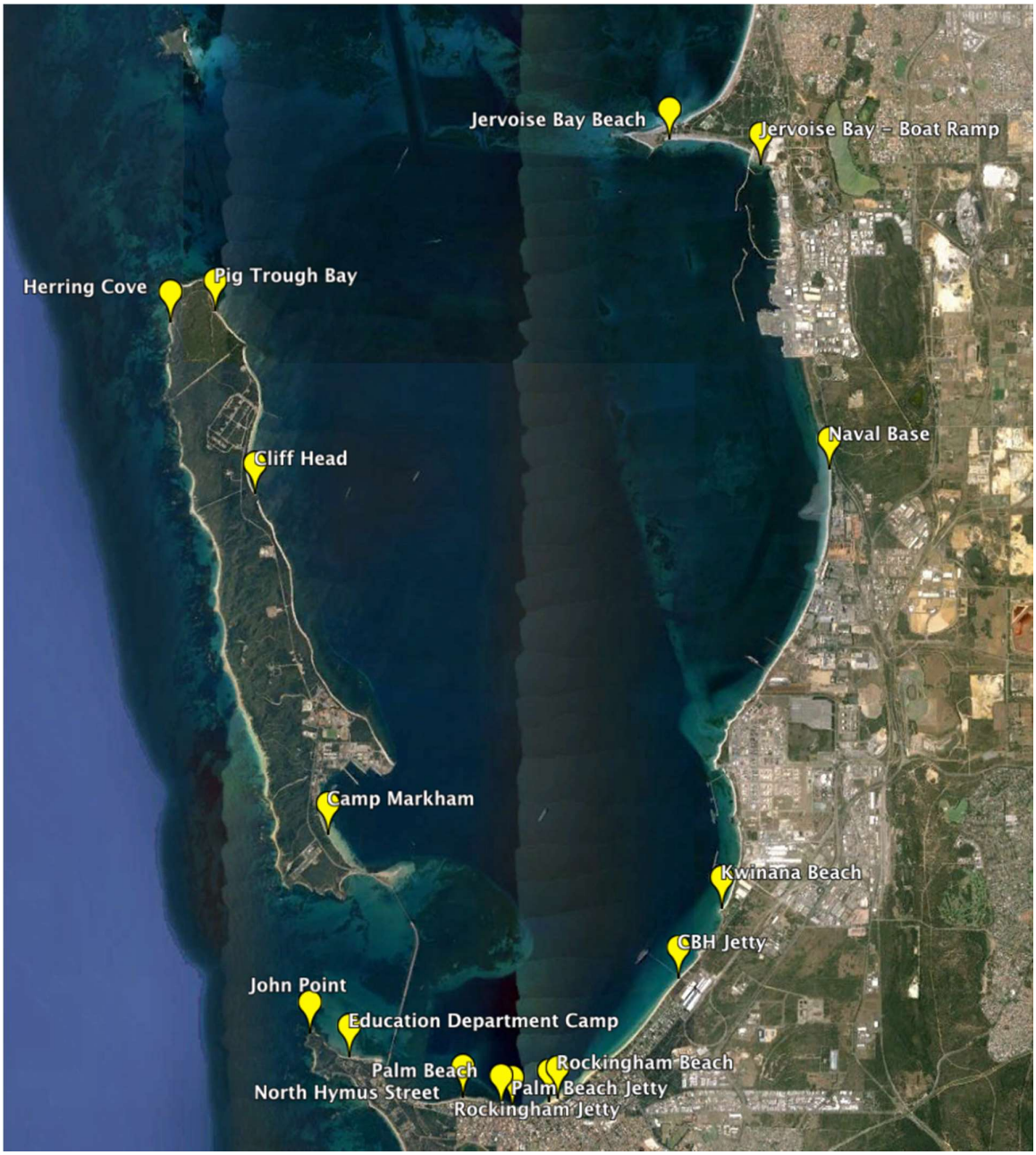


Figure 5. Location of bathing-beach (microbiological) monitoring sites.

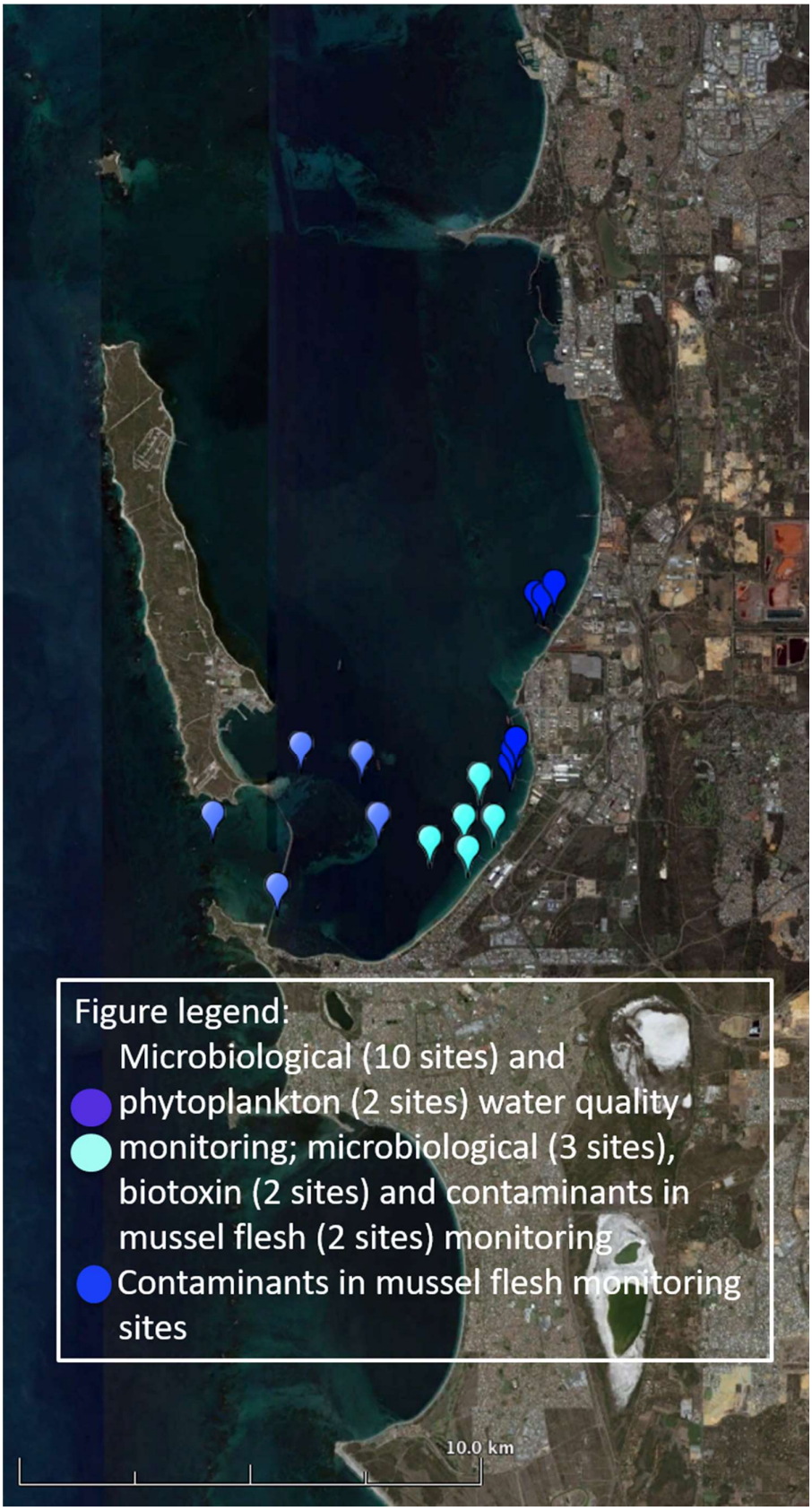


Figure 6. Location of seafood quality monitoring sites.

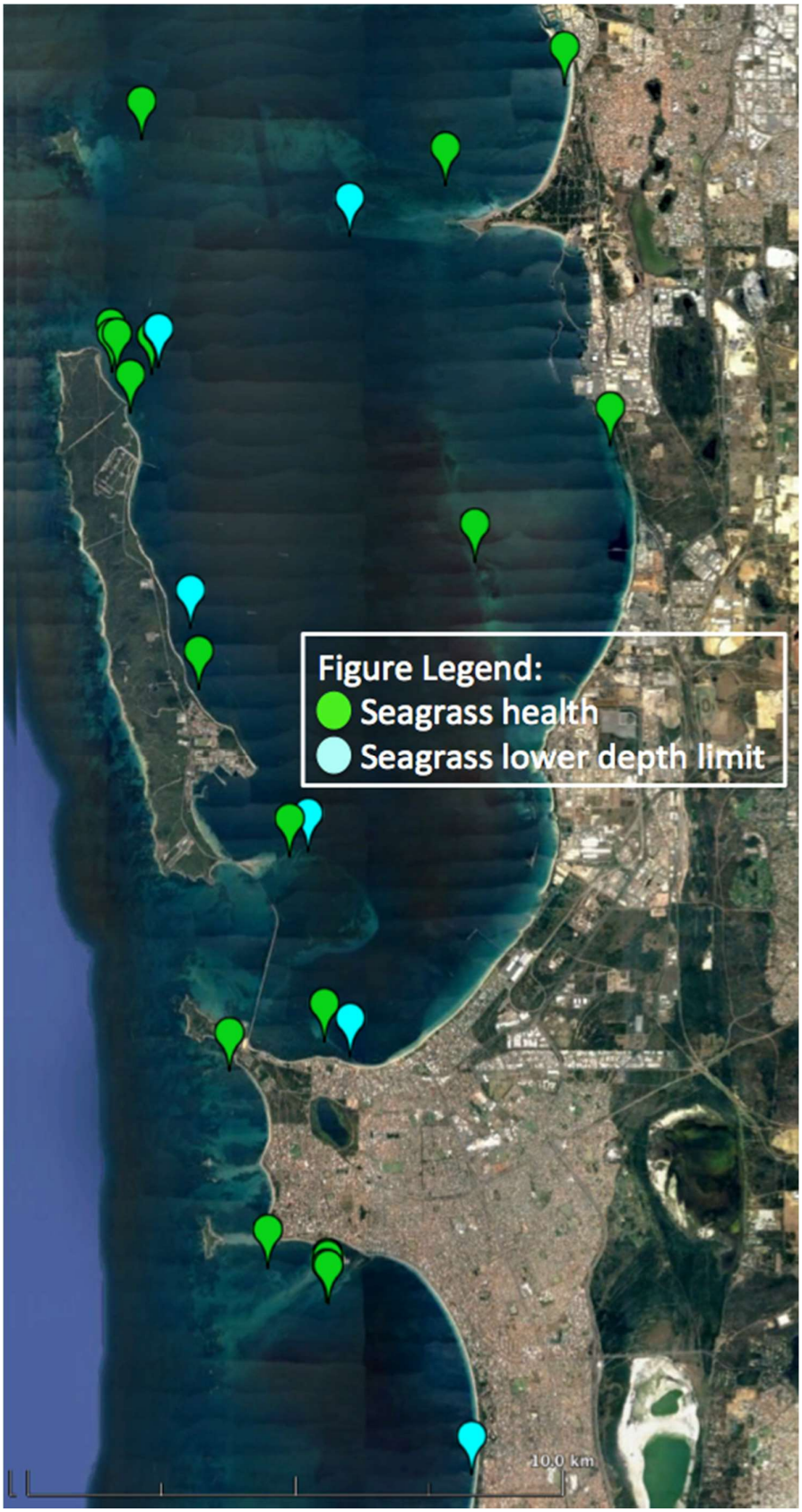


Figure 7. Location of seagrass health monitoring sites.

2.2 Metadata for monitoring programs in the Cockburn Sound marine area

Further information on the monitoring programs currently being undertaken in the Cockburn Sound marine area is provided in:

- Table 2 City of Cockburn
- Table 3 City of Kwinana
- Table 4 City of Rockingham
- Table 5 Australian Department of Defence
- Table 6 Department of Water and Environmental Regulation/CSMC
- Table 7 Department of Primary Industries and Regional Development
- Table 8 Department of Health
- Table 9 Fremantle Ports
- Table 10 Tronox Management Pty Ltd
- Table 11 UWA
- Table 12 Water Corporation

Table 13 provides a summary of the monitoring required by conditions of Ministerial Statements issued under Pt IV of the EP Act relating to discharges to Cockburn Sound.

Table 14 provides a summary of the monitoring required by conditions of licences granted by DWER Regulation under Pt V of the EP Act relating to discharges to Cockburn Sound.

Table 2. City of Cockburn (contact person: Jonathan McKay).

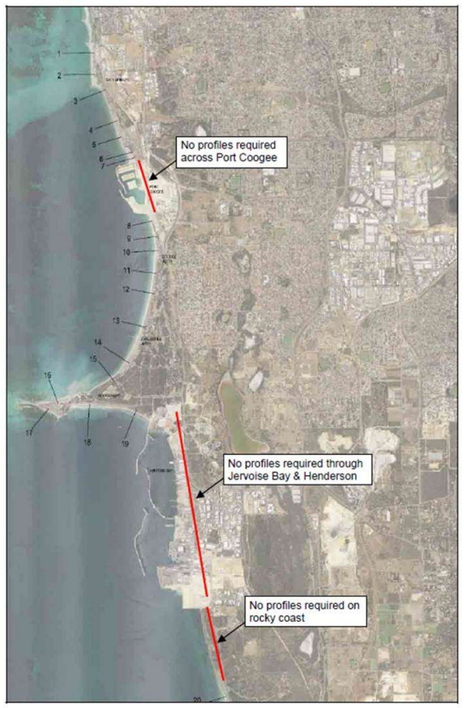
Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
City of Cockburn Beach Monitoring and Analysis	To better understand coastal processes and the impact on beaches and coastal reserves.	From immediately south of the Island Street groyne in North Coogee to the southern extent of the Naval Base Holiday Park. (Refer to the map below for 20 locations of beach profiles). 	Beach profiles	• Land and hydrographic surveys of 3 profiles (perpendicular to the shoreline). • Profiles extend from a minimum of 20 m behind the top of the primary dune or cliffs to about 500 m offshore from the waterline at mean sea level. • Elevations taken at 5 m intervals and at every change in grade. • Profiles show location of vegetation line and approximate waterline at time of survey. • A full-coverage hydrographic multibeam and terrestrial Dynascan survey dataset covering the City of Cockburn coastline captured in March/April 2017. Will serve as baseline for future 'full-coverage' monitoring.		Profiles: previously twice per year (Mar. and Oct.). From 2018, it will be once per year in Oct. Full-coverage multibeam/LIDAR: intention to complete in Mar./Apr. every 3 years.	Oct. 2012	City of Cockburn engages consultants (previously MP Rogers & Associates, drawing in part on coastal monitoring data provided for Cockburn Cement and for the Port Coogee development from Fraser Property Australia. The most recent (2017) survey and report were undertaken by EvoCoast Pty Ltd on contract to the City of Cockburn).	Survey data available on request
Beach Bacterial Monitoring	To undertake bacterial water quality monitoring from November through to May each year including conducting and reviewing sanitary inspections of popular beaches in partnership with the Department of Health, as part of the Metropolitan Oceans Bacterial Water Quality Monitoring Program	Sites monitored include: Robbs Jetty; Port Coogee Beach; Coogee Beach; John Graham Reserve Beach; Woodman Point Camp Beach; Jervoise Bay Beach; Jervoise Bay Woodman Point; and the Jervoise Bay Boat Ramp **Refer to Figure 5**	Water quality	Water samples taken from each of the beaches in accordance with Health Department guidelines	Health Department guidelines	Weekly from November to May each year	Unknown	City of Cockburn environmental health officers	Site classifications are updated annually and published on the Department of Health (and City of Cockburn as appropriate) website ww2.health.wa.gov.au/Articles/A_E/Beach-grades-for-Perth-metropolitan-ocean-sites

Table 3. City of Kwinana (contact person: Jarod Griffiths).

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Beach bacterial monitoring	Establish enterococci levels and visual water quality observation in partnership with the Department of Health.	Wells Park Beach, Challenger Beach	• Water temperature • Water clarity • Presence of algae • Tide • 24-hour rainfall • 48-hour rainfall • Wind direction • Wind strength • Discharge of stormwater • No. of bathers • No. of boats • No. of dogs/animals	• Bacteriological • Water samples • Visual observation	National Health and Medical Research Council (NHMRC) guidelines	Monthly (when resources permit)	Nov. to Apr. (when resources permit)	City of Kwinana environmental health officer	

Table 4. City of Rockingham (contact person: Brett Ashby).

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Beach Erosion/Accretion Monitoring	Monitor the change in beach profiles and the sea floor (80 m from waterline).	Point Peron – John Point to Point Peron Sand Trap Spur Groyne Horizontal datum is Map Grid of Australia (MGA94) Vertical datum is Australian height datum (AHD)	• Changes in beach grade • Vegetation line • 'Top' and 'toe' of sand dune RLs • Sea floor • Key structures, e.g. limestone seawall and footpath (Department of Biodiversity, Conservation and Attractions); Geotextile Sand Container Groyne (City of Rockingham); Limestone Spur Groyne and Breakwater (City of Rockingham) • Bank Volume Survey, City of Rockingham sand stockpile	• 11 x 100 m long beach profiles (A–K) defined coordinates • Conventional and GPS surveys	Shoalwater Islands Marine Park Management Plan (2007–2017)	Twice a year	Monitoring started before the construction of the Geotextile Sand Container Groyne in 2013. Post-construction monitoring is ongoing.	City of Rockingham – Matthew Donaldson, Coastal Engineering Officer Natalie Elliott, Coordinator Sustainability and Environment	Data available on request
Little Penguins (*Eudyptula minor*)	Monitoring the health and resilience of little penguins and the marine environment they occupy.	Penguin Island, Cockburn Sound, Warnbro Sound	• Little penguin movements • Duration of feeding journeys • Sea surface temperature • Breeding success	• GPS satellite tags • Monitoring nest boxes	Murdoch University research standards	Annually	2012	Dr Belinda Cannell, Murdoch University Natalie Elliott, Coordinator Sustainability and Environment	Data available on request, subject to permission from Murdoch University
Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) performance (due to start in 2019)	Monitor the effect of coastal hazards relative to modelled predictions and the performance of infrastructure designed to protect against coastal hazards.	City of Rockingham coastline – East Rockingham, Rockingham and Peron	Depends on the outcomes of the City's CHRMAP	Depends on outcomes of the City's CHRMAP	State Planning Policy 2.6 – State Coastal Planning Policy	Depends on outcomes of the City's CHRMAP	2019 (estimated)	Natalie Elliott, Coordinator Sustainability and Environment	Data available on request

Table 5. Australian Department of Defence (contact person: Mark Sweetman).

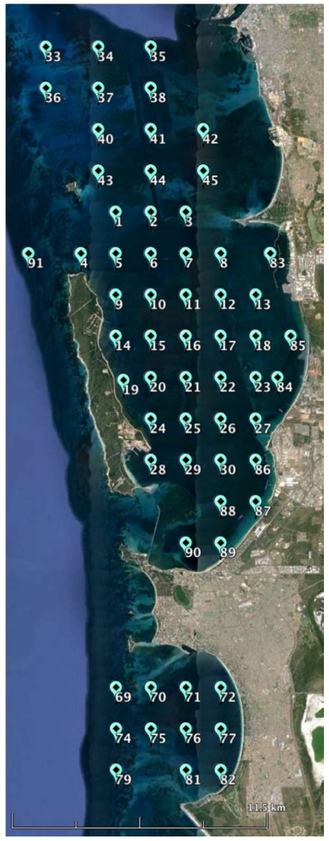
Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Annual Monitoring Of Little Penguin (*Eudyptula minor*) Colony	Monitor breeding success, general health and nesting locations of little penguin colony on Garden Island.	Careening Bay, Garden Island	• Burrow locations • Little penguins in each burrow • Chicks/eggs in each burrow • Moulting status and stage of adults • Overall health of little penguins • Mass, head length, beak length and beak depth of some birds (not all)	Onsite monitoring/field visits to the little penguin colony to make observations and obtain data (burrowscope used when required)	In line with State and Commonwealth ethics approvals and permits	Regular monitoring through the breeding season	2001	Dr Belinda Cannell (UWA)	Detailed information is subject to intellectual property with the researcher. Limited summary information may be available, if the researcher agrees
Potential Marine Pest Monitoring	To monitor for potential marine pests in the waters surrounding Garden Island.	Careening Bay, Parkin Point, Ammunition Wharf	Sampling for the presence of marine pests	• Boat-based (trawls, nets) • Dive-based (observations and taking samples) • Shore-based (observations and taking samples) • Monitoring arrays (samples)	Monitoring plan prepared by former Department of Fisheries in line with the National System for the Prevention and Management of Introduced Marine Pests	• Arrays – quarterly • Dive/boat-based work – annually	2012 (some monitoring undertaken in 2010–11 by former Department of Fisheries direct)	DPIRD	Limited summary information is available for use in CSMC reports. Full reports may be provided to the CSMC Coordinator by formal request

Table 6. Department of Water and Environmental Regulation/Cockburn Sound Management Council (contact person: Coordinator, CSMC).

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Water Quality Monitoring	To meet the monitoring and reporting requirements of the State Environmental (Cockburn Sound) Policy	18 sites in Cockburn Sound and two reference sites in Warnbro Sound **Refer to Figure 1 and Figure 2**	• Chlorophyll *a* • Nutrients (ammonium, nitrate + nitrite, filterable reactive phosphorus, total nitrogen, total phosphorus) • Total suspended solids and particulate organic carbon • Physical–chemical parameters: temperature, salinity, pH, turbidity, dissolved oxygen, fluorescence • Secchi disc depth • Light attenuation	• Depth integrated water sample • Depth integrated water sample and discrete surface and bottom samples at two sites • Sea-Bird Electronics SBE19plus V2 vertical profiling conductivity–temperature–depth (CTD) • Secchi disc • Simultaneous measurement using 2 underwater light sensors (1 m and 7 m below surface)	*Manual of standard operating procedures for environmental monitoring against the Cockburn Sound environmental quality criteria* (EPA 2005)	About weekly on 16 occasions over the non-river flow period (Dec. to Mar.)	Monitoring at some sites started in 1983 (additional sites incorporated since that time)	Murdoch University's Marine and Freshwater Research Laboratory (MAFRL); Mr Kris Wienczugow	• State of Cockburn Sound reports published on the CSMC website • Data/data reports available on request from CSMC@DWER.wa.gov.au
Seagrass Health Monitoring	To meet the monitoring and reporting requirements of the State Environmental (Cockburn Sound) Policy.	• 11 sites in Cockburn Sound • 5 sites outside Cockburn Sound • 6 depth transect sites (Garden Island North and South, Southern Flats, Mangles Bay, Woodman Point, Warnbro Sound) • 5 reference sites in Warnbro Sound **Refer to Figure 7**	• Shoot density • Shoot height • Percentage cover • Lower depth limit and depth along depth transects	• Counts in permanent quadrats • Measurements in permanent quadrats • Photograph of quadrat and point count analysis • Field measurements along transect line	*Manual of standard operating procedures for environmental monitoring against the Cockburn Sound environmental quality criteria* (EPA 2005)	Annually (generally in Jan. to Feb).	Current program started 2003–06 Historical monitoring undertaken since 1994	The Western Australian Marine Science Institution (WAMSI); Dr Matthew Fraser/Prof. Gary Kendrick/ Dr Michael Rule	• State of Cockburn Sound reports published on the CSMC website • Recent data reports published on the CSMC website • Data available on request from CSMC@DWER.wa.gov.au
Seagrass Mapping	To provide information on the current extent and distribution of seagrass (and other benthic habitat) in Cockburn Sound and to assess changes in seagrass area over time.	Cockburn Sound-wide	Distribution of seagrass habitat	• Classification of WorldView–3 satellite imagery • Field surveys (towed video)	None applicable	Every 5 years	Mapping previously undertaken in 1999 and 2012	UWA; Dr Renae Hovey/Dr Matthew Fraser	• Report published on the CSMC website • Data available on request from CSMC@DWER.wa.gov.au

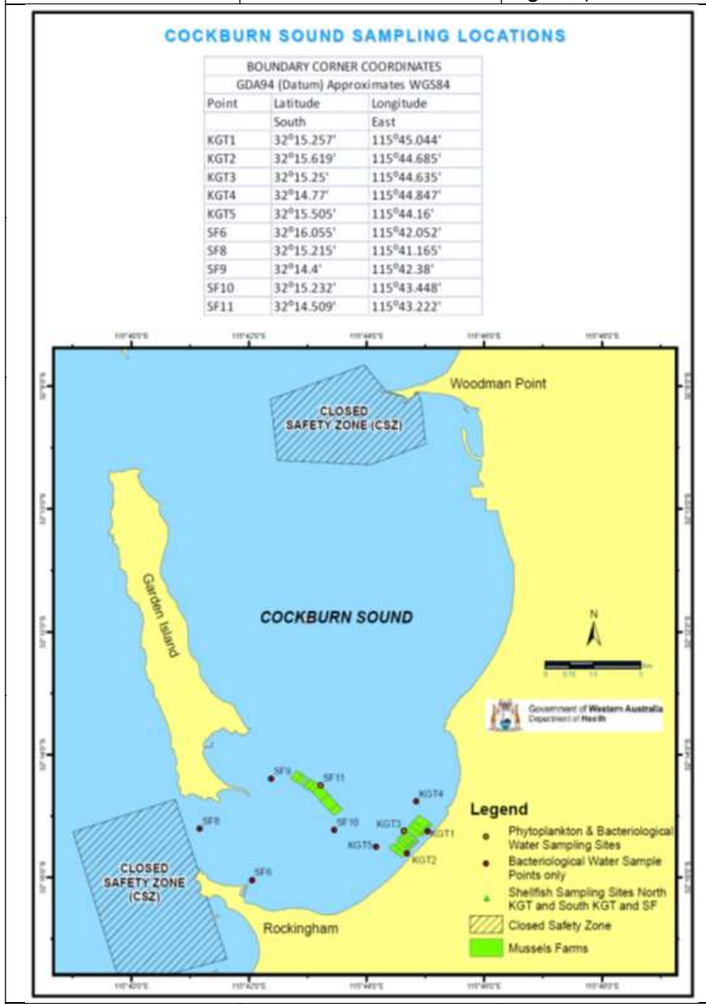
Table 7. Department of Primary Industries and Regional Development (contact person: Dr Dan Gaughan).

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Garden Island Early Warning Surveillance	Surveillance of introduced marine pests.	4 sites within Department of Defence (DoD) port area at Garden Island – details in unpublished reports (see 'Additional Information' column)	• Temperature (see crab monitoring) • Introduced pest presence/absence only	• Shoreline surveys • Passive arrays • Crab traps • Crab condos • In situ data loggers (please refer to crab monitoring data)	Unpublished internal Department of Fisheries Standard Operating Procedure (SOP)	Seasonally (every 3 months) Crab traps and shoreline every 6 months (summer–winter)	2012	Marine Biosecurity Science and Surveillance Section – Dr Justin McDonald	Unpublished report
Garden Island National Introduced Marine Pest Monitoring	Surveillance of introduced marine pests.	4 sites within Department of Defence port area at Garden Island, plus one site at the Ammunitions Jetty – details contained in unpublished reports (see 'Additional Information' column)	• Temperature (see crab monitoring) • Introduced pest presence/absence only	• Crab traps • Benthic sleds • Beam trawls • Phytoplankton and zooplankton tows • Subtidal infrastructure surveys • Shoreline searches	*Australian Marine Pest Monitoring Guidelines* version 2.0 (Cwlth of Australia 2009) Unpublished Internal Department of Fisheries SOP	Once a year (Feb.)	2012	Marine Biosecurity Science and Surveillance Section – Dr Justin McDonald	Unpublished report
Port of Fremantle National Introduced Marine Pest Monitoring	Surveillance of introduced marine pests.	4 sublocalities within Cockburn Sound – details contained in unpublished reports (see 'Additional Information' column)	Introduced pest presence/absence only	• Crab traps • Benthic sleds • Beam trawls • Phytoplankton and zooplankton tows • Subtidal infrastructure surveys • Shoreline searches	*Australian Marine Pest Monitoring Guidelines* Version 2.0 (Cwlth of Australia 2009) Department of Fisheries SOP	Once a year (Mar. to Apr.)	2011	Marine Biosecurity Science and Surveillance Section – Dr Justin McDonald	Unpublished reports: AUFRE PIR 2013 PIR AUFRE 2015
Port of Fremantle Early Warning System	Surveillance of introduced marine pests.	6 sites within Cockburn Sound – details contained in unpublished reports (see Additional Information column)	Introduced Pest presence/absence only	• Shoreline surveys • Passive arrays • Crab traps • Crab condos	Unpublished internal Department of Fisheries SOP	Seasonally (every 3 months) Crab traps and shoreline every 6 months (summer–winter)	2013	Marine Biosecurity Science and Surveillance Section – Dr Justin McDonald	Unpublished reports: South Australia FPA 2012 final draft FPA final report 2011–12 EWS Fremantle final report 2013–14 FPA annual report 2015
West Coast Nearshore Finfish Monitoring	Monitoring of nearshore finfish species as part of the management regime for the Cockburn Sound (Fish Net) Managed Fishery, and West Coast Nearshore Estuarine Finfish Resource.	Jetski Beach, Mangles Bay (netting); numerous sites for commercial and recreational fishing	• Temperature • Salinity • Juvenile finfish abundance • Blue swimmer crab (*Portunus armatus)* abundance • Herring and garfish skeletons (from commercial and recreational fishers) • Commercial catch/effort	• Handheld temperature/salinity probe • Beach seine netting • Statutory logbook returns	Refer to Fisheries research reports and relevant Status Reports of the Fisheries and Aquatic Resources (SOFAR) section for details (see 'Additional Information' column)	Juvenile fish and environmental data one day per month mostly between Sept. and Feb. each year Commercial catch/effort and skeletons monthly	Fish abundance 1994–2016; crabs 2005–16 Temperature and salinity off beach 1999–2016 Herring/garfish 2009–10	Nearshore/Estuarine Finfish Section – Dr Kim Smith	Fisheries research reports 246, 247, 248, 271 SOFAR
West Coast Demersal Scalefish Monitoring	Monitoring of demersal finfish species as part of the Cockburn Sound (Line and Pot) Managed Fishery.	Numerous sites (see details in Fisheries research reports and peer reviewed publications) (see 'Additional information'	• Pink snapper (*Pagrus auratus*) egg abundance • Pink snapper tagging	• Baited remote video (BRUV) surveys • Finfish tag and release sampling	Refer to Fisheries research reports, peer reviewed journal articles, and relevant SOFAR section for details	Annual surveys Tagging and egg surveys conducted in Nov. spawning period, one day every year	Biological 2002 BRUV sampling 2009 Temperature and salinity data	West Coast Demersal Finfish Section – Dr David Fairclough	Fisheries Research Reports 174, 181, 186, 187, 191, 250, 261 Breheny NB, Beckley LE & Wakefield CB 2012,

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
		column)	• Finfish abundance • Juvenile recruitment • Skeletons from recreational fishers • Commercial catch /effort	• Ichthyoplankton sampling (bongo net) • (Trawl surveys – as part of blue swimmer crab sampling) • Statutory logbook returns	(see 'Additional Information' column)	BRUV sampling conducted once annually (Apr. to May) Monthly logbook returns	associated with egg sampling from 2002 (2005 and 2009 missing)		'Ichthyoplankton assemblages associated with pink snapper *(Pagrus auratus)* spawning aggregations in coastal embayments of south-western Australia', *Journal of the Royal Society of Western Australia,* vol. 95, pp. 103–114. Wakefield CB 2010, 'Annual, lunar and diel reproductive periodicity of a spawning aggregation of snapper *Pagrus auratus* (Sparidae) in a marine embayment on the lower west coast of Australia', *Journal of Fish Biology,* vol. 77, pp. 1359–78. Wakefield CB, Fairclough DV, Lenanton RCJ & Potter IC 2011, 'Spawning and nursery habitat partitioning and movement patterns of *Pagrus auratus* (Sparidae) on the lower west coast of Australia', *Fisheries Research,* vol. 109, pp. 243–51. Wakefield CB, Lewis PD, Coutts TB, Fairclough DV & Langlois TJ 2013, 'Fish assemblages associated with natural and anthropogenically-modified habitats in a marine embayment: comparison of baited videos and opera-house traps', PLOS ONE, http://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0059959 SOFAR
(a) Map showing location of sites sampled for pink snapper egg abundance  (b) Map showing locations where BRUVs are deployed 									
Cockburn Sound Blue Swimmer Crab Monitoring	Monitoring of blue swimmer crab as part of the Cockburn Sound Crab Fishery and West Coast Blue Swimmer Crab Fishery	Details contained in Fisheries research reports (see 'Additional information' column)	• Temperature (logger) (**Refer to Figure 2**) • Temperature (handheld) • Dissolved oxygen (handheld) • pH (handheld) • Salinity (handheld)	• In situ temperature data loggers • Handheld sensor • Otter trawl surveys • Commercial crab trap surveys • Statutory logbook returns	Refer to Fisheries research reports and relevant SOFAR section for details (see 'Additional information' column)	Monthly during spawning (Sept. to Dec.) and recruitment (Apr. to Jun.) period annually In situ data loggers collect data hourly, other ad hoc/ occasional water	Commercial crab monitoring 1999 Independent breeding stock 2001 Independent juvenile recruitment trawls 2002	Crab section – Dr Danielle Johnston	SOFAR

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
			• Temperature (in situ loggers) • Blue swimmer crab juvenile abundance • Blue swimmer crab adult abundance • Commercial catch/effort			quality sampling as detailed in next column Monthly deployment of commercial crab traps Monthly logbook returns	Handheld data 2007–10 (large gaps in dataset) In situ temperature data loggers from 2007 (two sites have been discontinued)		
Octopus (*Octopus tetricus*) fishery Monitoring	Monitoring as part of the Cockburn Sound (Line and Pot) Managed Fishery and the Octopus Fishery Management	Details contained in Fisheries research reports (see 'Additional information' column)	Commercial catch/effort	Statutory logbook returns	Refer to Fisheries research reports and relevant SOFAR section for details (see 'Additional information' column)	Monthly logbook returns	2001	Mollusc Section – Dr Anthony Hart	Fisheries Research Report 270 SOFAR
Shark hazard monitoring	Monitoring for shark biology and hazard mitigation	Details contained in Fisheries research reports (see 'Additional Information' column)	Movement	Metro array of passive acoustic telemetry shark monitoring network was dismantled on 10 February 2016	Refer to Fisheries research reports (see 'Additional Information' column)	Daily monitoring by acoustic data loggers	2009	Shark Section – Dr Matias Braccini	Fisheries Research Report 273
Statewide recreational fishing	Monitoring of statewide boat-based recreational fishing	Details contained in Fisheries research reports (see 'Additional information' column)	Recreational fishing effort	• Phone surveys • Boat ramp surveys	Refer to Fisheries research reports (see 'Additional information' column)	Two yearly (after 2011) Occasional sampling prior to 2011–12 sampling (detailed in Fisheries research reports)	1996	Surveys Section – Dr Karina Ryan	Fisheries Research Reports 249, 268, 287 Fisheries Research Contract Report 023

Table 8. Department of Health (contact person: Tracey Stamp).

Monitoring program	Objective/Purpose of monitoring program	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Western Australia Shellfish Quality Assurance Program (WASQAP) – shellfish (mussel) monitoring	To minimise the level of risk and protect the health of consumers from foodborne illness	10 monitoring sites in 2 areas of Cockburn Sound (Kwinana Grain Terminal and Southern Flats) (refer to map below and **Figure 6**)	• 10 microbiological water sampling sites (total coliforms, thermotolerant coliforms, *E. coli*)	Water sample	WASQAP/Australian Shellfish Quality Assurance Program (ASQAP)	13 times per year at Kwinana Grain Terminal and 6 times per year at Southern Flats, with sampling spread over the year	Pre-2004	Glenn Dibbin – industry representative	All results contained in Cockburn Sound Shellfish Harvesting Area – Annual Reviews. Reports available on request.
			• Two water phytoplankton monitoring sites – microalgae species enumerated as per the Marine Biotoxin Monitoring and Management Plan	Depth integrated water sample	WASQAP/ASQAP	Twice monthly	Pre-2004	Glenn Dibbin – industry representative	All results contained in Cockburn Sound Shellfish Harvesting Area – Annual Reviews. Reports available on request.
			• 3 microbiological flesh sampling sites (*E. coli*)	Mussel sample	WASQAP/ASQAP Food Standards Code	13 times per year at Kwinana Grain Terminal and 6 times per year at Southern Flats, with sampling spread over the year	Pre-2004	Glenn Dibbin – industry representative	All results contained in Cockburn Sound Shellfish Harvesting Area – Annual Reviews. Reports available on request.
			• Two biotoxin flesh monitoring sites (amnesic shellfish poisoning (ASP)/diarrhoetic shellfish poisoning (DSP)/paralytic shellfish poisoning (PSP))	Mussel sample	Food Standards Code	Monthly	Prior to April 2016, monitoring for biotoxin levels in flesh samples occurred only when phytoplankton trigger levels had been exceeded. During May 2015 and April 2016 quarterly monitoring was undertaken. Since May 2016 monthly testing is a requirement	Glenn Dibbin – industry representative	
			• Chemicals (copper, zinc, cadmium, lead, mercury and inorganic arsenic, organochlorine and organophosphate pesticides, polychlorinated biphenyls (PCBs))	Mussel sample	Food Standards Code	Annually (during summer)	Pre-2004	Glenn Dibbin – industry representative	
Bacterial water quality monitoring program for recreational waters	To classify the health risk associated with popular primary contact (e.g. swimming) at recreational sites and to inform the community	10 sites: Jervoise Bay Beach, Naval Base, Kwinana Beach, Rockingham Jetty, Palm Beach Jetty, North Hymus Street, Cliff Head, Pig Trough Bay, Herring Cove, Camp Markum	Enterococci (in some instances *E. coli*)	Water sample (grab sample)		Fortnightly seasonal (Nov. to May); Infrequent/ occasional/sporadic/ response monitoring (May to Nov.)	Established in the 1960s	City of Rockingham, City of Kwinana, City of Cockburn and Department of Defence	Site classification summaries published on Department of Health website

Monitoring program	Objective/Purpose of monitoring program	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
		Six reference sites: Jervoise Bay – Boat Ramp, CBH Jetty, Rockingham Beach, Palm Beach, Education Department Camp, John Point **Refer to Figure 5**							

Table 9. Fremantle Ports (contact person: Denis Doak).

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Water Quality Monitoring	• Assess impacts to the environment of various port-related activities. • Satisfy the requirements of ISO 14001. • Integrate and support existing environmental monitoring carried out by other agencies. • Meet current environmental licence requirements.	Kwinana Bulk Terminal Site / Easting / Northing KBT1 / 383575 / 6435777 KBT2 / 383178 / 6435540 KBT3 / 383349 / 6435488 Kwinana Bulk Jetty Site / Easting / Northing KBJ1 / 382783 / 6432386 KBJ2 / 383178 / 6432179 KBJ3 / 383349 / 6431899 **Refer to Figure 1, Figure 2 and Figure 3**	• Temperature • Salinity • Dissolved oxygen • pH • Secchi disc depth • Total suspended solids • Nutrients (total nitrogen, total phosphorus, ammonium, nitrate + nitrite, filterable reactive phosphorus) • Dissolved organic carbon • Alkalinity • Chlorophyll *a*, *b*, *c* and phaeophytin • Total petroleum hydrocarbons (TPH) • BTEX (benzene, toluene, ethylbenzene, xylenes) • Dissolved copper	• Profiles using a Sea-bird 19 Multiprobe Logger • Secchi disc • Surface (~ 0.5 m below surface) samples (all parameters) and bottom (~ 0.5 m from seabed) samples (nutrients)	*Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC/ARMCANZ 2000) *The State Environmental (Cockburn Sound) Policy; Environmental Quality Criteria Reference Document for Cockburn Sound* (EPA 2015)	Annually from Jan. to Mar.	2001	BMT Western Australia Pty Ltd and Murdoch University's MAFRL	Data available annually (May to Jun.)
Sediment Monitoring	• Assess the impacts to the environment of various port-related activities. • Satisfy the requirements of ISO 14001. • Integrate and support existing environmental monitoring carried out by other agencies. • Meet current environmental licence requirements.	Kwinana Bulk Terminal and Kwinana Bulk Jetty **Refer to Figure 4**	• Total Kjeldahl nitrogen, total phosphorus • Total organic carbon • Arsenic, cadmium, chromium, copper, lead, mercury, zinc, selenium • Organotins (TBT, DBT, MBT) • Polycyclic aromatic hydrocarbons (PAH) • TPH	(1) Diver collected sediment cores (100 mm diameter) (2) 5 cores collected within same square metre (3) Top 2 cm from each core separated and homogenised to make up one composite sample (4) One composite sample collected at each site. (5) Each core photographed and described (colour, type of sediment, oxidation layer, presence of biota).	*Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC/ARMCANZ 2000) *The State Environmental (Cockburn Sound) Policy*; *Environmental Quality Criteria Reference Document for Cockburn Sound* (EPA 2015)	Annually (Jan. to Mar.)	2001	BMT Western Australia Pty Ltd and MAFRL	Data available annually (May to Jun.)
Sentinel Mussels	• Assess the impacts to the environment	Kwinana Bulk Terminal and Kwinana Bulk Jetty	• Inorganic arsenic, cadmium, chromium, copper,	• Sentinel mussels (50–90 mm length) deployed on	*Australian and New Zealand guidelines for fresh and marine water*	Annually (Jan. to Mar.)	2001	BMT Western Australia Pty Ltd and MAFRL	Data available annually (May to Jun.)

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
	of various port-related activities. • Satisfy the requirements of ISO 14001. • Integrate and support existing environmental monitoring carried out by other agencies. • Meet current environmental licence requirements.	**Refer to Figure 6**	lead, mercury, zinc, selenium • Organotins (TBT, DBT, MBT) • PAH	mussel lines in mesh baskets suspended ~ 1 m below the surface from a fixed jetty • Mussels deployed for 6 weeks	*quality* (ANZECC/ARMCANZ 2000) The *State Environmental (Cockburn Sound) Policy*; *Environmental Quality Criteria Reference Document for Cockburn Sound* (EPA 2015)				
Marine Pests	Surveillance of introduced marine pests.	2 shoreline search sites and 2 array deployment sites in Cockburn Sound	Introduced pest presence/absence	• Shoreline searches • Settlement arrays and next generational sequencing	Department of Fisheries' *State Wide Array Surveillance Program,* technical manual (Department of Fisheries 2016)	• Settlement arrays deployed for ~2 month soak period, twice a year (summer and winter) • Shoreline searches conducted twice a year at the same time as array collection	New format implemented since August 2016	Fremantle Ports/DPIRD	Early warning system implemented prior to August 2016
Seagrass Mapping	To provide information on the current extent and distribution of seagrass (and other benthic habitat) in Cockburn Sound and to assess changes in seagrass area over time	Cockburn Sound-wide	Distribution of seagrass habitat	• Classification of WorldView–3 satellite imagery • Field surveys (towed video)	None applicable	Every 5 years	Mapping previously undertaken in 1999 and 2012	UWA – Dr Renae Hovey/Dr Matthew Fraser	• Report published on the CSMC website • Data available on request from CSMC@DWER.wa.gov.au

Table 10. Tronox Management Pty Ltd, Tronox Kwinana Pigment Plant (contact person: Miranda Robinson).

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Sediment Monitoring	DWER licence compliance L5320/1988/14	Site / Easting / Northing 25N 382785 6433123 25S 382787 6433070 25E 382815 6433099 25W 382769 6433096 25NW 382768 6433121 50W 382734 6433098 50NW 382763 6433145 200N 382784 6433302 200E 382815 6433099 200W 382589 6433096 **Refer to Figure 4**	• Total organic carbon • Particle size distribution • Aluminium • Iron • Lead • Mercury • Manganese • Titanium • Vanadium	Sediment cores (100 mm diameter) collected by divers	*Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC/ARMCANZ 2000) ISQG levels *Environmental quality criteria reference document for Cockburn Sound* (EPA 2005)	3-yearly (last round 2015)	Current program started in 2006 Historical monitoring has occurred since plant commissioning in 1991	BMT Western Australia Pty Ltd	Reports are submitted to DWER as required by the licence
			• Loss on ignition [LOI] • Total Kjeldahl nitrogen • Total phosphate • Antimony • Arsenic • Cadmium • Chromium • Cobalt • Copper • Nickel • Silver • Zinc • Radium-226 • Radium-228 • Thorium-228			6-yearly (last round 2012)			

Table 11. The University of Western Australia (contacts: Professor Gary Kendrick, Dr Matthew Fraser, Dr Belinda Cannell).

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken on behalf of	Additional information
Seagrass Health Monitoring (currently undertaken by Dr Matthew Fraser, Prof. Gary Kendrick (both UWA) and Dr Michael Rule (Department of Biodiversity, Conservation and Attractions)	To meet the monitoring and reporting requirements of the State Environmental (Cockburn Sound) Policy.	• 16 potential impact sites; 11 in Cockburn Sound, 5 outside Cockburn Sound • 5 reference sites in Warnbro Sound • 6 depth transect sites (Garden Island North and South, Southern Flats, Mangles Bay, Warnbro Sound and Woodman Point) **Refer to Figure 7**	• Seagrass (*Posidonia sinuosa*) shoot density • Seagrass canopy height • Percentage cover • Lower depth limit of seagrass meadows at depth transects	Standardised methodology that consists of: • counts and measurements in permanent quadrats; • photograph of quadrat and point count analysis; and • field measurements along transect line	*Manual of standard operating procedures for environmental monitoring against the Cockburn Sound environmental quality criteria* (EPA 2005)	Annually (generally in Jan. to Feb.)	Current program started 2003–06 Historical monitoring undertaken since 1994	WAMSI (Prof. Gary Kendrick/Dr Michael Rule) under a Service Level Agreement with DWER	• State of Cockburn Sound reports published on the CSMC website • Recent data reports published on the CSMC website • Data available on request from CSMC@DWER.wa.gov.au
Seagrass Mapping	To provide information on the current extent and distribution of seagrass (and other benthic habitat) in Cockburn Sound and to assess changes in seagrass area over time.	Cockburn Sound-wide	Distribution of seagrass habitat	• Classification of WorldView–3 satellite imagery • Field surveys (towed video)	None applicable	Every 5 years	Mapping previously undertaken in 1999 and 2012	UWA – Dr Renae Hovey/Dr Matthew Fraser	• Report published on the CSMC website • Data available on request from CSMC@DWER.wa.gov.au
Health of Little Penguins (*Eudyptula Minor*) on Garden Island	To determine the health of the little penguin colony on Garden Island.	Garden Island	• Timing of breeding • Breeding success • Foraging habitat • Diet • Causes of mortality • Population estimates	• Regular monitoring of all burrows and nest boxes within the colony • Deployment of tags (GPS, 3D) • Collection of faecal samples • Necropsies • Counts of active burrows	None applicable	• Burrows monitored once a month • Tags attached to birds guarding chicks. Young chicks are found May to Nov. so tags are potentially deployed and retrieved in any of these months • Population estimate annually	2001	UWA and DoD	No funding available for the diet analysis or foraging habitat. Diet samples have been collected in some years but not analysed. Foraging habitat determined in some years but not funded.

Table 12. Water Corporation (contact person: Grant Griffith).

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Routine Water Quality Monitoring	To observe if there are any irregular changes in water quality. To fulfil obligations of Ministerial Statement no. 655.	50H 380136 6431053 Water Corporation site reference: South (the historical location of the Southern RTMS station). This site is in deep water in the southern part of the Sound and was used for calibration of real-time sensors and for response monitoring based on low dissolved oxygen trigger. Data are still collected from this location to observe irregular changes and to record seasonal patterns. (Refer to adjacent map for site locations and **Figure 2**). 50H 377680 6437341 Water Corporation site reference: Central (the historical location of the Central RTMS station). This site is in deep water in the central part of the Sound and was used for calibration of real-time sensors and for response monitoring based on low dissolved oxygen trigger. Data are still collected from this location to observe irregular changes and to record seasonal patterns. 50H 377334 6444407 Water Corporation site reference: Parmelia. A historical location used to monitor dissolved oxygen in shallow water as a reference site for water just outside the Sound. 50H 379071 6446878 Water Corporation site reference: OA2. A deep-water reference site in Owen Anchorage that is designed to show natural dissolved oxygen variation in a reference embayment location outside of Cockburn Sound. This site is a historical water quality site for Owen Anchorage that has previously been monitored by the CSMC. 50H 383769 6436757 Water Corporation site reference: DIFF50W. Site added in June 2014. It is 50 m west, off the end of the diffuser. Used to calibrate against online seawater intake monitors onsite. Redundant sites. Data collection ceased in June 2014. • Causeway 50 H 377927 6431583 • North RTMS location 50 H 377175 6441257	Depth profiling for: • temperature • salinity • conductivity • dissolved oxygen (percentage and milligrams per litre)	A calibrated handheld Sea-bird Logger	Refer to Murdoch University's MAFRL	Jul. 2015 – current: quarterly (Jan. Apr. Jul. and Oct.) Jun. 2014 – Jun. 2015: monthly Dec. 2010 – May 2014: fortnightly and during low dissolved oxygen (DO) events Pre-Dec. 2010: weekly/fortnightly and during low DO events	Operational marine monitoring started in 2006	MAFRL; Mr Kris Wienczugow	Data available on request from the Water Corporation
Real-Time, Online Water Quality Monitoring Of Intake	Seawater quality determines the level of pretreatment required to	Seawater Intake Building at the Perth Seawater Desalination Plant	• pH • Conductivity • Turbidity	Onsite instrumentation which feeds into the site's SCADA system	Instruments are calibrated to Australian	Continuous during Plant operation	2006	proAlliance staff	Data available on request

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
Seawater	ensure optimal performance of the reverse osmosis system and to prevent fouling and scaling.		• Oxidation reducing potential (ORP) • Hydrocarbons • Temperature • Oxygen • Silt density index (SDI)		Standards				from the Water Corporation
Laboratory Water Quality Analysis of Intake Seawater	Seawater quality determines the level of pretreatment required to ensure optimal performance of the reverse osmosis system and to prevent fouling and scaling.	Seawater Intake Building at the Perth Seawater Desalination Plant	Bacteria	• Samples are collected by proAlliance staff using the Water Corporation's internal sampling procedures which incorporate requirements from the Australian Standard for Water Quality Sampling (AS/NZS 5667.1:1998) and the *Standard methods for the examination of water and wastewater* (21st edn). • Samples couriered to an external National Association of Testing Authorities (NATA) registered laboratory for analysis	*Standard methods for the examination of water and wastewater* – APHA AWWA WEF	Weekly sampling	2006	Sample collection by proAlliance staff, analysis by external laboratory	Data available on request from the Water Corporation
Laboratory Water Quality Analysis of Intake Seawater	Seawater quality determines the level of pretreatment required to ensure optimal performance of the reverse osmosis system and to prevent fouling and scaling	Seawater Intake Building at the Perth Seawater Desalination Plant	Phytoplankton	• Samples are collected by proAlliance staff using the Water Corporation's internal sampling procedures that incorporate requirements from the Australian Standard for Water Quality Sampling (AS/NZS 5667.1:1998) and the *Standard methods for the examination of water and wastewater* (21st edn). • Samples couriered to an external NATA registered laboratory for analysis	*Standard methods for the examination of water and wastewater* – APHA AWWA WEF	Monthly sampling	2006	Sample collection by proAlliance staff, analysis by external laboratory	Data available on request from the Water Corporation
Laboratory Water Quality Analysis of Intake Seawater	Seawater quality determines the level of pretreatment required to ensure optimal performance of the reverse osmosis system and to prevent fouling and scaling	Seawater Intake Building at the Perth Seawater Desalination Plant	• Hydrocarbons • Nutrients • Antimony • Cadmium • Copper • Chromium • Lead	• Samples are collected by proAlliance staff using the Water Corporation's internal sampling procedures that incorporate requirements from the Australian Standard for	*Standard Methods for the Examination of Water and Wastewater* – APHA AWWA WEF	Quarterly sampling	2006	Sample collection by proAlliance staff, analysis by external laboratory	Data available on request from the Water Corporation

Monitoring program	Objective/Purpose	Sites	Parameters monitored	Method	Standard used	Frequency and timing of monitoring	When monitoring started	Monitoring undertaken by and team leader(s)	Additional information
			• Nickel • Zinc • Arsenic • Barium • Beryllium • Boron • Mercury • Molybdenum • Selenium • Silver • Uranium • pH • Conductivity • Colour • Alkalinity • Aluminium • Calcium • Filterable organic carbon • Hardness • Iron • Magnesium • Manganese • Potassium • Silicon • Sulfur • Sulfate • Turbidity • Bromine • Fluorine • Suspended solids • Total filterable solids	Water Quality Sampling (AS/NZS 5667.1:1998) and the *Standard methods for the examination of water and wastewater* (21st edn). • External NATA registered laboratory					
Laboratory Water Quality Analysis of Intake Seawater	Seawater quality determines the level of pretreatment required to ensure optimal performance of the reverse osmosis system and to prevent fouling and scaling	Seawater Intake Building at the Perth Seawater Desalination Plant	• Iodine • Cyanide • Pesticides	• Samples are collected by proAlliance staff using the Water Corporation's internal sampling procedures that incorporate requirements from the Australian Standard for Water Quality Sampling (AS/NZS 5667.1:1998) and the *Standard methods for the examination of water and wastewater* (21st ed.). • External NATA registered laboratory	*Standard methods for the examination of water and wastewater* – APHA AWWA WEF	Annual sampling	2006	Sample collection by proAlliance staff; analysis by external laboratory	Data available on request from the Water Corporation

Table 13. Monitoring required by Ministerial Statements issued under Pt IV of the *Environmental Protection Act 1986* relating to discharges to Cockburn Sound.

Proposal/Proponent	Ministerial Statement no.	Condition	Monitoring requirements/commitments	Other information
Kwinana Gas-Fired Power Station (Water-Cooled Condenser) **NewGen Power Kwinana Pty Ltd**	698 (Nov. 2005)	**6. Marine Environment** 6-7, 6-8, 6-9, 6-10. Marine Environment Temperature Elevation Management Plan	Plan to address specific measures to monitor: • cooling water effluent temperature; • mixing performance of the diffuser to the edge of the near-field mixing zone; and • temperature elevation field in Cockburn Sound. Monitoring plan to be in accordance with the *Manual of standard operating procedures 2005* which supports the State Environmental (Cockburn Sound) Policy 2005, and its updates	The *Marine Environment Temperature Elevation Management Plan* (amended Sept. 2014) provides information on the monitoring of temperature limits (s.7.1), diffuser performance (s.7.2) and temperature elevations (s.7.3). The management plan is available at: newgenpowerkwinana.com.au/environment.html
		6.12. Measurement of free chlorine residual concentrations	Measure free chlorine residual concentrations at the discharge and at the edge of the near-field mixing zone under representative range of known plant operating conditions and biocide dosing regimes	
Perth Metropolitan Desalination Plant **Water Corporation**	655 (Jul. 2004) 832 (Jun. 2010)	8. Marine water quality	Monitoring to include dissolved oxygen levels of the bottom waters (defined as ≤0.5 m above the seabed) and other parameters related to dissolved oxygen levels	Not applicable
Staged Expansion of Tiwest Pigment Plant **Tronox Management Pty Ltd**	452 (Jun. 1997)	Environmental Management Commitment 2. Environmental Management	The Environmental Management Plan will address monitoring and management of effluent discharge to Cockburn Sound	Not Applicable
		Environmental Management Commitments 15–17. Wastewater Discharge	• Discharge to Cockburn Sound of wastewaters, which permit the maintenance of environmental quality objectives of the receiving waters, outside the mixing zone. • Conduct further investigations to better define extent of enrichment of metals in marine sediments adjacent to outfall and address likely consequences of increased discharge resulting from proposed expansion. Report of findings of investigations submitted to Department Environmental Protection by 1 February 1998. • In event monitoring results demonstrate increasing trend with potential to cause unacceptable impact to the marine environment, undertake appropriate investigations and, if necessary, corrective measures.	
Kwinana Ammonia Project **CSBP Limited**	648 (Apr. 2004)	Wastewater discharged through the Cape Peron Outlet managed under Ministerial Statement no. 665 Water quality discharge limits managed under a Pt V licence issued under the EPA Act.		CSBP Ltd normally discharges wastewater to the Sepia Depression Ocean Outlet Landline (SDOOL). In emergency situations or unavailability of the SDOOL, CSBP Ltd discharges to Cockburn Sound.
Ammonium Nitrate Production Facility Expansion **CSBP Limited**	689 (Sept. 2005)			
Ammonium Nitrate Production Expansion Project: Phase 2 **CSBP Limited**	875 (Oct. 2011)			

Table 14. Monitoring required by conditions of licences granted under Part V of the *Environmental Protection Act 1986* relating to discharges to Cockburn Sound.

Premises/Company	Licence no.	Condition	Discharge authorised/Parameters monitored	Other information
Cockburn Power Station No. 1 **Electricity Generation and Retail Corporation**	L7860/2003/5	2.3.1 Emission points to surface water	Cooling water to Cockburn Sound	Not applicable
		2.3.2 Point source emission limits to surface water	• Total residual chlorine • Temperature	
		3.3.1 Monitoring of point source emissions to surface water		
Kwinana Power Station **Electricity Generation and Retail Corporation**	L5366/1972/14	2.3.1 Emission points to surface water	Cooling water and reverse osmosis wastewater to Cockburn Sound	Not applicable
		2.3.2 Point source emission limits to surface water	• Temperature • Residual chlorine	
		2.3.3 Management actions	• Temperature	
		3.3.1 Monitoring of point source emissions to surface water	• pH • Total phosphorus, filterable reactive phosphorus, total nitrogen, nitrate nitrogen, ammonium ion nitrogen • Total residual chlorine • Metals (aluminium, arsenic, cadmium total chromium, cobalt, copper, iron, lead, manganese, mercury, nickel and zinc) • Temperature • Volume of wastewater discharged	
Kwinana Gas-Fired Power Plant **NewGen Power Kwinana Pty Ltd**	L8271/2008/1	2.3.1 Emission points to surface water	• Seawater used for cooling • Wastewater treatment plant wastewater	Not applicable
		2.3.2 Point source emission limits to surface water	Residual chlorine	
		2.3.1 Monitoring of point source emissions to surface water	• Residual chlorine • Temperature	
Perth Seawater Desalination Plant **Water Corporation**	L8108/2004/4	1. Discharge to water	Brine	Not applicable
		2. Monitoring condition 3. Monitoring condition	Total volume and daily average flow of desalination effluent and brine	
Kwinana Bulk Terminal **Fremantle Port Authority**	L4476/1984/12	9 and 10. Cockburn Sound monitoring and reporting	• Water quality (physicochemical, carbon, nutrients, total suspended solids, biological response, organics) • Mussels (metals) • Sediment (metals)	Not applicable
		11. Emissions	Washwater and stormwater	
Kwinana Bulk Jetty **Fremantle Port Authority**	L4474/1976/14	7 and 8. Cockburn Sound monitoring and reporting	• Water quality (physicochemical, carbon, nutrients, total suspended solids, biological response, organics) • Mussels (metals) • Sediment (metals)	Not applicable
		9. Emissions	Washwater and stormwater	
BP Refinery (Kwinana) Pty Ltd	L5938/1967/12	M1. Cooling water monitoring requirements	• Temperature • Total hydrocarbons • Chlorine	BP Refinery (Kwinana) Pty Ltd normally discharges the process wastewater via the SDOOL. However, there is still the option in case of emergency to discharge to Cockburn Sound.
		M3. Cooling water discharge limits	• Temperature • Total hydrocarbons	
		M4. Process wastewater monitoring requirements	• Total hydrocarbons • Nitrogen • Phenolics • Sulfides • pH • Chemical Oxygen Demand (COD) • Biological Oxygen Demand (BOD) • Total suspended solids (TSS) • Fluoride • Heavy metals	

Premises/Company	Licence no.	Condition	Discharge authorised/Parameters monitored	Other information
		M5. Process wastewater discharge limits and requirements	• pH • Volume • Total hydrocarbons • Nitrogen • Phenolics • Sulfides • pH • COD • BOD • TSS • Fluoride • Heavy metals	
Tronox Kwinana Pigment Plant **Tronox Management Pty Ltd**	L5320/1988/14	31. Wastewater discharge point	Process wastewater to submarine outfall via settling ponds	Not applicable
		32-35. Wastewater monitoring requirements	• Flow • pH • Suspended solids • Metals • Total nitrogen	
		36. Discharge limits	• Suspended solids • pH • Manganese	
		37. Sediment monitoring program – Cockburn Sound	Marine sediment quality in accordance with documented plan	Latest marine monitoring report by BMT Oceanica, Jun. 2015
CSBP Limited	L6107/1967/17	M2. Marine discharges	Process wastewater via diffuser at end of sub-marine pipeline to Cockburn Sound or emergency beach outfall to Cockburn Sound	CSBP Limited normally discharges wastewater to the SDOOL. In emergency situations or unavailability of SDOOL, CSBP Limited discharges to Cockburn Sound.
		M3. Monitoring program for emergency marine discharges M4. Monitoring program for discharge via the submarine pipeline or to SDOOL	• Volume • pH • Total inorganic nitrogen, orthophosphate • Aluminium, arsenic (inorganic), cadmium, chromium, cobalt, copper, free cyanide, fluoride, iron, lead, manganese, MDEA, mercury, molybdenum, nickel, vanadium and zinc	
		M6. Discharge Limits		
Woodman Point Wastewater Treatment Plant **Water Corporation**	L4201/1991/11	2.3.1 Emission points to surface water	Treated effluent only discharged during routine maintenance or emergency situations, in order of priority, to: • Woodman Point Ocean Outlet; and • Jervoise Bay Ocean Outlet.	The last time the Water Corporation had to use the emergency outfalls, it monitored the water quality of the area surrounding its emergency outfalls, mainly from a public health point of view.

3. Research and Investigative Studies in the Cockburn Sound marine area

3.1 Summary of research and investigative studies in the Cockburn Sound marine area

The current and recent (previous three to five years) research and investigative studies undertaken in the Cockburn Sound marine area and the organisations responsible for undertaking and/or supporting these studies are summarised in Table 15.

For further information on the research and investigative studies, refer to the metadata in s.3.2.

Table 15. Summary of current and recent research and investigative studies undertaken in the Cockburn Sound marine area.

For further information	Water quality trends/nutrient budgets	Seagrass						Marine habitat monitoring	Benthic communities	Invertebrate biology/ecology	Fish				Marine mammals		Birds		Ocean forecasting	Coastal vulnerability/coastal hazards	climate change/ extreme weather events	Maritime archaeology	Contaminants	Assessment and mitigation of environmental impacts	Assessment of infrastructure	Drivers–pressures–states–impacts–responses assessment
		Biology/Ecology/Genetics	Drivers of decline	Carbon cycling/sequestration	Effects of ocean acidification	Long-term ecosystem dynamics	Restoration				Population status	Behaviour/ecology/biology/genetics	Distribution	Fish kills	Dolphin ecology/biology	Dolphin monitoring tools	Little penguins	Seabirds of the South West Region								
Cockburn Sound Management Council/DWER	X		X				X													X			X			X
DPIRD										X	X			X							X					
City of Cockburn																				X						
City of Kwinana																				X						X
City of Rockingham																	X			X						X
Australian DoD			X																							
LandCorp							X																			
Water Corporation									X															X	X	
Fremantle Ports			X														X									
Kwinana Industries Council																										X
Western Australian Museum																		X				X				
CSIRO	X																									
Curtin University								X		X		X	X		X	X								X		
Edith Cowan University				X		X						X														
Murdoch University					X		X			X		X					X				X					
UWA		X	X				X												X							

Notes:

1. DPIRD provided information on research projects undertaken more than 3 years ago that are not included in this table.
2. The City of Cockburn provided information on research projects that are not included in this table.
3. The Cockburn Sound Coastal Alliance's Coastal Vulnerability and Adaptation Planning Project covered the full Owen Anchorage and Cockburn Sound coastline from Fremantle to Point Peron in Rockingham.

3.2 Metadata for research and investigative studies in the Cockburn Sound marine area

Further information on the current and recent research and investigative studies being undertaken in the Cockburn Sound marine area is provided in:

- Table 16 City of Cockburn
- Table 17 City of Kwinana
- Table 18 City of Rockingham
- Table 19 Cockburn Sound Management Council/DWER
- Table 20 CSIRO
- Table 21 Curtin University
- Table 22 DPIRD
- Table 23 Edith Cowan University
- Table 24 LandCorp (Western Australian Land Authority) and Cranford Pty Ltd
- Table 25 Murdoch University
- Table 26 University of Western Australia
- Table 27 University of Western Australia/Department of Biodiversity, Conservation and Attractions
- Table 28 Water Corporation
- Table 29 Western Australian Museum

Note that where an organisation has provided information on research that is being undertaken outside the Cockburn Sound marine area but which may be of interest, or historical research or investigative studies, this is also included in the relevant tables.

Table 16. City of Cockburn (contact person: Jonathan McKay).

Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Coastal Vulnerability and Flexible Adaptation Pathways Project	Cockburn Sound Coastal Alliance (cities of Fremantle, Cockburn, Kwinana, Rockingham and Perth Region NRM); Doug Vickery, Manager Infrastructure Services City of Cockburn, and Joanna Garcia-Webb, Marina and Coastal Engineering Manager, City of Cockburn	• Improve the understanding of the coastal features, processes and hazards of the Owen Anchorage/Cockburn Sound coast. • Determine the vulnerability of the coast within each coastal compartment based on an understanding of current and future physical changes. • Identify what assets are situated along the Owen Anchorage/Cockburn Sound coast including the services and functions they provide. • Identify the 'value at risk' of assets potentially affected by coastal processes and climate change under different timeframes and scenarios. • Consult with key stakeholder groups and the community to undertake a detailed analysis of most effective and feasible adaptation options that could include coastal protections, planning instruments and market interventions. • Facilitate an understanding of coastal hazards and risk management among key stakeholders and the community. • Incorporate the results of the project (scientific information and consultation output) into existing decision-making frameworks and physical works being undertaken in the coastal environment.	2010–present Implementation of actions to begin in 2018	The project covers the Owen Anchorage/Cockburn Sound coastal areas from the South Groyne of Fremantle Harbour to Cape Peron, including the eastern side of Garden Island. The research and investigative phase of the project is now largely complete, with the focus now moving to implementation of study recommendations and continued ongoing monitoring.	Further project information is available on the Cockburn Sound Coastal Alliance website at: www.cockburnsoundcoastalalliance.info Project reports include: • Coastal climate change background report and summary report; • Stage 1 – Coastal vulnerability study; • Stage 2 – Coastal values and risk assessment study; and • Stage 3 – Adaptation report and local government adaptation plans.
Eco Shark Barrier Fauna and Flora Monitoring (Coogee Beach) Honours Project	City of Cockburn (Chris Beaton) and Murdoch University student (Joel Chan)	The project aims to study the impact of the Eco Shark Barrier on the local fish population. It will also study the colonisation rate of algae and coral on the Eco Shark Barrier.	3 years (Mar. 2015 to Nov. 2017)	The project focuses on the Eco Shark Barrier, which is at the northern end of Coogee Beach and south of the Port Coogee Breakwater, Owen Anchorage. Ten 50 cm x 50 cm quadrats will be installed on each side (north, west, south) of the barrier. Five of the 10 quadrats will be located inside the barrier and the other 5 will be located outside the barrier. A camera will be used to video each quadrat. The video will be used to identify and quantify algae and coral. A camera will also be used to film fish activity on each side of the barrier. The footage will be used to identify and quantify the fish. The condition of the barrier will also be recorded using a camera. Environmental conditions such as weather conditions, water temperature, salinity, turbidity and pH will be measured and recorded. Sampling and data collection will be conducted once a month and after major storm events.	A report will be given to the City of Cockburn every 12 months. The final report will be written up as a thesis for the Honours project. The final report will be available to the public.
Coogee Maritime Trail Flora and Fauna Monitoring (UWA Master Project(s))	UWA, City of Cockburn and subcontractor	These projects aim to study the colonisation rates of marine life on the artificial reef structures installed on the marine trail.	1 year with another Master project starting in 2018	This project focuses on the Coogee Maritime Trail, which is adjacent to the southern breakwater at Port Coogee. It starts at the Omeo wreck and follows the breakwater 230 m out to sea. The trail is made up of 33 purpose-built habitat structures and 5 underwater art pieces. Information signage has also been installed. Quadrants, colonisation plates and underwater cameras are used to assess marine flora and fauna assemblages. Baseline data were collected at the site immediately after installation. The breakwater and a site in the bay are used as comparison sites.	A copy of the results presentation may be available by contacting: Dianne McLean, Research Assistant Professor Marine Ecology Group – Fisheries Research The UWA Oceans Institute T: 08 6488 4648 M: 0402 842 601 E: dianne.mclean@uwa.edu.au

Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
				The first Masters project indicated that the structures were being colonised by a variety of marine flora and fauna after 11 months. A second Master project on the site will start in 2018.	

Table 17. City of Kwinana (contact person: Ash Harding).

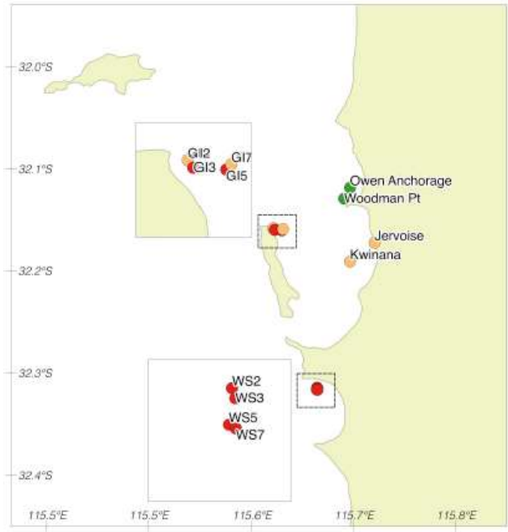
Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Cockburn Sound Drivers-Pressures-State-Impacts-Responses Assessment	BMT Western Australia Pty Ltd; Dr Rob De Roach and Dr Adam Gartner	To undertake a comprehensive critical assessment of the current and emerging driving forces and pressures on the Cockburn Sound marine area, the Sound's current condition and trends, impacts and management responses.	2017–18	Based on the best available information and using best-practice approaches, frameworks and tools, the aim of the project is to: • identify and evaluate the environmental, social, cultural and economic driving forces and pressures affecting the environmental values of the Cockburn Sound marine area; • describe and assess the actual and potential impacts and their effects on the environmental values of the Cockburn Sound marine area, including direct, indirect, consequential and cumulative impacts and impacts from past and present activities, including identifying and evaluating successive and combined effects of the key impacts on water quality and seagrass meadows in Cockburn Sound; • describe and assess the current condition and trend in the environmental values of the Cockburn Sound marine area; • evaluate the effectiveness of existing management arrangements to manage impacts to protect and maintain the environmental values of the Cockburn Sound marine area; • assess the risks to the environmental values of the Cockburn Sound marine area, based on an evaluation of trends in driving forces and pressures, the effects of identified impacts, current condition and trends, the effectiveness of current management and the resilience of the Cockburn Sound ecosystem; • describe the likely long-term outlook for the environmental values of the Cockburn Sound marine area, based on an evaluation of actual and potential impacts, current condition and trends, the effectiveness of management arrangements, the resilience of the Cockburn Sound ecosystem and the overall risk assessment; and • identify key knowledge gaps and priorities for research, modelling and monitoring to address critical information needs.	Reports will be published on the CSMC website.

Table 18. City of Rockingham (contact person: Brett Ashby).

Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Cockburn Sound Drivers-Pressures-State-Impacts-Responses Assessment	BMT Western Australia Pty Ltd; Dr Rob De Roach and Dr Adam Gartner	To undertake a comprehensive critical assessment of the current and emerging driving forces and pressures on the Cockburn Sound marine area, the Sound's current condition and trends, impacts and management responses.	2017–18	Based on the best available information and using best-practice approaches, frameworks and tools, the aim of this projects is to: • identify and evaluate the environmental, social, cultural and economic driving forces and pressures affecting the environmental values of the Cockburn Sound marine area; • describe and assess the actual and potential impacts and their effects on the environmental values of the Cockburn Sound marine area, including direct, indirect, consequential and cumulative impacts and impacts from past and present activities, including identifying and evaluating the successive and combined effects of the key impacts on water quality and seagrass meadows in Cockburn Sound; • describe and assess the current condition and trend in the environmental values of the Cockburn Sound marine area; • evaluate the effectiveness of existing management arrangements to manage impacts to protect and maintain the environmental values of the Cockburn Sound marine area; • assess the risks to the environmental values of the Cockburn Sound marine area, based on an evaluation of trends in driving forces and pressures, the effects of identified impacts, current condition and trends, the effectiveness of current management and the resilience of the Cockburn Sound ecosystem; • describe the likely long-term outlook for the environmental values of the Cockburn Sound marine area, based on an evaluation of actual and potential impacts, current condition and trends, the effectiveness of management arrangements, the resilience of the Cockburn Sound ecosystem and the overall risk assessment; and • identify key knowledge gaps and priorities for research, modelling and monitoring to address critical information needs.	Reports will be published on the CSMC website.
Coastal Hazard Risk Mitigation and Adaptation Plan (CHRMAP)	City of Rockingham: Natalie Elliott Cardno; David Van Senden and Chris Scraggs	To identify the parts of the City's coastline that are potentially vulnerable to coastal hazards over the next 100 years.	The CHRMAP will outline key directions for coastal adaptation over a 100-year planning timeframe, as well as prioritising management works over the next 10 years. The final CHRMAP document will be completed in early 2019.	A CHRMAP is a strategic planning document that informs decision makers about potential coastal hazards, the consequences and necessary actions. Sea-level rise has been measured over recent decades. Coastal planning is required to address coastal erosion and inundation associated with a predicted rise of 0.9 m over the next 100 years in WA. The CHRMAP will build upon previous studies and undertake a detailed analysis of the coastline to identify the most vulnerable areas. This will include modelling of coastal hazards. Following this, risk management and adaptation options (avoid, retreat, accommodate or protect) will be identified. The adaptation responses will be defined by evaluating the methods against multiple social, economic and environmental criteria.	The CHRMAP will be made publicly available on the City of Rockingham's website.

Table 19. Cockburn Sound Management Council/DWER (contact person: Coordinator, CSMC).

Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Coastal Vulnerability and Flexible Adaptation Pathways Study	Cockburn Sound Coastal Alliance	• To improve the understanding of the Cockburn Sound's coastal features, processes and hazards. • To determine the vulnerability of the coast within each coastal compartment based on an understanding of current and potential physical changes to coastal processes. • To identify Cockburn Sound coast's assets, including the services and functions they provide. • To identify the 'value at risk' of assets potentially affected by coastal processes and climate change under different timeframes and scenarios. • To undertake a detailed analysis of the most effective and feasible adaptation options which could include coastal protections, retreat and planning controls. • To facilitate an understanding of coastal hazards and risk management of those hazards among key stakeholders and the community. • To inform existing decision-making frameworks and physical works being undertaken along the coast.	Initiated in 2010, implementation started in 2016	**Stage 1 – Coastal vulnerability study (completed 2013)** • Analysis of coastal processes (metocean and sediment movement) to improve the understanding of existing coastal dynamics • Assessment of potential changes arising from climate change (from present day (2013) to 2110) to determine the vulnerability of sections of the coastline to erosion and flooding, taking into account local geomorphologic and engineered structures **Stage 2 – Coastal values and risk assessment study (completed 2014)** • Identify the 'value at risk' of coastal assets by processes including climate change • Risk assessment of likelihood and consequence of the identified hazards • First pass assessment of potential adaptation options for the coastal assets at risk **Stage 3 – Adaptation plan development and review report (started 2015)** • Refine the adaptation options developed in Stage 2 • Consult interested stakeholder groups and the broader community • Identify ongoing monitoring program needs and recommend improvements to local coastal management strategies and plans • Independently evaluate the methodologies and outcomes of stages 1, 2 and 3 **Stage 4 – Implementation and monitoring** • Implement the first scheduled adaptation actions identified from Stage 3 • Manage plan reviews • Carry out initial onground works such as dune vegetation planting in identified areas to increase the system's resilience to coastal processes	Information available at: www.cockburnsoundcoastalalliance.info
Cockburn Sound Contaminant Review	GHD (professional services company)	Review of historical and contemporary contaminant loads entering Cockburn Sound, addressing a key finding from an audit by the WA Office of the Auditor General on the environmental management of Cockburn Sound that total contaminant discharges into Cockburn Sound are not monitored.	Feb. 2013	• Review of contaminant loads entering Cockburn Sound and Owen Anchorage to provide a contemporary understanding of contaminant loads entering the system • Report on changes or trends in contaminant inputs compared to previous contaminant input inventories for Cockburn Sound and Owen Anchorage • Provide recommendations to address the Office of the Auditor General's recommendations and findings with respect to contaminant loads • Provide recommendations for general process and structure of a potential environmental risk assessment	Report: GHD 2013, *Cockburn Sound contaminant review final report*, available from CSMC@DWER.wa.gov.au
Monitoring of Seagrass (*Posidonia australis*) Transplants in Mangles Bay, southern Cockburn Sound	Murdoch University; Dr Mike van Keulen	Monitoring of *Posidonia australis* transplants in 3 mooring scars in Mangles Bay. Mooring scars manually revegetated using sprig transplants in March 2010.	Mar. 2013	• 3 mooring scars in Mangles Bay • No. of surviving planting units recorded • Survival of planting units previously monitored in Jul. 2010 (3 months), Sept. 2010 (6 months), Mar. 2011 (12 months)	Report: van Keulen M 2013, *Monitoring of seagrass transplants into mooring scars in Mangles Bay, southern Cockburn Sound, March 2013,* available from CSMC@DWER.wa.gov.au

Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Drivers of Seagrass Decline in Cockburn and Warnbro Sound	UWA; Professor Gary Kendrick, Mr Matthew Fraser	To identify the drivers of continued seagrass decline in Cockburn and Warnbro Sounds, with a focus on the belowground stressors on seagrass meadows, specifically sulfide intrusion from sediments and sediment contaminants (metals).	Mar. to Jun. 2015	• 12 sites (4 in Cockburn Sound/Woodman Point, 4 in Warnbro Sound and 4 around Garden Island) (refer to map below)  • Measurements included seagrass shoot density, biomass and productivity, total sulfur, $\delta^{34}S$ isotope ratios, carbon–nitrogen–phosphorus (CNP) content, metal content, water quality (photosynthetically active radiation, dissolved oxygen, pH, salinity, temperature) and sediment characteristics (organic matter content, phosphorus content, metal content) • Light loggers deployed for one month; conductivity–temperature–depth (CTD) loggers deployed for one month	Report: Fraser MW, Kendrick GA & Zavala-Perez A 2015, *Drivers of seagrass decline in Cockburn and Warnbro Sound*, available on the CSMC website
Assessment of Water Column Nitrogen Trends in Cockburn Sound Relative to Existing Loads, Concentrations and Fluxes	CSIRO; Dr John Keesing, Dr Don McFarlane, Dr Mike Donn, Dr Jim Greenwood	To develop a nitrogen budget for Cockburn Sound to determine the relative importance of inputs of nitrogen (N) into Cockburn Sound.	2015–16	• Analysis of spatial and temporal trends in water column N concentrations in Cockburn Sound between 1987 and 2013 using CSMC monitoring data. Trends compared to historical and recent measurements of loads and fluxes of N inputs into Cockburn Sound. CSIRO will use current projections of submarine groundwater discharge input to Cockburn Sound based on the Australian Water Recycling Centre of Excellence project and recent measurements of N loads in marine sediments from Cockburn Sound and fluxes of N from the sediment to the water column, together with historical analyses and accounts of nutrients in Cockburn Sound. • Water quality survey to assist in identifying the spatial extent of submarine groundwater discharge into Cockburn Sound. • Development of a nitrogen budget for Cockburn Sound.	Reports: • Keesing J, Greenwood J, Donn M & McFarlane D 2016, *Spatial and temporal analysis of water quality monitoring data collected from Cockburn Sound and Warnbro Sound between 1982/83 and 2013/14,* CSIRO, Australia. • Greenwood J, Keesing J, Donn M & McFarlane D 2016, *Nitrogen budget for Cockburn Sound, Western Australia,* CSIRO, Australia. Reports available on the CSMC website.
Cockburn Sound Drivers–Pressures–State–Impacts–Responses Assessment	BMT Western Australia Pty Ltd; Dr Rob De Roach and Dr Adam Gartner	To undertake a comprehensive critical assessment of the current and emerging driving forces and pressures on the Cockburn Sound marine area, the Sound's current condition and trends, impacts and management responses.	2017–18	Based on the best available information and using best-practice approaches, frameworks and tools, the aim of the project is to: • identify and evaluate the environmental, social, cultural and economic driving forces and pressures affecting the environmental values of the Cockburn Sound marine area; • describe and assess the actual and potential impacts and their effects on the environmental values of the Cockburn Sound marine area, including direct, indirect, consequential and cumulative impacts and impacts from past and present activities, including identifying and evaluating the successive and combined	Reports available on the CSMC website.

Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
				effects of the key impacts on water quality and seagrass meadows in Cockburn Sound; • describe and assess the current condition and trend in the environmental values of the Cockburn Sound marine area; • evaluate the effectiveness of existing management arrangements to manage impacts to protect and maintain the environmental values of the Cockburn Sound marine area; • assess the risks to the environmental values of the Cockburn Sound marine area, based on an evaluation of trends in driving forces and pressures, the effects of identified impacts, current condition and trends, the effectiveness of current management and the resilience of the Cockburn Sound ecosystem; • describe the likely long-term outlook for the environmental values of the Cockburn Sound marine area, based on an evaluation of actual and potential impacts, current condition and trends, the effectiveness of management arrangements, the resilience of the Cockburn Sound ecosystem and the overall risk assessment; and • identify key knowledge gaps and priorities for research, modelling and monitoring to address critical information needs.	

Table 20. CSIRO (contact person: Dr John Keesing).

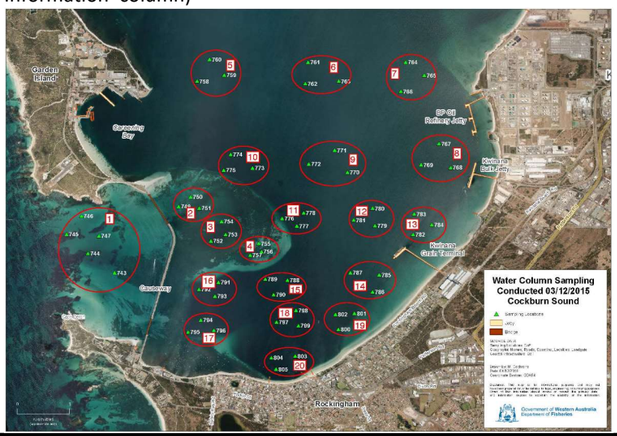
Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary details of the research program	Additional information
Assessment of Water Column Nitrogen Trends in Cockburn Sound Relative to Existing Loads, Concentrations and Fluxes	CSMC, Department of Water and CSIRO	Analysis of spatial and temporal trends in water quality monitoring data from historical data and the development of a nitrogen budget.	2015–16 to 2016–17	The study principally makes use of data collected by the CSMC water quality monitoring program from 1982–82 up to 2013–14, but also draws on the results of previous projects conducted by CSIRO to model the spatial variability of submarine ground water flows into Cockburn Sound and the amount of N this contributes to the Sound.	Reports to the CSMC and the Department of Water available on the CSMC website: • Keesing J, Greenwood J, Donn M & McFarlane D 2016, *Spatial and temporal analysis of water quality monitoring data collected from Cockburn Sound and Warnbro Sound between 1982/83 and 2013/14*, CSIRO, Australia. • Greenwood J, Keesing J, Donn M & McFarlane D 2016, *Nitrogen budget for Cockburn Sound, Western Australia,* CSIRO, Australia.

Table 21. Curtin University (refer to individual contact details provided in the table).

Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Contact:	**Office of R&D, Research Support – Science and Engineering (ORD-Support-SAE@curtin.edu.au)**				
Validation of Aging techniques for Southern Reef Squid (*Sepioteuthis australis*) from Cockburn Sound, Western Australia	Recreational Fishing Initiatives Fund – Recfishwest and the Department of Fisheries (Project Number 2012/002)	This study aimed to use a double staining technique to validate the use of statoliths to age southern reef squid following the one day – one increment hypothesis.	Jun. 2012–Jun. 2015	*Field sites*: seagrass beds at the northern end of Cockburn Sound and Parmelia Bank. *Frequency of sampling*: 16 May 2014 – 25 May 2015, about every 8 weeks. *Parameters measured*: 44 squid (*Sepioteuthis australis*) were collected by jigging. Squid were cultured at the Curtin Aquatic Research Laboratories and injected with calcein solution on 2 occasions to create 2 fluorescent stained rings in the statolith. The number of growth increments between the stains were counted.	Final report: *2012/002 – Determining the dynamics of WA squid populations through research and recreational fishing,* submitted to Recfishwest and the Department of Fisheries
Contact Person:	**Director, Curtin Marine and Coastal Research Network (MCRN@curtin.edu.au)**				
An Assessment of the Effectiveness of High Definition Cameras as Remote Monitoring Tools for Dolphin Ecology Studies	Curtin University, Fremantle Ports	Assess effectiveness of high definition camera versus live observers to detect the presence/absence of marine mammals travelling between Swan Estuary and Cockburn Sound.	Two years (2012–2015 including MSc thesis writing)	*Field site*: one field site at the entrance of the Swan Estuary. *Frequency of sampling*: continuous during daylight over four months. *Parameters measured:* frequency of detection of Indo-Pacific bottlenose dolphins by cameras.	Paiva EG, Salgado-Kent C, Gagnon MM, Parnum I & McCauley R 2015, 'An assessment of the effectiveness of high definition cameras as remote monitoring tools for dolphin ecology studies', PLOS ONE, journals.plos.org/plosone/article?id=10.1371/journal.pone.0126165
Reduced Detection of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*) in an Inner Harbour Channel during Pile Driving Activities	Curtin University, Fremantle Ports	Assess if the pile driving required as part of the Fremantle Port expansion interfered with the travel of Indo-Pacific bottlenose dolphins from Cockburn Sound into the Swan Estuary and out again.	Two years (2012–2015 including MSc thesis writing)	*Field site*: one field site at the entrance of the Swan Estuary. *Frequency of sampling*: continuous during daylight over 4 months. *Parameters measured*: frequency of detection of Indo-Pacific bottlenose dolphins during pile driving activities as well as during quiet timeframes.	Paiva EG, Salgado-Kent CP, Gagnon MM, McCauley R & Finn H 2015, 'Reduced detection of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in an inner harbour channel during pile driving activities', *Aquatic Mammals,* vol. 41, pp. 455–68, cmst.curtin.edu.au/wp-content/uploads/sites/4/2016/05/paiva_salgado_reduced_detection_2015.pdf
The Use of Imaging Sonar in Monitoring Fish Distribution and Behaviour		Tests the efficacy of sonar systems to detect, count and monitor fish species and compare how estimates of individual fish length compare with those of stereo-baited remote underwater video systems (BRUVs).	Oct. 2014–Apr. 2016	3 field sites near Point Peron, stereo-video and imaging sonar backscatter. Each site sampled for 30 minutes to one hour; each site sampled four times, each time using a different sonar system.	None available yet
The Use of Combined Acoustic and Optical Techniques to Monitor Spawning Aggregations of Pink Snapper (*Pagrus Auratus*) in Cockburn Sound		Tests the efficacy of vessel-based (mounted or towed) multi-frequency echosounders, imaging sonars and drop cameras to map the biomass of pink snapper aggregations.	Oct. 2016	Two aggregations were mapped at Garden Island jetty and a locally known wreck (D9). Samples were taken for computed tomography (CT) scanning by DPIRD to develop species acoustics target strength models.	
Ecological Patterns and Evolutionary Consequences of Latitudinal Shifts in Tropical Reef Fish along the Coast of Western Australia	Curtin University	1) Develop appropriate genetic markers for select tropical reef fish species known to occur on temperate reefs along the southwest coast of Western Australia. 2) Use these genetic markers to develop a model of connectivity between tropical (source) reefs and temperate (sink) reefs along the coast of Western Australia with novel genomic and analytical approaches. 3) Characterise increasing ecological interactions between vagrant tropical reef fish species and resident temperate fauna owing to climate change.	Apr. 2015–Apr. 2019	Tissue sample collection and gut content analysis. Cockburn Sound is one site embedded within a network of 9 other sites along the coast of WA. Most samples were donated by commercial anglers or received via DPIRD.	
Acoustic Whistle Repertoire of Bottlenose Dolphins (*Tursiops aduncus*)	Self-funded		Honours (one year project)	*Field site*: entrance of the Swan Estuary (Fremantle Inner Harbour). *Frequency of sampling*: surveys conducted several times a week over 2 months. *Parameters measured*: occurrence, photo-identification, acoustic	Ward R, Parnum I, Erbe C & Salgado-Kent C 2016, 'Whistle characteristics of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in the Fremantle Inner Harbour, Western Australia', *Acoustics Australia,* vol. 44, pp. 159–69.

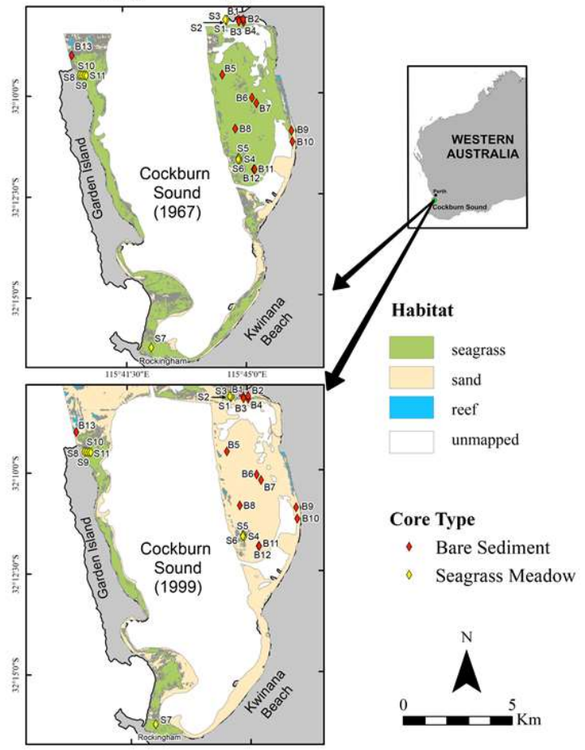
Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
				recordings, group cohesion, number in dolphin group, behaviours.	Curtin Honours thesis
Bottlenose Dolphin (*Tursiops aduncus*) Behavioural Ecology in a Noisy Environment	Swan River Trust		PhD 3–4 years	*Field sites*: entrance of the Swan Estuary (Fremantle Inner Harbour), plus other sites in the Swan River (but not considered part of Cockburn Sound). *Frequency of sampling:* during target survey periods over 2 years. *Parameters measured*: abundance, movement (tracks using a theodolite), underwater soundscape recordings, behaviours.	Marley SA, Erbe C & Salgado-Kent CP 2016, 'Underwater sound in an urban estuarine river: sound sources, soundscape contribution, and temporal variability', *Acoustics Australia,* vol. 44, pp. 171–86. Other papers and PhD thesis in progress.
Modelling the Occurrence of Bottlenose Dolphins (*Tursiops aduncus*) using Citizen Science Observations	Self-funded		Honours (one-year project)	*Field sites:* entrance of the Swan Estuary (Fremantle Inner Harbour), plus other sites in the Swan River (but not considered part of Cockburn Sound). *Frequency of sampling:* weekly observations over 5 years. *Parameters measured:* occurrence (presence and absence), environmental parameters acquired, models produced.	Beidatsch K. *Machine learning for species distribution modelling: An empirical evaluation of a novel method used with Indo-Pacific bottlenose dolphin citizen science observations*. Curtin Honours thesis
Foraging Ecology of Bottlenose Dolphins (*Tursiops aduncus*)	Fremantle Ports		Two years	*Field site*: entrance of the Swan Estuary (Fremantle Inner Harbour). *Frequency of sampling*: during target survey periods over 2 years. *Parameters measured*: frequency of detection of Indo-Pacific bottlenose dolphins, behaviour, fish prey and distribution using a combination of echosounder surveys and BRUVs.	None available yet
Predicting Distribution of Demersal Fish	Self-funded	To develop techniques for predicting fish distribution. Parameters assessed: fish presence, depth and seafloor habitat, and depth.	PhD 3–4 years	Part of Jervoise Bay was surveyed in May 2016 using echosounder and underwater video.	None available yet
Monitoring Marine Habitats using Multibeam Sonar	Self-funded	To investigate using multibeam sonar for monitoring seafloor habitats over time.	PhD 3–4 years	Part of Minden Reef was mapped in July 2017.	None available yet

Table 22. Department of Primary Industries and Regional Development (contact person: Dr Dan Gaughan).

Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Marine Heatwave off Western Australia	Invertebrate Branch – Dr Nick Caputi	Investigation into the influences of the 2011 marine heatwave.	2010–13	Refer to the reports listed in the 'Additional Information' column for details of methodology and sampling sites.	*Fisheries Research Reports 222, 250*
Implications of Climate Change on Fisheries in Western Australia	Invertebrate Branch – Dr Nick Caputi	Examination of the implications and management issues associated with climate change and wild fisheries in WA.	2010–14	Refer to the report listed in the 'Additional Information' column for details of methodology and sampling sites.	*Fisheries Research Report 261*
Innovative Development of the Octopus (*Octopus tetricus*) Fishery	Mollusc Section – Dr Anthony Hart	Sustainable development of the octopus fishery.	2010–14	Refer to the report listed in the 'Additional Information' column for details of methodology and sampling sites.	*Fisheries Research Report 270*
Status of Southern Garfish (*Hyporhamphus melanochir*) in Cockburn Sound, Western Australia	Finfish Branch – Dr Kim Smith	Determine status of local southern garfish stock to inform fishery management.	2010–15	Refer to the report listed in the 'Additional Information' column for details of methodology and sampling sites.	*Fisheries Research Report 271*
Cockburn Sound Fish Kill December 2015		Collection of water column profiles, water samples and fish samples to support investigation into Nov. to Dec. 2015 fish kill	Dec. 2015	Water samples for toxic phytoplankton, chemical toxins analysis taken at several locations (refer to the report listed in the 'Additional Information' column). 62 physical water column profiles sampled throughout Cockburn Sound (see map below) (refer to the report listed in the 'Additional Information' column) 	Report: *Fish kill incident, Cockburn Sound, Western Australia, November–December 2015* available at: www.fish.wa.gov.au/Documents/corporate_publications/fish-kill-incident-cockburn-sound-2015.pdf
Catch/Effort and Gill Net Conversion for Cockburn Sound	Crab Section – Dr Danielle Johnston	Work to support move of commercial fishing from gillnets to traps for blue swimmer crabs (*Portunus armatus).*	1994–98	Refer to the report listed in the 'Additional information' column for details of methodology and sampling sites.	*Fisheries Research Report 113*
Review of Productivity Levels of Western Australian Coastal Waters	Dr Alan Pearce	Review of water quality/chlorophyll *a* to support bivalve culture planning.	2000	Refer to the report listed in the 'Additional information' column for details of methodology and sampling sites.	*Fisheries Research Report 123*
Management and Monitoring of Fish Spawning Aggregations	Finfish Branch – Dr Brett Molony	Identify aggregations, examine biology, establish monitoring methods and provide management recommendations.	2004–07	Refer to the report listed in the 'Additional information' column for details of methodology and sampling sites.	*Fisheries Research Report 187*
Developing Long-Term Indicators for subtidal communities of Cockburn Sound	Crab Section – Dr Danielle Johnston	Gain a better understanding of the biodiversity and community structure within Cockburn Sound to inform development of effective and efficient	2006–08	Refer to the report listed in the 'Additional information' column for details of methodology and sampling sites.	*Fisheries Research Report 181*

Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
		resource condition targets.			
Introduced Pest survey of Swan River Region	Marine Biosecurity Science and Surveillance Section – Dr Justin McDonald	Survey of introduced marine pests including Cockburn Sound.	2007	Refer to the report listed in the 'Additional information' column for details of methodology and sampling sites.	*Fisheries Research Report 189*
Preliminary Investigation into Kwinana Quay Development	Finfish Branch – Dr Corey Wakefield Crab Section – Dr Danielle Johnston	Baseline data collection of key finfish and crab species, and preliminary examination of potential impacts.	2009	Refer to the report listed in the 'Additional information' column for details of methodology and sampling sites.	*Fisheries Research Report 186*
***Asian Green Mussel (Perna viridis)* Detection**	Marine Biosecurity Science and Surveillance Section – Dr Justin McDonald	Survey of Asian green mussel within DoD port area at Garden Island.	2009	One-off subtidal survey of infrastructure within DoD port area for abundance of introduced marine pest species.	Unpublished report

Table 23. Edith Cowan University (contact person: Dr Oscar Serrano).

Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary details of the research program	Additional Information
Carbon Cycling and Bacterial Carbon Sources in Coastal Habitats	Edith Cowan University internal funds	The aim of the research project is to elucidate the importance of bacterial communities in carbon cycling in seagrass meadows (*Posidonia sinuosa*).	2012–15	Bacteria, sediment and water samples have been collected from seagrass meadows at a range of sites in the southern Cockburn Sound. Data are currently being analysed.	
Coastal Biogeochemistry Carbon Cluster	CSIRO	Estimate the carbon sequestration capacity of coastal vegetated ecosystems (seagrass, mangrove and saltmarsh).	2012–16	Collection of sediment cores (up to 1 m long and 70 mm in diameter) in 24 field sites (11 sites in seagrass meadows and 13 sites in bare sand but previously vegetated; see Figure 1 below). The cores were dated (radiocarbon and 210Pb) to determine the age-depth relationships; the dry bulk density (g cm^{-3}), organic and inorganic carbon content and sediment grain size were analysed. The cores were sampled once and no further sampling is planned. Figure 1. Location of the study sites at Cockburn Sound Western Australia. Area of different habitat types in (a) 1967 and (b) 1999 (modified from Kendrick *et al.* 2002). Four habitat types are discerned in the maps: reef (light blue), sand (sand), seagrass (green) and unmapped (white). Yellow rhombuses indicate the location of the cores sampled in persistent seagrass meadows. Red rhombuses indicate the sampling site of cores from bare sediments (i.e. bare at present but previously vegetated 1967). 	Information on the carbon cluster can be found: www.csiro.au/en/Research/OandA/Areas/Coastal-management/Coastal-Carbon-Cluster Data from Cockburn Sound have not been published. Reports/data are not publicly available but further details on the results and conclusions obtained could be made available to the CSMC on request. Report: Kelleway J, Serrano O, Baldock J, Cannard T, Lavery P, Lovelock CE, Macreadie P, Masqué P, Saintilan N & Steven ADL 2017, *Technical review of opportunities for including blue carbon in the Australian Government's Emissions Reduction Fund,* final report prepared for the Department of the Environment and Energy, CSIRO, Australia.
Revealing Long-Term Ecosystem Dynamics using Seagrass Archives (Cockburn Sound, Western Australia)	Edith Cowan University internal funds CSIRO Coastal Carbon Biogeochemistry Cluster	Use seagrass cores to reconstruct the environmental history of Cockburn Sound, including effects on blue-carbon stocks.	2015	• One field site, Mangles Bay, 32.2051° S, 115.7242° E • Organic carbon, sediment grain size, stable C and N isotopes, 210Pb • 5 sites northwest of Garden Island: 32°09'35.6"S, 115°40'16.4"E • Parameters as above plus radio carbon	Data available through the CSIRO Coastal Carbon Biogeochemistry Cluster website and links. Publications: Serrano O, Lavery PS, Rozaimi M & Mateo MA 2014, 'Influence of water depth on the carbon sequestration capacity of seagrasses', *Global Biogeochemical Cycles,* vol. 28, pp. 950–61. Serrano O, Ricart AM, Lavery PS, Mateo MA, Arias-Ortiz A, Masqué P, Steven A & Duarte CM 2015, 'Key biogeochemical factors affecting soil carbon storage in

					Posidonia meadows', *Biogeosciences, Discussion* 12, 18913–44.
The Impact of Range Shifts on the Stability of the Gastrointestinal Microbial Community of the Tropical Herbivorous Fish *Siganus fuscescens*	Edith Cowan University and Curtin University	To determine if range shifts of a key herbivorous fish species impacted the gut microbiome.	One year (mid 2015–mid 2016) with an interest in expanding if funding becomes available	*Siganus fuscescens* individuals (12 fish) were obtained from Cockburn Sound by a commercial fisher who caught the fish using a purse seine in Feb. 2016 only. Comparative samples from *Siganus fuscescens* populations were obtained via researchers from Curtin University and other commercial fishers from other locations along the WA coastline.	

Table 24. LandCorp and Cranford Pty Ltd (Cedar Woods) (contact person: Sharon Clark, LandCorp).

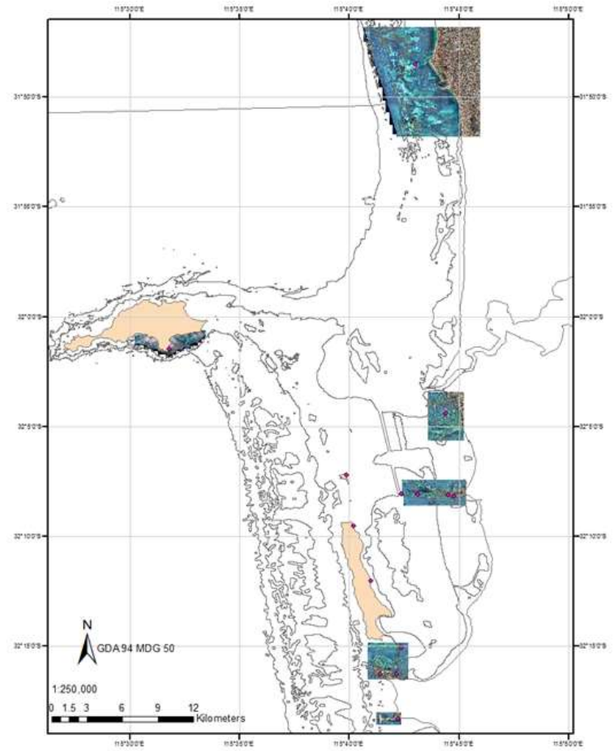
Research project title	Research undertaken by and team leader(s)	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Mangles Bay Marina Seagrass Transplant Pilot Study 2015	BMT Western Australia Pty Ltd; Dr David Rivers and Dr Karen Hoefhamer	To implement the Mangles Bay Marina Seagrass Transplant Pilot Study (required by Condition 11-5(1) of Ministerial Statement no. 974) including: • selecting suitable transplant areas; • undertaking harvesting and transplanting of seagrass; and • set up donor meadow recovery study.	Nov. to Dec. 2015–17	4 sites in the southern end of Cockburn Sound were selected for a seagrass transplanting pilot study with 4 replicate plots at each site (see map below). Each plot was transplanted with 61 seagrass sprigs (sections of rhizome with leaves attached), with 9 sprigs in each plot measured for rhizome length. The donor meadow study was set up at 2 sites with shoot density measured at 10 quadrats per site.	Seagrass restoration works are continuing. A second round of annual monitoring of the seagrass replanting trial plots was conducted in Dec. 2017. Monitoring of 5 plots showed that seagrass survival is at 75%, which is consistent with the requirements of the Ministerial Statement. Report: BMT Oceanica 2015, *Mangles Bay Marina: seagrass transplant pilot study 2015 summary report*. This report is not currently publicly available. Please note confidentiality issues are associated with releasing the locations of the selected pilot study sites at this time. A map showing indicative pilot study locations has been provided.

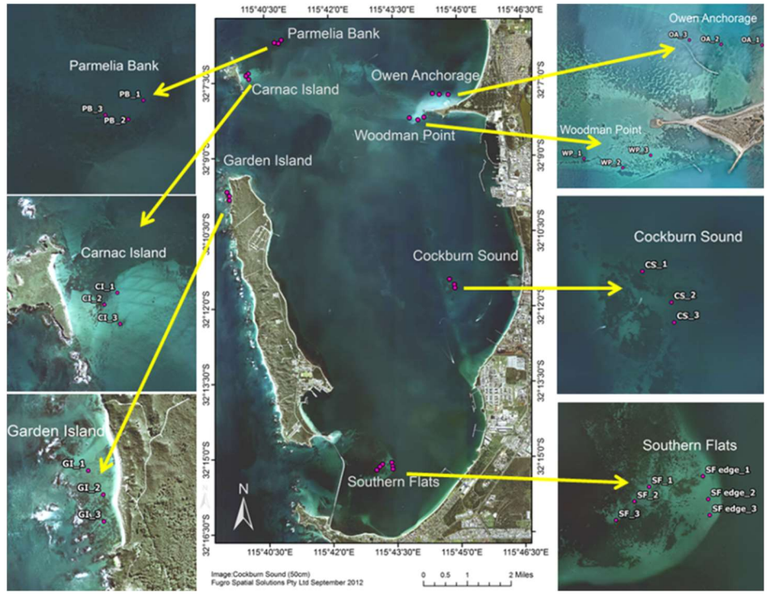
Table 25. Murdoch University (contact: researchsupport@murdoch.edu.au; Belinda Cannell (b.cannell@murdoch.edu.au)).

Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
The Development of Techniques for the Collection of Fertilised Eggs from Cockburn Sound Australasian Snapper (*Chrysophrys auratus*) Spawning Aggregations and Culture of Snapper Juveniles to Release for Enhancement	Project led by Challenger Institute of Technology Murdoch University side led by Dr Jennifer Chaplin Funded by Recfishwest	• To investigate the genetic implications of culturing Australasian snapper from wild-caught eggs • Development of techniques to collect and identify fertilised eggs of snapper from Cockburn Sound during the species spawning aggregations • If successful, the proponents will culture the fertilised eggs that are captured and test the genetic diversity of the offspring. • If approval to release the cultured juveniles can be acquired, then marked juvenile snapper will be released into the Cockburn Sound snapper nursery areas. If successful, then this project will enable a cost-effective method to replenish snapper stocks when required.	Project started 2 Mar. 2015 Project ended 30 Nov. 2015	Research was conducted in Cockburn Sound and Fremantle.	No intellectual property issues are associated with this project. Thesis: Prokop N 2015, *Genetic implications of culturing Australasian Snapper* (Chrysophrys auratus*) from wild-caught eggs*, Honours Thesis, Murdoch University. Report: Prokop N & Chaplin J 2016, *Genetic implications of culturing Australasian Snapper* (Chrysophrys auratus) *from wild-caught eggs,* final report to the Australian Centre for Applied Aquaculture Research, Murdoch University.
Monitoring Seagrass Transplants in Mangles Bay, Cockburn Sound	Research led by Murdoch University, lead investigator Dr Michael Van Keulen Funded by Cockburn Sound Management Council	Small consultancy agreement to undertake shoot counts of seagrasses planted as a pilot study 18 months prior to commencement.	Project started 4 Mar. 2013 Project ended 11 Nov. 2013	Field counts, working from a small boat to count shoots of seagrass in Mangles Bay, Cockburn Sound	Report: van Keulen M 2013, *Monitoring of seagrass transplants into mooring scars in Mangles Bay, southern Cockburn Sound, March 2013*, available on request from CSMC@DWER.wa.gov.au
Population Biology of the Pink Sand Dollar (*Peronella Lesueuri*) in Cockburn Sound, Southwest Australia	Murdoch University PhD project by Sharon Yeo Sue-Yee; Principal Supervisor Dr Mike van Keulen and Associate Supervisor Dr John Keesing (CSIRO)	Project to investigate the biology and ecology of the pink sand dollar in Cockburn Sound.	Study started in 2009 Thesis submitted in 2013; conferred in 2015	Field sampling and tracking of sand dollars in Cockburn Sound	PhD project supervised by Murdoch University and CSIRO; student received WAMSI top-up funding
The Ecophysiological Effects of Ocean Acidification on the Seagrass *Posidonia Australis* and their Calcifying Epiphytes: a Study using Pulse Amplitude Modulated Fluorometry	Murdoch University Honours project by Kirsten Ball, supervised by Dr Mike Van Keulen and Dr Navid Moheimani	Project examining seagrass and epiphyte physiological responses to ocean acidification.	Study undertaken in 2014 Study completed and thesis submitted in 2014	Field sampling of seagrasses at Garden Island and Woodman Point; laboratory experiments on seagrasses collected from Cockburn Sound	
How Resilient are Little Penguins (*Eudyptula Minor*) and the Coastal Marine Habitats they use?	Project led by Dr Belinda Cannell Funded by the City of Rockingham, Australian Geographic (1 year), Fremantle Ports	• Improve predictions of the likelihood of the little penguin colony surviving impacts associated with climate change and coastal use. • Understand the health of the coastal marine habitat using little penguins as bioindicators. • Determine the population of the little penguin colony following the strong Leeuwin Current. • Learn about the habitats the little penguins use in years of poor and good fish availability. • Determine if there are any spatial or seasonal patterns in observations of dead little penguins along the foreshores from Safety	2013–15	Determine various breeding parameters, body condition of adults and chicks, and foraging habitat of adults during incubation and guard phase of chicks. Foraging habitat determined using satellite tags (deployed on adult little penguins during incubation), and GPS tags (deployed during the chick-guard phase).	This project is largely focused on the little penguin colony at Penguin Island, but also includes some of the little penguins from Penguin Island that forage in Cockburn Sound. In addition, tags have been deployed on little penguins from Garden Island, although this is not directly supported by the funding bodies and therefore is not included in any reporting. Blogs and final report found on Fremantle Ports website: www.fremantleports.com.au/Visiting/Pages/Dolphin-news.aspx

Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
		Bay to Dunsborough. • Promote general community stewardship of the environment by: ○ raising community awareness of the little penguins in the marine environment; ○ involving the community in monitoring for injured or dead little penguins; and ○ educating the community about impacts of climate change and human-driven threats. • Contribute to conservation strategies for little penguins in collaboration with other agencies.			
Understanding the Toll of Consecutive Years of Warm Waters On Little Penguins (*Eudyptula Minor*) and Redefining their Capacity as Bioindicators of the Marine Coastal Ecosystem	Project led by Dr Belinda Cannell Funded by the City of Rockingham, Fremantle Ports and SeaDogTV	To study the foraging habitat, diet composition and population abundance of little penguins to better predict the role of oceanographic, environmental variables and anthropogenic factors on: • the presence of specific fish species in the local marine system; • the little penguins' breeding; and • survival.	2016–18	Determine various breeding parameters, body condition of adults and chicks, and foraging habitats of adults during incubation and guard phase of chicks. Determine population estimate using mark-recapture program. Diet samples are being collected but no funds are available to determine the diet composition via deoxyribonucleic acid (DNA) analysis of the faeces.	This project is largely focused on the little penguin colony at Penguin Island, but also includes some of the little penguins from Penguin Island that forage in Cockburn Sound. In addition, tags have been deployed on little penguins from Garden Island, although this is not directly supported by the funding bodies and therefore is not included in any reporting. 2017 report available on Fremantle Ports website: www.fremantleports.com.au/SiteCollectionDocuments/Little%20Penguin%20Report%20Year%201%20April%202017.pdf

Table 26. University of Western Australia (refer to individual contact details provided in the table).

Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Contact:	**Professor Gary Kendrick, Dr Siegy Krauss (Botanic Gardens and Parks Authority), Dr Elizabeth Sinclair**				
Genetic and Ecological Connectivity of the Seagrass *Posidonia australis*	ARC Linkage Project 100200429, BMT Oceanica, Cockburn Cement, Shark Bay Salt Pty Ltd	To assess the connectivity of meadows within and outside of Cockburn Sound to manage loss and plant sourcing in restoration.	Current program 2010–13 (wish to continue in limited fashion around students)	• 8 sites within Cockburn Sound plus 5 outside the Sound (see map below):  • Measurements: genetic and genotypic diversity, mating system and pollen transport, and seed transport and genetic diversity. • Standardised methodology consists of collection of plant seeds and seedlings, microsatellite analysis, *F*-statistic (F_{ST}; a measure of genetic differentiation) and other genetic analyses. • Undertaken throughout the year depending on the flowering and seed set and recruitment of seeds.	Publications: Kendrick GA, Waycott M, Carruthers T, Cambridge M, Hovey R, Krauss SL, Lavery P, Les D, Lowe RJ, Mascaró O, Ooi Lean Sim J, Orth RJ, Rivers D, Ruiz-Montoya L, Sinclair EA, Statton J, van Dijk K & Verduin J 2012, 'The central role of dispersal in the maintenance and persistence of seagrass populations', *BioScience,* vol. 62, pp. 56–65. Ruiz-Montoya L & Lowe RJ 2014, 'Summer circulation dynamics within the Perth coastal waters of southwestern Australia', *Continental Shelf Research,* vol. 77, pp. 81–95. Ruiz-Montoya RJ, Lowe RJ, Van Niel KP & Kendrick GA 2012, 'The role of hydrodynamics on seed dispersal in seagrasses', *Limnology and Oceanography,* vol. 57, pp. 1257–65. Ruiz-Montoya RJ, Lowe RJ & Kendrick GA 2015, 'Contemporary connectivity is sustained by wind- and current-driven seed dispersal among seagrass meadows', *Movement Ecology,* vol. 3, p. 9. Sinclair EA, Anthony JM, Coupland GT, Waycott M, Barrett MD, Barrett RL, Cambridge ML, Wallace MJ, Dixon KW, Krauss SL & Kendrick GA 2009, 'Characterisation of polymorphic microsatellite markers in the widespread Australian seagrass, *Posidonia australis* Hook. f. (Posidoniaceae), with cross-amplification in the sympatric *P. sinuosa', Conservation Genetics Resources*, vol. 1, pp. 273–76. Sinclair EA, Krauss SL, Anthony J, Hovey R & Kendrick GA 2014, 'The interaction of environment and genetic diversity within meadows of the seagrass *Posidonia australis* (Posidoniaceae)', *Marine Ecology Progress Series,* no. 50, pp. 87–98. Sinclair EA, Verduin J, Krauss SL, Hardinge J, Anthony J & Kendrick GA 2013, 'A genetic assessment of a successful Seagrass meadow (*Posidonia australis*) restoration trial', *Ecological Management and Restoration,* vol. 14, pp. 68–71. See list below Table 28 for other publications.
Contact:	**Matthew Fraser, Dr John Statton, Professor Gary Kendrick**				
Overcoming Critical Recruitment Bottlenecks Limiting Seedling Establishment in Degraded Seagrass Ecosystems: a Systems Approach to Restoration	ARC Linkage Project 130100155; Shark Bay Salt Pty Ltd; BMT Oceanica (on behalf of Cockburn Cement); Botanic Gardens and Parks Authority	The goal is to apply a demographic approach, adapted from terrestrial models of seed-based restoration, to seagrasses. The expected outcome is to identify those early life-stage transitions most limiting to seedling establishment for targeted management options.	2013–16	• 8 field locations with 3 sites within each location (see map below). • Measured seedling survival; fauna abundance in 5 m x 1 m transects (3 times at each site) and hydrodynamics using acoustic Doppler velocimeters (ADVs).	Annual reporting is provided to the ARC, BMT Oceanica and Shark Bay Salt Pty Ltd (all are publicly available). Research publications are pending but will be available through journal publishers.

Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
					
Drivers of Seagrass Decline in Cockburn and Warnbro Sounds	Department of Environment Regulation (research undertaken by UWA; Dr Matthew Fraser, Professor Gary Kendrick)	To identify the drivers of continued seagrass decline in Cockburn and Warnbro Sounds, with a focus on the belowground stressors on seagrass meadows, specifically sulfide intrusion from sediments and sediment contaminants (metals).	2015	• 12 sites (4 in Warnbro Sound, 4 in Cockburn Sound/Woodman Point and 4 around Garden Island). • Measurements included seagrass shoot density, biomass and productivity, total sulfur, delta ^{34}sulfur ($\delta^{34}S$) isotope ratios (an indicator of seagrass stress), carbon–nitrogen–phosphorus (CNP) content, metals concentration; water quality (photosynthetically active radiation, dissolved oxygen, pH, salinity, temperature) and sediment characteristics (organic matter, metal content). • Light loggers and conductivity-temperature-depth (CTDs) instruments deployed for one month.	Report: Fraser MW, Kendrick GA & Zavala-Perez A 2015, *Drivers of seagrass decline in Cockburn and Warnbro Sound*, available on the CSMC website. Fraser MW & Kendrick GA 2017, 'Belowground stressors and long-term seagrass declines in a historically degraded seagrass ecosystem after improved water quality', *Scientific Reports,* vol. 7, article no. 14469.
Sulfide Intrusion and Microbial Communities in Seagrass Sediments of Cockburn Sound	Fremantle Ports (research undertaken by UWA; Dr Matthew Fraser, Professor Gary Kendrick)	To investigate if the composition of the sediment microbial community is linked to the vulnerability of seagrasses to sulfide intrusion and to characterise the microbial community in surrounding sediments to determine if sulfide intrusion in seagrasses is correlated to a change in the functional traits of sediment microorganisms.	2016–17	Seagrasses in Cockburn and Warnbro Sound continue to decline in spite of good water quality and recent evidence suggests that intrusion of sulfides from sediments is a contributor to this decline. The metabolic processes carried out by sediment microorganisms largely control the concentration of sulfide in sediments, but little is known of their link to sulfide intrusion into seagrass tissues. This study investigated if the composition of the sediment microbial community is linked to the vulnerability of seagrasses to sulfide intrusion. Sediments and seagrasses were collected from six subtidal sites across Cockburn Sound and Warnbro Sound that were dominated by *Posidonia sinuosa*. Seagrass $\delta^{34}S$ signatures varied across the study area, with sites at Parmelia Bank and Warnbro Sound showing the highest signature of sulfide intrusion from sediments. Microbial communities also differed between sites, with communities at Jervoise Bay and Dredge Spoil being distinct taxonomically and functionally from the remainder of the sites. Microbial communities at Warnbro Sound, Parmelia Bank and Garden Island had a high relative abundance of Chromatiaceae and Ectothiorhodospiraceae; two families of purple sulfur bacteria that have a dominant role in sulfur oxidation	Report completed November 2017.

Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
				processes and thrive in environments low in oxygen and high in sulfides. These sites also had a high abundance of functional genes related to sulfur metabolism. The relative abundance of Chromatiaceae and Ectothiorhodospiraceae was negatively correlated with leaf $\delta^{34}S$, suggesting that these microorganisms may directly or indirectly play a role in sulfide intrusion. The study highlights the need for further research investigating the role that the rhizosphere microbiome plays in altering the health of seagrasses.	
Investigating Seagrass Dieback at Garden Island	DoD through Aurecon (research undertaken by UWA; Dr Matthew Fraser, Professor Gary Kendrick)	To develop an understanding of rapid seagrass die-off, and the role of biological oxygen demand and sulfides. This will allow for the development of a fast-response toolkit to assess and combat large-scale ecosystem shifts. Overall, this project will aid the DoD to manage seagrass meadows surrounding Garden Island.	2016–18	• Work has measured in situ oxygen concentrations in rhizomes of seagrasses growing in shallow areas off Garden Island. This fieldwork will be expanded in Nov. 2016, where experiments at additional sites will be set up to determine in situ seagrass oxygen concentrations and the role of anoxia in seagrass declines. • Research coupled with fine-scale hydrodynamic measurements (led by Professor Ryan Lowe).	Report completed Feb. 2018. Workshop and presentation, May 2018
Contact Person:	**Professor Chari Pattiaratchi**				
Ocean Forecasts for West Coast of Western Australia including high resolution data for Cockburn Sound	UWA	To provide atmospheric and ocean forecasts for the west coast of WA. A nested high-resolution model (500 m) is used for the Perth Metropolitan Region.	Ongoing	• Provided at coastaloceanography.org/ • Atmospheric variables (winds, pressure, rainfall, stability) • Ocean variables (currents, temperature, salinity in 3D)	Data available publicly through Coastal Oceanography website: coastaloceanography.org/

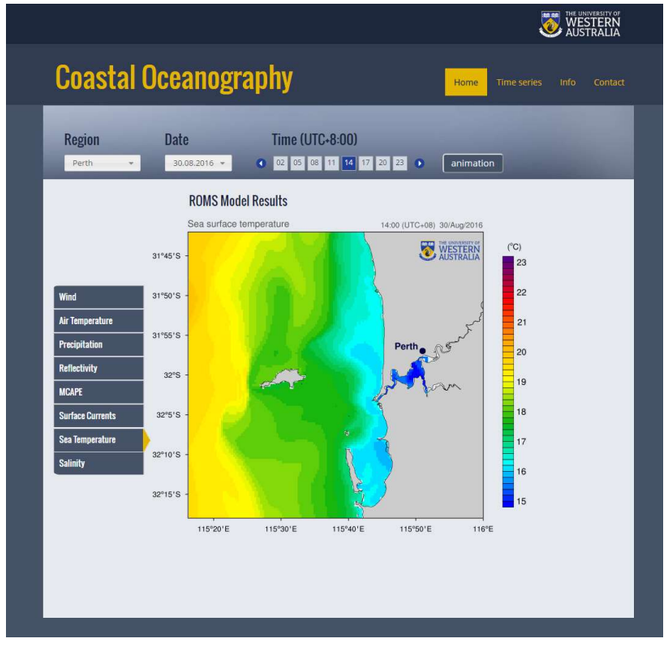


Table 27. The University of Western Australia/Department of Biodiversity, Conservation and Attractions (contacts: Professor Gary Kendrick, Dr Siegy Krauss, Dr Elizabeth Sinclair).

Research project title	Research supported by	Objective/Purpose	Timeframe/ Duration	Summary	Additional information
Ecological and genetic connectivity in seagrasses: the role of sexual reproduction, dispersal and recruitment on meadow restoration	ARC linkage grant (LP130100918) Industry partner: Botanic Gardens and Parks Authority, Western Australia	• Quantify genetic connectivity among meadows through pollen (dispersal within the water column) and seeds (floating fruit dispersal on the water surface) by the use of molecular markers and population genetic assignment procedures, over multiple years • Quantify natural recruitment rates, success and growth in established meadows and open sandy substrate • Integrate ecological and genetic data with a recently developed hydrodynamic model to infer the demographic consequences of dispersal for improved restoration practice and outcomes	Aug. 2013 – Jul. 2016	Sampled and genotyped 13 meadows within Perth metropolitan waters, 8 of which were within Cockburn Sound. Genetic analysis of meadows within Cockburn Sound showed a strong isolation by distance relationship (Sinclair *et al*. 2014a). A mating system study at two of these sites showed all seeds were produced as a result of outcrossing, thus pollen is being mixed (Sinclair *et al*. 2014b). A hydrodynamic model has been developed for the region (Ruiz-Montoya *et al*. 2012, 2015). Currently analysing genetic data for floating seed collections and seedling recruits over 2 consecutive years in conjunction with this model and other ecological data	Genetic data contributed to development of best practice restoration guidelines for *Posidonia* seagrasses (BMT Oceanica 2013 *Seagrass Transplant Guidelines*). Publications Kendrick GA, Orth RJ, Statton J, Hovey R, Ruiz-Montoya L, Lowe R, Krauss S.L. and Sinclair EA (2017). Demographic and genetic connectivity among seagrass meadows: the role and consequences of reproduction, dispersal and recruitment in seagrasses. *Biological Reviews* 92, 921–938. Sinclair EA, Gecan I, Krauss SL & Kendrick GA 2014, 'Against the odds: complete outcrossing in a monoecious clonal seagrass *Posidonia australis* (Posidoniaceae)', *Annals of Botany,* vol. 113, pp. 1185–96. Sinclair EA, Hovey R, Statton J, Fraser MW, Cambridge ML, Kendrick GA 2016, Comment on 'Seagrass viviparous propagules as a potential long distance dispersal mechanism' by ACG Thomson *et al.* 2014, *Estuaries and Coasts* DOI 10.1007/s12237-014-9850-1. *Estuaries and Coasts* 39, 290–293. Sinclair EA, Statton J, Hovey R, Anthony JM, Dixon KW, Kendrick GA 2016, 'Reproduction at the extremes: pseudovivipary and genetic mosaicism in *Posidonia australis* (Posidoniaceae) *Posidonia australis* Hooker (Posidoniaceae)', *Annals of Botany,* vol. 117, pp. 237–47. See list below for other publications.

Publications

Ruiz-Montoya L., Lowe R.J. and Kendrick G.A. (2015). Contemporary connectivity is sustained by wind and current-driven seed dispersal among seagrass meadows. *Movement Ecology* 3: 9.

Ruiz-Montoya L., Lowe R.J., Van Niel K.P. and Kendrick G.A. (2012). The role of hydrodynamics on seed dispersal in seagrasses. *Limnology and Oceanography* 57, 1257–1265.

Sinclair E.A., Krauss S.L., Anthony J., Hovey R. and Kendrick G.A. (2014a). The interaction of environment and genetic diversity within meadows of the seagrass *Posidonia australis* (Posidoniaceae). *Marine Ecology Progress Series* 50, 87–98.

Sinclair E.A., Gecan I., Krauss S.L. and Kendrick G.A. (2014b). Against the odds: complete outcrossing in a monoecious clonal seagrass *Posidonia australis* (Posidoniaceae). *Annals of Botany* 113, 1185–1196.

Sinclair E.A., Verduin J., Krauss S.L., Hardinge J., Anthony J. and Kendrick G.A. (2013). A genetic assessment of a successful Seagrass meadow (*Posidonia australis*) restoration trial. *Ecological Management and Restoration* 14, 68–71.

Other articles

Sinclair EA 2009, 'Restoration genetics of seagrass meadows', *For People and Plants,* summer, pp. 20–21.

Sinclair EA 2012, 'Dispersal on the high seas – the ecological genetics of seagrass seed dispersal', *For People and Plants,* autumn, pp. 20–22.

Sinclair EA 2014, 'Sexual promiscuity in the shallows', *For People and Plants, s*ummer, pp. 27–30.

Sinclair EA and Kendrick GA 2017, 'New beginnings – the bottleneck in the cycle of seagrass life', *For People and Plants,* autumn, pp. 24–26.

Verduin JJ and Sinclair EA 2013, 'Seagrass meadow restoration trial using transplants – Cockburn Sound, Western Australia', site.emrprojectsummaries.org/2013/03/08/seagrass-meadow-restoration-trial-using-transplants-cockburn-sound-western-australia/

Table 28. Water Corporation (contact person: Grant Griffith).

Research project title	Research undertaken by and team leader(s)	Objective/purpose	Timeframe/ Duration	Summary	Additional information
Assessing and mitigating environmental impacts of seawater reverse osmosis (SWRO) outfalls on key benthic marine organisms	Funding: The National Centre of Excellence in Desalination Australia (NCEDA) Research: UWA and Deakin University (Principal Investigator – Dr Julie Mondon of Deakin University)	This study addresses the impact of hypersaline discharge from SWRO plants on recipient marine ecosystems. The study will identify critical thresholds for key marine species to the physical and chemical characteristics of desalination waste brine discharge, identify biomarkers of exposure and effect, and develop bio-monitoring tools for currently operating and planned desalination plants to measure and mitigate environmental impacts. The principal objective is to develop a detailed understanding of tolerances of marine species to brine discharge in the vicinity of SWRO outfalls to mitigate environmental impacts and contribute to bio-monitoring tools.	Started in 2012	The Water Corporation has provided significant in-kind support to this research project. Operational data provided includes intake seawater quality and outfall water quality datasets. Seawater and brine discharge samples have been collected and provided to researchers. Footage and stills from the annual inspection of marine infrastructure at the Perth Seawater Desalination Plant have also been provided to the researchers (see below).	Reports are available on request from the Water Corporation.
2013 benthic survey	Consultancy – Oceanica	The Water Corporation's environmental management commitments for the desalination plant (Ministerial Statement no. 655, Minister for the Environment 2004) include the development and implementation of a Water Quality Management Plan. This plan includes a requirement to undertake monitoring of the sediment habitat pre- and post-commissioning of the desalination plant. The objective of the 2006 baseline survey was to determine the spatial extent and patterns of benthic infauna and epibenthic fauna communities in Cockburn Sound. The objective of the 2008 and 2013 repeat surveys was to determine whether operation of the desalination plant had adversely impacted benthic macrofauna communities.	Benthic surveys to date include one precommissioning baseline survey (Mar. 2006) and 2 post-commissioning repeat surveys (Mar. 2008, Mar. 2013)	Broad spatial sampling at 77 sites in the deep basins (>17 m) of Cockburn Sound. The repeat surveys included a re-sampling of a subset of 41 of the baseline sites, plus an additional 5 sites in the central-west basin (46 total sites). In combination, the baseline, 2008 and 2013 surveys highlight the natural spatial and temporal variation in benthic macrofauna communities in Cockburn Sound. As there was no evidence of impact from operation of the desalination plant, these surveys effectively constitute 3 years of reference data for benthic macrofauna communities in Cockburn Sound.	Reports are available on request from the Water Corporation.
Annual inspection and clean of the Perth Seawater Desalination Plant's intake and outfall infrastructure	Contractor – Fremantle Commercial Diving	To assess the integrity of the intake and outfall infrastructure and undertake cleaning of the intake tower and 40 port diffusers to remove marine growth that may impact performance.	Annually	Marine divers undertake an annual visual assessment of the Perth Seawater Desalination Plant's marine infrastructure. If required, the top 10–15 cm of each diffuser is cleared of marine growth to ensure performance remains optimal.	A report and footage of the inspection is available on request from the Water Corporation.

Table 29. Western Australian Museum (contact person: Diana Jones).

Research project title	Research supported by	Objective/purpose	Timeframe/ Duration	Summary	Additional information
In situ Preservation Studies of *James Matthews* (1841) Shipwreck	Western Australian Museum	Test multiple techniques for long-term stabilisation and preservation in situ of the remains of the *James Matthews* shipwreck on the northern side of Woodman Point	Ongoing since early 2000	• Numerous visits since the start of the project • Conservation condition measurement undertaken • Protection measure installed and monitored	Work conducted mainly under the guidance of the Material Conservation Department of the Western Australian Museum, producing numerous scientific publications.
Remote Sensing and Metal Detection Survey for *Rockingham* (1830) Cannon, Henderson Beach	Western Australian Museum	Attempt to locate 2 cannon from the ship *Rockingham*, jettisoned in 1830 during a grounding event and believed to have been unsalvaged at the time. Material from *Rockingham* survivor camp reported to have been located on adjacent coastline	Oct. 2013 and Nov. 2015	• 2 visits to the site • Remote sensing and metal detector survey conducted • One magnetic anomaly ground-truthed and found to be not historic (old mooring)	Further work to be conducted.
Inspection and Condition Survey of the *Redemptora* (1898) Shipwreck	Western Australian Museum	Provide condition information of the *Redemptora* shipwreck site in preparation for a coastal development around the AME shipbuilding site	Mar. 2014 and Jun. 2016	• One inspection survey conducted • One condition survey conducted • Recommendations provided in condition report	Report: Anderson R, Bigourdan N and Souter C 2014, *Wreck Inspection Report* Redemptora *(1853–1898)*, report of the Department of Maritime Archaeology, Western Australian Museum no. 308.
3D Recording of the *Omeo* shipwreck	Maritime Archaeology Association of Western Australia and the Western Australian Museum	Undertake a 3D photogrammetry survey of a large section of the historic *Omeo* shipwreck for research and outreach	Aug. 2014 to Apr. 2015	• 12 visits to the site • More than 100,000 images collected and processed • 3D model produced	Edwards K, Bigourdan N, McCann I & Cooper D 2017, '3DMAPPR: community-based underwater archaeological photogrammetry program in Perth, Western Australia,' *Journal of the Australasian Institute for Maritime Archaeology,* vol. 40, pp. 1–16.
Coogee Maritime Trail, around the Shipwreck of the *Omeo*	City of Cockburn, Western Australian Museum, Murdoch University divers and Perth Region NRM	Develop a recreational land and underwater maritime trail around the *Omeo*, WA's premier beachside shipwreck spot, including artificial marine habitat	Ongoing since Jan. 2015	• Coogee Maritime Trail launched Feb. 2017 • No Fishing Zone declared Oct. 2017 • Baseline flora and fauna survey conducted by UWA	www.cockburn.wa.gov.au/Recreation-and-Attractions/Attractions-Art-and-Culture/Trails-and-Lookouts/Coogee-Maritime-Trail
3D Recording of the Robb Jetty	Maritime Archaeology Association of Western Australia and the Western Australian Museum	Undertake a 3D photogrammetry survey of a large section of the historic Robb Jetty for research and outreach	Mar. 2015	• 2 visits to the site • More than 10,000 images collected and processed • 3D model produced	Edwards K, Bigourdan N, McCann I & Cooper D 2017, '3DMAPPR: community-based underwater archaeological photogrammetry program in Perth, Western Australia', *Journal of the Australasian Institute for Maritime Archaeology,* vol. 40, pp. 1–16.
Seabirds of the South-West Region	Western Australian Museum	Overview of distribution, status, relative abundance, breeding, migration and movements of seabirds in the South-West Marine Region, of which Cockburn Sound is a part.	Ongoing since 1988	Historical data extracted and numerous visits to region since 1960s. Publications: Storr GM and Johnstone RE 1988, 'Birds of the Swan Coastal Plain and adjacent seas and islands', *Records of the Western Australian Museum*, supplement no. 28. Johnstone RE and Storr GM 1998, *Handbook of Western Australian birds, vol. 1 non-passerines*, Western Australian Museum.	Currently working on a monograph dealing with the seabirds of the South-West Marine Region