Marine Biodiversity Hub

National Environmental Science Programme

National Outfall Database - Prospectus Report 2019

John Gemmill, Qurratu A'yunin Rohmana, Andrew M. Fischer, Boyd Blackwell and John Cumming

Project C4 - National Outfall Database

3 September 2019

Milestone 14 – Research Plan v3 (2017)

National Outfall Database

clean ocean foundation

UNIVERSITY of TASMANIA

Enquiries should be addressed to:

John Gemmill
CEO Clean Ocean Foundation
0409 425 133
johng@cleanocean.org
www.cleanocean.org

Preferred Citation

Gemmill, J., Rohmana, Q. A., Fischer, A., Blackwell, B. & Cumming, J. 2019. National Outfall Database: Prospectus Report 2019. Report to the National Environmental Science Program, Marine Biodiversity Hub. *Clean Ocean Foundation.*

Copyright

Acknowledgement

This work was undertaken for the Marine Biodiversity Hub, a collaborative partnership supported through funding from the Australian Government's National Environmental Science Program (NESP). NESP Marine Biodiversity Hub partners include the University of Tasmania; CSIRO, Geoscience Australia, Australian Institute of Marine Science, Museums Victoria, Charles Darwin University, the University of Western Australia, Integrated Marine Observing System, NSW Office of Environment and Heritage, NSW Department of Primary Industries.

Important Disclaimer

Project Leader's Distribution List

Clean Ocean Foundation	John Gemmill
University of Tasmania	Andrew Fischer
Federal	
Minister for Environment	Sussan Ley
Minister for Water	David Littleproud
Minister for Cities and Urban Infrastructure	Alan Tudge
Minister for Health	Greg Hunt
Department of the Environment and Energy	
Chemicals Management Branch, Environmental Protection Division	
Waste Management Branch, Environmental Protection Division	
Victoria	
Minister for Environment	Lily D'Ambrosio
Minister for Water	Lisa Neville
Barwon Water	Geoff Jones
	Luke Christie
City West Water	Kevin He
Gippsland Water	Boon Huang Goo (Fan)
Melbourne Water	Erik Ligtermoet
South East Water	Jon Theobald
	Michael Caelers
South Gippsland Water	Bree Wiggins
Wannon Water	Luke Dunlop
Westernport Water	Nick Stephens
New South Wales	
Minister for Environment	Matt Kean
Minister for Water	Melinda Pavey
Bega Valley Shire Council	Ken McLeod
Ballina Shire	Andrew Swan
	Garry Merrith
Clarence Valley	Frank Vaarwerk
Coffs Harbour	Angus Sharpe
Kempsey	Wes Trotter
Port Macquarie-Hastings Shire	Clayton Miechel
Midcoast City Council	Graeme Watkins
Hunter Water	Lachlan King
Sydney Water	Bala Selvananthan
Shoalhaven City Council	Ivan Wady
Eurobodalla Shire Council	Brett Corvern
	Brent Parker

Central Coast Council	Mark Coleman
	Stephen Shinners
Queensland	
Minister for Environment	Leeanne Enoch
Minister for Water	Anthony Lynham
Department of Environment and Science	Dr Celine Clech-Goods
Northern Territory	
Minister for Environment and Natural Resources	Eva Dina Lawler
Power and Water Corporation	Annie Andrews
Western Australia	
Minister for Environment	Stephen Dawson
Minister for Water	Dave Kelly
Water Corporation	Lisa Mills
South Australia	
Minister for Environment & Water	David Speirs
SA Water	Julia De Cicco
Tasmania	
Minister for Environment	Elise Archer
Minister for Water	Guy Barnett
EPA Tasmania	Glen Naphtali

Contents

List of Figures

List of Tables

1. INTRODUCTION

Wastewater disposal into the marine environment is one of the main factors leading to the deterioration of coastal water quality. Poorly managed disposal can lead to increased concentrations of nutrients, organic and inorganic pollutants, as well as alter levels of turbidity, pH and bacteria (Carey and Migliaccio, 2009; Beck and Birch, 2012; Cheung et al., 2015). An increase in the level of pollutants can have an impact on coastal ecology and biodiversity and affect the health of recreational users (Schwarzenbach et al., 2010; Burd et al., 2012; Eugenia et al., 2016; Boehm et al., 2017).

The Australia State of Environment Report (2016) identified a significant deterioration in a number of components of the coastal environment (Clark and Johnston, 2017). A key finding of the Coasts chapter highlights that the current degradation of the coastal environment is “tightly correlated” with human population, and agriculture or industrial development. These stressors may impact coastal systems in complex and synergistic ways across a variety of temporal and spatial scales. In addition, other key findings state that, “data are insufficient to assess many aspects of the state of the environment of the coast.” The “Coastal Waters” section of the chapter highlighted the two pathways for nutrients to enter the coastal waters. These were sewage outfalls and the diffuse sources, such as runoff. These inputs can lead to degraded states in the coastal environment such as eutrophication, harmful algal blooms, low-oxygen dead zones, the disruption of biogeochemical cycling and disturbance of the ecological balance of marine ecosystems (e.g. crown-of-thorns) (Clark and Johnston, 2017).

Providing a comprehensive understanding of nutrient and pollutant loads into the marine environment around Australia is difficult given the different sampling and reporting requirements. The lack of consistency across reporting methods exemplifies the lack of transparency or openness in governance, which can have negative consequences on Australia’s coastal environment. Australia is obligated to manage resources of National Interest and as a signatory to the Convention on Biological Diversity, is required to safeguard its biological diversity, as well as manage the impacts of nutrients on ecosystem function and structure (Aichi Biodiversity Targets (8)) (NRMMC, 2010). An improvement in reporting requirements that aligns with national and regional interests, MNES, transboundary pollution and environmental concerns is warranted.

In order to reduce water quality degradation, there is a need to increase communication between the relevant stakeholders and the general community. The effectiveness of science communication will enable the general public to make a sound choice regarding the environmental issues as well as helping the decision makers to improve the marine environment management (Mea et al., 2016). Public notifications, particularly in relation to water quality events, play an active role in managing health risks for both humans and the environment. However, public notification or mis-notification can be fraught with errors (Thoe et al., 2014). For instance, clean beaches can be closed inadvertently because managers may feel unsure of the spatial extent of water contamination. On the other hand, contaminated beaches may remain open, due to the time mismatch between sampling and notification (Pendleton, 2008). Around the world, programs have been developed to notify the public about water quality issues, for instance, the Beachwatch monitoring program in NSW, which was started in 1989 in response to community concern about sewage pollution washing up on Sydney's beaches (Beder, 1991; OEH, 2019). However, communication practices among the programs are variable and lack formal evaluation of their effectiveness (Pratap et al., 2011).

The National Outfall Database (NOD), developed by the Clean Ocean Foundation (COF) in collaboration with States and Territories Governments, provides policy makers with a guide to help prioritise outfall reform and identify public and private sector opportunities for wastewater recycling (Marine Biodiversity Hub, 2015). In collaboration with the National Environmental Science Programme – Marine Biodiversity Hub, the NOD also provides Australian water authorities and the public an accessible database to help identify pollutant loads and assess any potential health and environmental impact risks of sewerage outfalls on the marine environment and surrounding communities. The NOD provides an unprecedented national collection of water quality data, collected by water authorities and Local Governments according to guidelines set out in Environmental Protection Authority (EPA) licenses. Given the NOD's centralized collection of national scale water quality data, the opportunity to examine the comprehensive impacts of sewerage outfalls at regional scales becomes possible. The aim of the NOD was to facilitate cross-institutional data sharing among federal, state, local governments and the community to promote transparency and openness of governance for managing pollutants from WWTPs. The NOD also provides data and information that could be helpful for integrating infrastructure planning and decision making of sewage effluent impacts on marine environment.

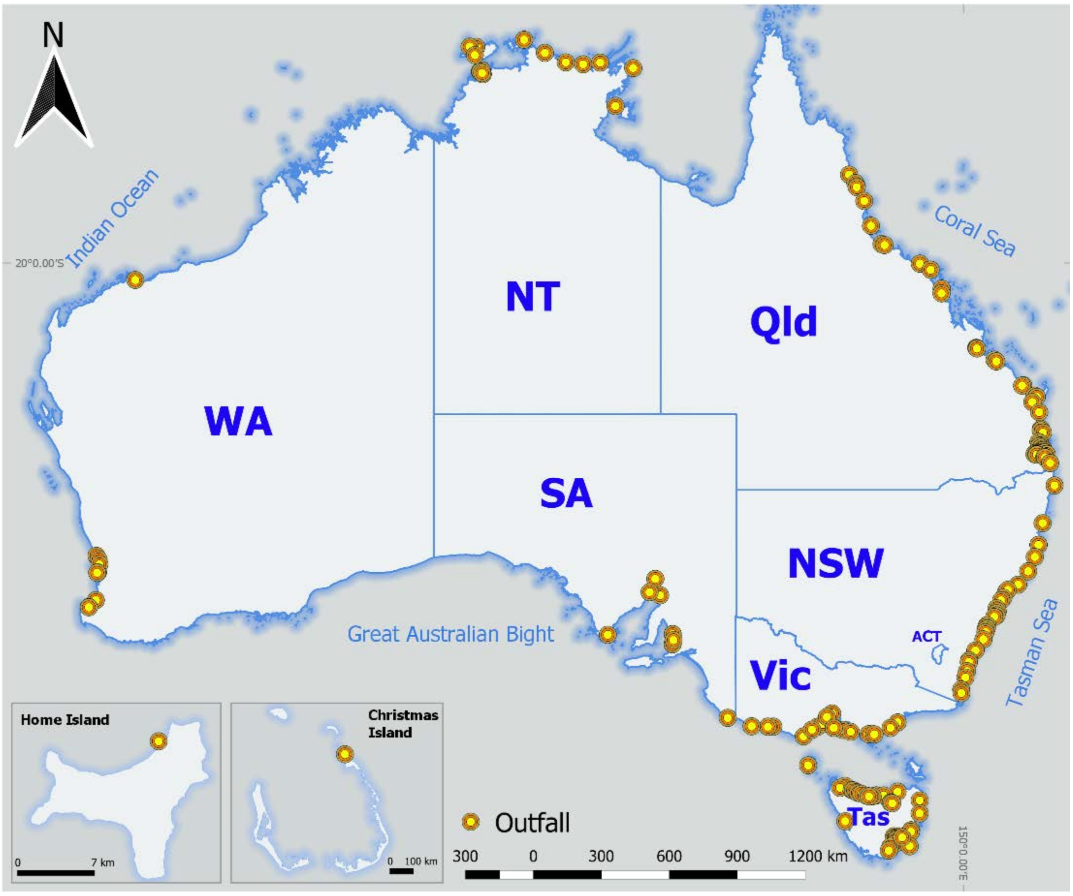
2. MAJOR FINDINGS

During these last few years, COF has produced many significant results for the NOD project. Some of them are comprehensively identifying the number of outfalls along the Australian coast, ranking the outfalls based on nitrogen and phosphorus load indices, and grouping the outfalls according to their similarities and differences. Early 2019, COF also conducted a community survey to assess the effectiveness of communication efforts between the Water Authorities and general public in regard to water quality degradation events. This survey supports the notion of public transparency in water quality data to assess possible risks on ecosystem and human health. In order to support water recycling in Australia, we published the Coastal Outfall System Upgrades in Australia: Benefits, Costs, and Improved Transparency report for identifying the cost and benefit of Australian coastal outfall upgrades (Blackwell and Gemmill, 2019). These major findings are explained further in the subsections below.

2.1 Outfalls map

The NOD has successfully recorded and mapped 181 outfalls in six states and the Northern Territory. The Australian Capital Territory (ACT) was not considered in the database because it does not have any ocean, coastal or estuarine outfalls and has a high rate of water recycling. Currently in the ACT, about 4,360 ML/yr of treated effluent is recycled for use as irrigation water and almost all of the water used in the sewerage system is returned to the Murrumbidgee River after a high level of treatment and is available for various downstream uses (Icon Water, 2018). The distance of the sewage discharge point to the point where the Murray Darling system enters Lake Alexandria is sufficiently long enough for effluent parameters to change from their initial state and be influenced by other biogeochemical factors along the way and eventually representing background environmental conditions.

Figure 1. Outfalls recorded, including Home Island and Christmas Island.



2.2 Outfalls ranking

The pollutant contribution index, based on nitrogen and phosphorous loads, was calculated for each outfall (Figure 1). Outfalls were ordered from lowest to highest based on the pollutant contribution index to rank them according to their relative pollutant contribution to the coastal and marine environment. The index is based on a total nutrient load discharge (see below) using the variables of flow, and nitrogen and phosphorous concentrations. Nitrogen and phosphorous (nutrient) load was calculated based on the Load Calculation Protocol (DECC NSW, 2009) using

$$N_l = \sum_{n,p} \frac{Tf * N_a}{1000}. (1)$$

where, N_l is the total nutrient load in tonnes, calculated for nitrogen and phosphorous individually, Tf is the total annual flow from each outfall in megalitres (ML) and N_a is the annual average nutrient concentration in mg/L. Nitrogen and phosphorous loads were summed to provide the total nutrient load. Values were sorted and ranked for 140 outfall locations and grouped into quartiles. Those sites with incomplete data for 2017-2018 were not considered in the final ranking.

Top and bottom quartiles of the outfall rankings are presented in Table 1. Total nutrient load from individual outfalls sites ranged from 90.4 to 14,324,559.1 kg with a mean of 420,398.19 kg. Tasmania and South Australia each had 15 out of 36 and 1 out of 10 outfall sites in the top quartile (lowest nutrient load). New South Wales, Victoria and Queensland each had 5 out of 21, 5 out of 17, and 5 out of 41 respectively, and Western Australia had 4 out of 11 outfall sites. The bottom quartile (highest nutrient load) was represented by eight outfalls from New South Wales, six each from Tasmania and Queensland, and five, four, three and three from Victoria, Western Australia, the Northern Territory and South Australia, respectively. The mean nutrient loads from the top and bottom quartiles were 2618 kg and 1,615,801 kg

Table 1. Top (green) and bottom (red) quartiles of outfall ranking

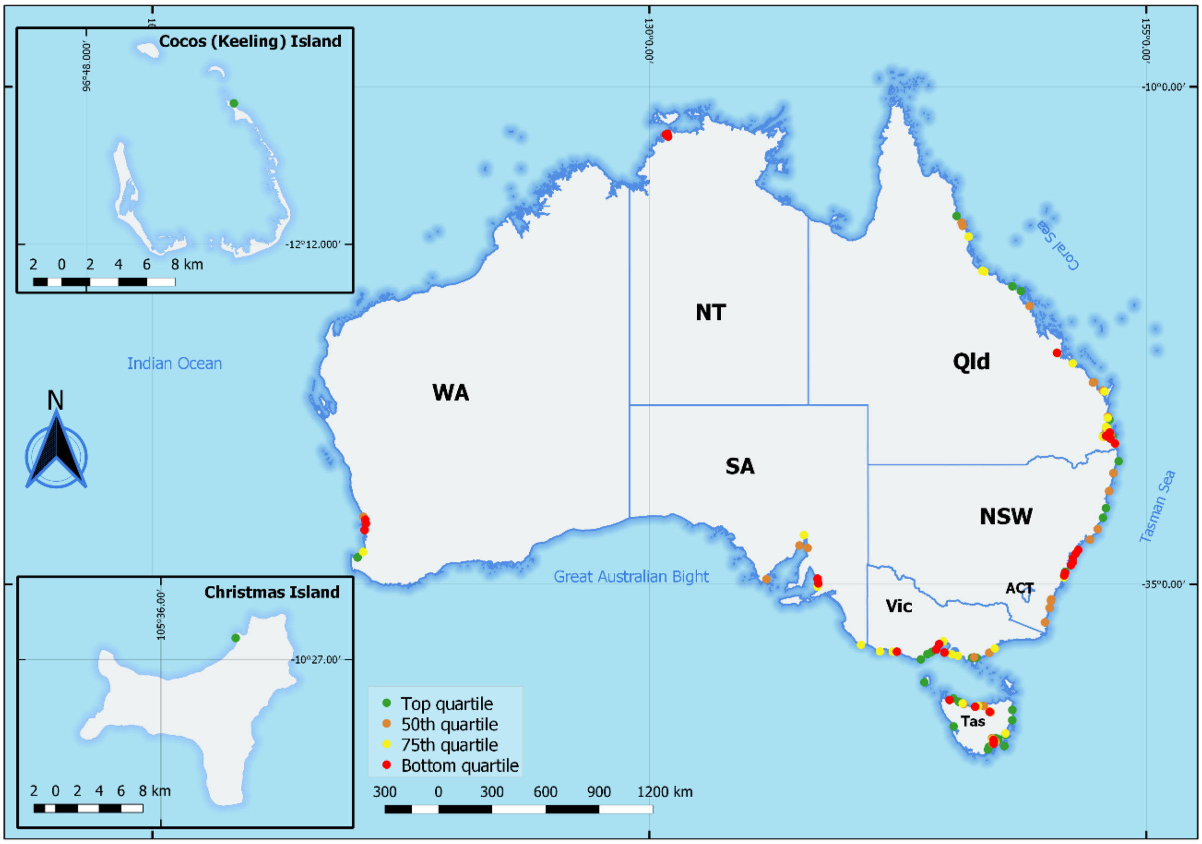
Outfall	Nutrients Load (kg)	State	Rank
Iluka	90	New South Wales	1
Christies Beach-Southern	287	South Australia	2
Home Island	359	Western Australia	3
Port Welshpool	414	Victoria	4
Sisters Beach	476	Tasmania	5
Boat Harbour	490	Tasmania	6
Busselton (North)	567	Western Australia	7
Bicheno	646	Tasmania	8
St Helens	729	Tasmania	9
Busselton (South)	1339	Western Australia	10
Dover	1349	Tasmania	11
Crescent Head	1357	New South Wales	12
Christmas Island	1691	Western Australia	13
Bermagui	1900	New South Wales	14
Cambridge/airport	2041	Tasmania	15
Orford	2051	Tasmania	16
Anglesea	2234	Victoria	17
Port Arthur	2287	Tasmania	18
Apollo Bay	2379	Victoria	19

Outfall	Nutrients Load (kg)	State	Rank
Stanley	2393	Tasmania	20
Karana Downs	2748	Queensland	21
Lorne WRP	2872	Victoria	22
Camden Haven	2901	New South Wales	23
Risdon (east)	3449	Tasmania	24
Electrona	3858	Tasmania	25
Cygnet	4139	Tasmania	26
Port Douglas	4258	Queensland	27
Currie	4805	Tasmania	28
East Strahan	4830	Tasmania	29
Cannonvale	4881	Queensland	30
Bridgewater	5008	Tasmania	31
Landsborough	5376	Queensland	32
Victoria Point	5598	Queensland	33
Foster	5624	Victoria	34
Merimbula	6219	New South Wales	35
North Rockhampton	104646	Queensland	106
Gibson Island	108970	Queensland	107
Loganholme	113088	Queensland	108
Smithton	122576	Tasmania	109
Coombabah	132233	Queensland	110
Blackmans Bay	137078	Tasmania	111
Boags Rock (Boneo)	151645	Victoria	112
Ti-tree Bend	178405	Tasmania	113
Prince of Wales Bay	180990	Tasmania	114
Oxley	193897	Queensland	115
Macquarie Point	238933	Tasmania	116

Outfall	Nutrients Load (kg)	State	Rank
Shellharbour	240151	New South Wales	117
Palmerston	242436	Northern Territory	118
Black Rock	245826	Victoria	119
Leanyer Sanderson	252787	Northern Territory	120
Winney Bay (Kincumber)	261452	New South Wales	121
Ludmilla	267783	Northern Territory	122
Pardoe	305653	Tasmania	123
Warrnambool WRP	307302	Victoria	124
Glenelg	383036	South Australia	125
Warriewood	429849	New South Wales	126
Subiaco	573772	Western Australia	127
Bolivar High Salinity	604478	South Australia	128
Bolivar WWTP	685004	South Australia	129
Point Peron	692652	Western Australia	130
Potter Point (Cronulla)	911183	New South Wales	131
Luggage Point	925360	Queensland	132
Coniston Beach (Wollongong)	1186472	New South Wales	133
Beenyup	1514724	Western Australia	134
Woodman Point	2345688	Western Australia	135
Boags Rock (ETP)	3669779	Victoria	136
Bondi	4527083	New South Wales	137
Port Phillip Bay (WTP)	7988464	Victoria	138
North Head	12005094	New South Wales	139
Malabar	14324559	New South Wales	140

The map in Figure 2 shows the distribution of ranked outfalls throughout Australia with outfalls grouped by quartiles. The top quartile (lowest nutrient load) of outfalls seem to be more prevalent in regional areas and discharge less nitrogen and phosphorus loads into the coastal and marine environment. Discharges in the top quartile ranged between 90 to 6,219 kg (Table 1). The bottom quartile, on the other hand, with higher nutrient loads appear to occur around the major cities. The total load discharged by this quartile ranged between 104,646 to 14,324,559 kg. Each quartile consisted of 35 outfalls. The rankings for all the outfalls appear in Appendix A.

Figure 2. Australian coastal and river/estuary outfalls ranked by quartiles.



2.3 Outfalls clustering

In order to highlight the similarities and differences that may influence effluent quality between Australian states and the Northern Territory a principal component analysis (PCA) and cluster analysis was applied. The PCA output shows patterns of water quality parameters (Figure 4). The first principal component, explaining 62% of the variance on the horizontal axis, has positive coefficients (right) for six parameters and slightly negative (left) for pH. Total suspended solids, oil and grease, enterococci and faecal coliform have a strong influence towards PC 1. The second principal component explaining 17% of the variance on the vertical axis, has positive coefficient vectors (top) for seven parameters, especially PH, and negative for oil and grease, enterococci and faecal coliform (bottom).

Prior conducting the cluster analysis, the gap statistics was used to determine the optimal values for *k-means* clusters (Tibshirani et al., 2001). Figure 3 showed that a cluster of five is the suitable grouping for water quality analysis in this report. Furthermore, the clusters also separated the extreme polluters within the data set. Figure 4 shows the distribution of the five clusters. On the lower right, cluster 2 and part of 3 cluster around oil and grease, enterococci and faecal coliforms PCA scores. The top right is filled by a majority of cluster 1, 4 and some from cluster 3. These sites cluster near the PCA scores of high turbidity, total nitrogen and total suspended solids. Next, on the top left, pH is the only parameter which was contributed by some outfall sites in cluster 1 and 5.

Figure 3. Gap statistics for determining optimal value of clusters.

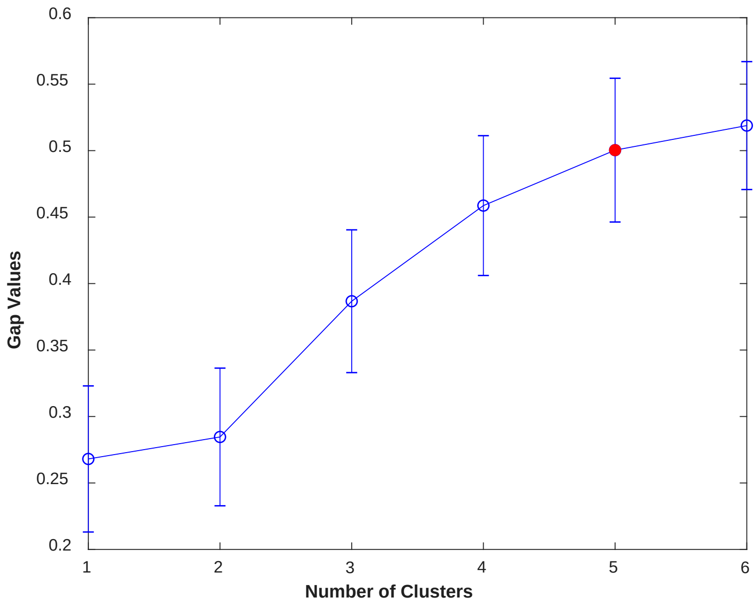
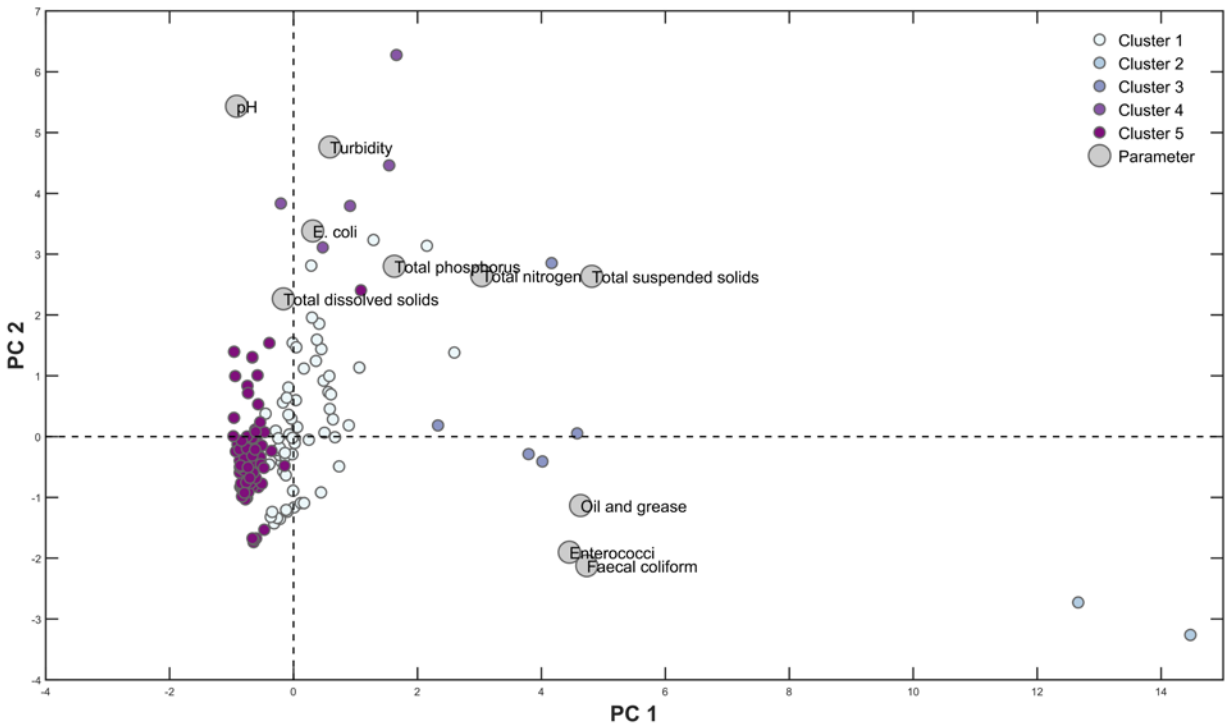


Figure 4. PCA clusters of six states and a territory with the variance explained of 62% (PC 1) and 17% (PC 2).



The cluster analysis results also suggested that each outfall site did not group according to its state or territory, instead they tended to spread over five clusters (Figure 4 and Table 2). Tasmania was the most diverse state in which outfall sites were distributed across four out of five clusters. The second most diverse was New South Wales and Western Australia outfall sites across three clusters. Northern Territory outfall sites were grouped into two clusters only. Cluster 1 is the only group that consists all state/territory (Table 2).

Table 2. Australian state and territory distribution over five clusters along with the number of outfalls sites in each group.

Cluster	State/Territory (N)
1	New South Wales (8), Northern Territory (1), Queensland (8), South Australia (3), Tasmania (29), Victoria (9) and Western Australia (3)
2	Tasmania (2)
3	New South Wales (3), Tasmania (1) and Western Australia (1)
4	Northern Territory (3) and South Australia (2)
5	New South Wales (16), Queensland (41), South Australia (5), Tasmania (9), Victoria (10) and Western Australia (8)

Cluster 2 consists two Tasmanian outfalls (Pardoe and Ulverstone), which discharge higher faecal coliform and enterococci values. Cluster 3 contains Sydney's largest ocean outfalls (Bondi, Malabar and North Head), Electrona (Tasmania) and Point Peron (Western Australia), that mostly produce higher concentration of oil and grease, total nitrogen and total phosphorus. Cluster 4 represented outfalls (Berrimah, Leanyer Sanderson, Palmerston, Port Pirie and Bolivar WTP) with higher reading of E. coli, turbidity and pH.

The cluster analysis indicates how the variation in water quality from outfalls depends on several factors in addition to their state/NT jurisdiction. Further analysis of the environmental and human causes of the clustering is needed before it would be practical to suggest uniform water quality criteria and standards, or standards tailored to the receiving environment. Water quality criteria and standards guiding prioritisation of facility upgrades need to reflect the level of treatment and not local environmental conditions. Absolute water quality remains the more appropriate measure for human and potentially ecosystem health considerations. The ultimate objective of the imposition standards, which may necessitate extensive treatment prior to use, is the protection of the end users of the marine environment, be these by humans, animals, agriculture and industry. In the present context, however, the main considerations are in regard to safeguarding public health and the protection of the whole aquatic environment (Campos et al., 2015; Jagai et al., 2015; Stark et al., 2016). A comprehensive understanding of the constituents and level of pollutants in coastal WTP effluent within a public database provides an opportunity to apply the best possible knowledge to inform decisions in these complex transboundary ecosystems. The NOD helps improve the management of coastal biodiversity and obligations of agencies to inform citizens of recreational health risks.

2.4 Community perceptions

As part of the data collection process, the NOD prepared a document outlining a predefined format in which the data was to be delivered (Rohmana et al., 2019). The initial data request for the WTAs consisted of a variety of parameters, including flow volumes (ML), pH, and total dissolved solids, etc. (Table 2). The basic criteria for the NOD for suitable water quality was a requirement to have at least flow volume (ML), total phosphorus (mg/L), and total nitrogen (mg/L). These basic criteria were further used for calculating the nutrient loads and its impact towards the marine environment (Rohmana et al., 2019).

As stated earlier, the collection process was not always straight forward. In practice, a key problem for water authorities is the cost involved in collecting and collating data. There is an inevitable tension between minimising costs and their ability and willingness to provide comprehensive data in a timely manner. We found that centralised water authorities, such as Queensland, Tasmania, South Australian, and Western Australia, tended to produce a more standardised set of parameters and reporting times while WTAs in New South Wales (outside the centralised Sydney Water catchment area in the treatment plants run by councils), Victoria and Northern Territory provided data in less consistent formats. Even with this minimal set, some WTAs had difficulty supplying the information requested. There were various reasons cited by the WTAs in order to avoid data submission to the NOD. Often the WTAs did not collect certain parameters as they were not required in the license. In some cases, the WTAs were not prepared to publish the data for the public. Limited resources might also be a barrier to providing data. Overall, each WTA tended to provide its own customised dataset reporting with varying combinations of variables presented in Table 2. This variation was frequently due to reporting requirements as set out in their licenses.

Table 3. Initial request of water quality data parameter for 2015 data.

Parameter	Unit
Flow volume	**ML**
pH	pH
Total Dissolved Solids	mg/L
Total Suspended Solids	mg/L
Total Phosphorus	**mg/L**
Total Nitrogen	**mg/L**
Oil and grease	mg/L
Surfactants (MBAS)	mg/L
E. coli	org/100mL
Enterococci	org/100mL
Faecal coliforms	org/100mL
Turbidity	NTU
Colour	Pt. Co. Units
Algal blooms	Frequency
Blue Green algal bloom	Frequency

Water quality parameters collected by all WWTPs appear in bold.

NOD data collection has been running since 2015. After the fourth year of data collection (2018) most WTAs (98%) have met the basic (bolded) criteria for supplying the data (Table 3). Across these four years, Queensland, South Australia, Tasmania, and Western Australia were able to maintain consistency in providing water quality data. Despite having various WTAs, Victoria has been successfully maintaining the data submission to the NOD. New South Wales has shown significant improvement with more time enabling trust and effective communication to yield benefits across a number of stakeholders. The Northern Territory appears under resourced to supply the requested information.

Table 4. Data collection progress from 2015 to 2018

States/Territory	Number of outfalls	2015	2016	2017	2018
New South Wales	29	32%	83%	97%	98%
Northern Territory	14	30%	30%	30%	30%
Queensland	51	100%	100%	100%	100%
South Australia	10	100%	100%	100%	100%
Tasmania	41	100%	100%	100%	100%
Victoria	19	100%	100%	100%	100%
Western Australia	12	100%	100%	100%	100%

2.5 Upgrades net benefits

Blackwell and Gemmill (2019) prepared an analysis of the likely costs and benefits of upgrading Australia's coastal wastewater outfalls. They found that across the nation the net benefits from upgrades sum to between $12 to 28 billion. Net benefits are benefiting less costs. Costs include upfront capital and ongoing operational costs.

State and territory total rankings of net benefits from upgrades are summarized in Table 4 for a 30-year project period and in Table 5 for a 15-year project period. The total state rankings do not change depending on the period or discount rate (3, 6 & 9%) used but are provided to give best practice interval rather than point estimates. In contrast, the magnitude of net benefits changes considerably, with net benefits being larger for a longer project period because the capital costs are born early while benefits flow throughout time

Table 5. Net benefits (NBs) and Costs of outfalls, ranked by state totals, 2019 $m, t=30 years

State/territory	n	NB r=9%	Costs	NB r=6%	Costs	NB r=3%	Costs
New South Wales	28	11,667.3	5,246.6	14,380.0	5,887.7	18,769.8	6,959.4
Western Australia	12	3,380.3	620.2	4,118.5	675.3	5,318.3	767.3
South Australia	10	2,142.3	280.5	2,597.5	305.8	3,337.6	348.0
Queensland	51	294.7	842.4	460.0	902.7	726.5	1,003.3
Victoria	19	33.2	291.0	76.8	311.7	146.8	346.3
Northern Territory	6	-52.5	94.0	-50.0	99.7	-46.1	109.2
Tasmania	41	-413.7	499.8	-429.7	533.0	-457.4	588.5
Grand Total	**167**	**17,051.6**	**7,874.6**	**21,153.1**	**8,715.9**	**27,795.6**	**10,122.0**

Table 6. Net benefits (NBs) and Costs of outfalls, ranked by state totals, 2019 $m, t=15 years

State/territory	n	NB r=9%	Costs	NB r=6%	Costs	NB r=3%	Costs
New South Wales	28	8,430.4	4,840.2	9,157.1	5,143.5	10,118.5	5,552.2
Western Australia	12	2,553.5	585.3	2,771.1	611.4	3,060.0	646.5
South Australia	10	1,636.4	264.5	1,772.0	276.5	1,952.2	292.6
Queensland	51	88.0	804.2	128.7	832.7	182.5	871.1
Victoria	19	-23.5	277.8	-13.6	287.6	-0.5	300.8
Northern Territory	6	-57.9	90.4	-58.0	93.1	-58.3	96.8
Tasmania	41	-411.2	478.8	-421.6	494.5	-435.8	515.7
Grand Total	**167**	**12,215.7**	**7,341.4**	**13,335.7**	**7,739.3**	**14,818.6**	**8,275.6**

All states and territories overall have net benefits from upgrades except for the Northern Territory and Tasmania which experience net losses. Victoria's net benefits move from negative to positive when moving from a 15 to 30-year time period of assessment. NSW has the largest net benefit ($8-19 billion), followed by Western Australia ($3-5 billion), South Australia ($2-3 billion), Queensland ($90-730 m), Victoria (-$24 m to 150 m), Northern Territory ($-46 m to -54 m) and Tasmania (-$411m to -460m).

Costs of upgrades are also presented alongside the net benefits (NBs). Total national costs of upgrades range from $7.3 billion to just over $10 billion with a median score of $7.9 billion for a 30-year project period at a discount rate of nine percent. The ranking of state or territory costs for upgrades does not match that for net benefits; while New South Wales has the largest and most significant state costs ($4.8-$7 billion), Queensland has the next highest total state costs ($0.8-$1 billion), followed by Western Australia ($0.6-$0.8 billion) and then Tasmania ($0.5-$0.6 billion). Northern Territory has the least costs of upgrades ($90-$110 m) closely followed by South Australia ($300-$350 m). These cost structures are partly reflected by Queensland having the largest number of coastal outfalls at 51, followed by Tasmania with 41, and NSW at 28. The Northern Territory has the fewest number of coastal outfalls at 6, two of which have limited information. The net loss for Tasmania reflects a recent period of difficulties in water reform with movements to regional water authorities from local government management of water and wastewater services, back to a single state-based agency. This may well reflect a large number of aging assets across a relatively small population of users. In contrast, NSW has the largest population of all states across which a larger accumulation of net benefits is likely, though one would expect the same for Victoria being the second largest populated state, but it has nine fewer outfalls than NSW. Interestingly, Queensland has the largest number of outfalls and the third largest population in Australia relative to NSW and Victoria, but the benefits from upgrades are relatively smaller. This may reflect a large state area and greater dispersal of population (i.e. relatively smaller local populations for a given outfall) along the coast where outfalls are located. Victoria may suffer from smaller local populations too.

3. NOD FUTURE PLANS

The NOD project will support greater data transparency in the future by:

1) Embracing data formats that are easily accessible, promote insight-driven decisions and reduce compliance burdens.

    a. For example, the NOD website enables the comprehensive visualization of available water quality parameters throughout Australia, facilitating cross institutional coordination across Federal, State/Territory, and local authorities to integrate infrastructure planning and decision making of wastewater effluent from ocean outfalls in Australia.

2) A data repository that is accessible to everyone. By replacing documents (such as online PDF documents) with standardized open data, Federal and State/Territory governments and water authorities will improve transparency within the community and provide more useful data to Governments, supporting their prioritisation of infrastructure and environmental needs.

3) Evolving community awareness, scientific research (e.g. drug consumption as measured by influent to WWTP by the sewAus project (O'Brien et al., 2016)), cost opportunities for recycling wastewater (upgrade proposals etc.) and environmental concerns including those related to emerging contaminants (e.g. microplastics and heavy metals) and process efficiencies (through Industry 4.0) of environmental datasets.

4) Promoting data transparency, as in the case of the NOD,

    a. The general public will feel more informed and involved and can act as stewards of the marine and coastal environment.

    b. Will allow for the identification of problem hotspots and the effective decision making and resource allocation for conservation measures.

    c. Will encourage WTAs and governments to build trust with the general communities.

In order to facilitate transparency between WTAs and the community, the NOD identifies that what is needed is:

- Adequate mechanisms be developed to allow the co-operation and exchange of information with other water authorities in cases where discharges of wastewater have a transboundary effect on water quality of jurisdictions shared waters.

- Enhancing the reporting process and the generation of information for policy makers, interested parties and the general public.

- The adoption and maintenance by authorities of the right of everyone to receive outfall pollutant information that is held by public authorities to enhance the public's ability to participate in environmental decision-making.
- A representative body of industry, academic, community and government to develop National Wastewater Treatment Plant Performance, Discharge and Transparency Standards and report to Federal and State Environment Ministers.
- ongoing support to assist with the development of reporting standards that encompass points detailed in the Discussion section. Ideally it would be more appropriate for a statutory agency to adopt this role once an appropriate framework has been established.
- The status of water treatment performance to be reported bi-annually to State governments and to the Federal government once every 5 years as part of the State of Environment reporting.

The NOD has made a start but more needs to be done to maintain the existing progress and to extend the reporting to all WTA and expand the minimum set of variables that is reported to include all those essential for improving decisions on upgrade opportunities and priorities.

REFERENCES

Beck, H.J., and Birch, G.F. (2012). Spatial and Temporal Variance of Metal and Suspended Solids Relationships in Urban Stormwater-Implications for Monitoring. *Water, Air, & Soil Pollution* 223**,** 1005-1015. doi: 10.1007/s11270-011-0919-1.

Beder, S. (1991). Controversy and closure: Sydney's beaches in crisis. *Social Studies of Science* 21(2)**,** 223-256.

Blackwell, B.D., and Gemmill, J. (2019). "Coastal Outfall System Upgrades in Australia: Benefits, Costs, and Improved Transparency – Final Report". (Wonthaggi, Victoria: Clean Ocean Foundation).

Boehm, A.B., Ismail, N.S., Sassoubre, L.M., and Andruszkiewicz, E.A. (2017). Oceans in Peril: Grand Challenges in Applied Water Quality Research for the 21st Century. *Environmental Engineering Science* 34(1)**,** 3-15. doi: 10.1089/ees.2015.0252.

Burd, B., Bertold, S., and Macdonald, T. (2012). Responses of infaunal composition, biomass and production to discharges from a marine outfall over the past decade. *Marine Pollution Bulletin* 64**,** 1837-1852.

Campos, C.J.A., Avant, J., Gustar, N., Lowther, J., Powell, A., Stockley, L., et al. (2015). Fate of Human Noroviruses in Shellfish and Water Impacted by Frequent Sewage Pollution Events. *Environmental Science & Technology* 49(14)**,** 8377-8385. doi: 10.1021/acs.est.5b01268.

Carey, R.O., and Migliaccio, K.W. (2009). Contribution of Wastewater Treatment Plant Effluents to Nutrient Dynamics in Aquatic Systems: A Review. *Environmental Management* 44(2)**,** 2015-2017. doi: 10.1007/s00267-009-9309-5.

Cheung, P.K., Yuen, K.L., Li, P.F., Lau, W.H., Chiu, C.M., Yuen, S.W., et al. (2015). To swim or not to swim? A disagreement between microbial indicators on beach water quality assessment in Hong Kong. *Marine Pollution Bulletin* 101**,** 53-60. doi: http://dx.doi.org/10.1016/j.marpolbul.2015.11.029.

Clark, G.F., and Johnston, E.L. (2017). "Australia state of the environment 2016: coasts, independent report to the Australian Government Minister for Environment and Energy". (Canberra: Australian Government Department of the Environment and Energy).

DECC NSW (2009). "Load Calculation Protocol". Department of Environment and Climate Change NSW).

Eugenia, B., SantiagoLucerito, Rodolfo, B., and Alberto, V. (2016). Assessing sewage impact in a South-West Atlantic rocky shore intertidal algal community. *Marine Pollution Bulletin* 106(1-2)**,** 388-394. doi: https://doi.org/10.1016/j.marpolbul.2016.02.038.

Icon Water (2018). *Canberra Sewerage Strategy 2010–2060: Future Sewerage Options Review Summary* [Online]. Canberra, Australia: Icon Water. Available: https://www.iconwater.com.au/Water-and-Sewerage-System/Water-and-sewerage-system/Sewage-Treatment/Fyshwick-Sewage-Treament-Plant.aspx [Accessed].

Jagai, J.S., Li, Q., Wang, S., Messier, K.P., Wade, T.J., and Hilborn, E.D. (2015). Extreme precipitation and emergency room visits for gastrointestinal illness in areas with and without combined sewer systems: an analysis of Massachusetts data 2003–2007. *Environmental health perspectives* 123(9), 873-879.

Marine Biodiversity Hub (2015). *Project C4 - National Outfall Database* [Online]. NESP Marine Biodiversity Hub. Available: http://www.nespmarine.edu.au/project/project-c4-national-outfall-database [Accessed 15 March 2016].

Mea, M., Newton, A., Uyarra, M.C., Alonso, C., and Borja, A. (2016). From science to policy and society: enhancing the effectiveness of communication. *Frontiers in Marine Science* 3, 168.

NRMMC (2010). "Australia's Biodiversity Conservation Strategy 2010-2030", (ed.) Natural Resource Management Ministerial Council. (Canberra: Australian Government, Department of Sustainability, Environment, Water, Population and Communities).

O'Brien, J., Grant, S., and Mueller, J. (2016). *SewAus: estimating per capita use and release of chemicals by wastewater analysis* [Online]. Queensland: EnTox, University of Queensland. Available: https://www.qldwater.com.au/e-flashes-1/sewaus-sampling [Accessed 06 April 2019].

OEH (2019). *Beachwatch water quality program* [Online]. Sydney: The Office of Environment and Heritage, New South Wales. Available: https://www.environment.nsw.gov.au/topics/water/beaches/beachwatch-water-quality-program [Accessed 27 May 2019].

Pendleton, L. (2008). The economics of using ocean observing systems to improve beach closure policy. *Coastal Management* 36(2), 165-178.

Pratap, P.L., Desai, P., and Dorevitch, S. (2011). Beach communications: A need for evaluation of current approaches. *Journal of water and health* 9(3), 556-568.

Rohmana, Q.A., Fischer, A., Gemmill, J., and Cumming, J. (2019). "National Outfall Database: Outfall Ranking Report 2017-2018". (Australia: Report to the National Environmental Science Program, Marine Biodiversity Hub).

Schwarzenbach, R.P., Egli, T., Hofstetter, T.B., Gunten, U.v., and Wehrli, B. (2010). Global Water Pollution and Human Health. *Annual Review of Environment and Resources* 35, 109-136. doi: 10.1146/annurev-environ-100809-125342.

Stark, J.S., Bridgen, P., Dunshea, G., Galton-Fenzi, B., Hunter, J., Johnstone, G., et al. (2016). Dispersal and dilution of wastewater from an ocean outfall at Davis Station, Antarctica, and resulting environmental contamination. *Chemosphere* 152, 142-157. doi: http://dx.doi.org/10.1016/j.chemosphere.2016.02.053.

Thoe, W., Gold, M., Griesbach, A., Grimmer, M., Taggart, M.L., and Boehm, A.B. (2014). Predicting water quality at Santa Monica Beach: evaluation of five different models for public notification of unsafe swimming conditions. *Water research* 67, 105-117.

APPENDIX A – OUTFALLS RANKING

Table 7. Australian coastal outfalls ranking by quartiles.

Rank	Outfall	State	Total nutrients load (kg)
1	Iluka	New South Wales	90
2	Christies Beach-Southern	South Australia	287
3	Home Island	Western Australia	359
4	Port Welshpool	Victoria	414
5	Sisters Beach	Tasmania	476
6	Boat Harbour	Tasmania	490
7	Busselton (North)	Western Australia	567
8	Bicheno	Tasmania	646
9	St Helens	Tasmania	729
10	Busselton (South)	Western Australia	1339
11	Dover	Tasmania	1349
12	Crescent Head	New South Wales	1357
13	Christmas Island	Western Australia	1691
14	Bermagui	New South Wales	1900
15	Cambridge/airport	Tasmania	2041
16	Orford	Tasmania	2051
17	Anglesea	Victoria	2234
18	Port Arthur	Tasmania	2287
19	Apollo Bay	Victoria	2379
20	Stanley	Tasmania	2393
21	Karana Downs	Queensland	2748
22	Lorne WRP	Victoria	2872
23	Camden Haven	New South Wales	2901
24	Risdon (east)	Tasmania	3449

Rank	Outfall	State	Total nutrients load (kg)
25	Electrona	Tasmania	3858
26	Cygnet	Tasmania	4139
27	Port Douglas	Queensland	4258
28	Currie	Tasmania	4805
29	East Strahan	Tasmania	4830
30	Cannonvale	Queensland	4881
31	Bridgewater	Tasmania	5008
32	Landsborough	Queensland	5376
33	Victoria Point	Queensland	5598
34	Foster	Victoria	5624
35	Merimbula	New South Wales	6219
36	Bowen	Queensland	6232
37	Somerset	Tasmania	6677
38	Edmonton	Queensland	6989
39	Capalaba	Queensland	7193
40	Bridport	Tasmania	7368
41	Long Nose (Tomakin)	New South Wales	7377
42	Thorneside	Queensland	7451
43	Forster	New South Wales	8710
44	Nambour	Queensland	8714
45	Yamba	New South Wales	8763
46	Whyalla	South Australia	9253
47	Berrimah	Northern Territory	9438
48	Marlin Coast	Queensland	9773
49	Turners Beach	Tasmania	10348
50	Mackay North (Bucasia)	Queensland	10382

Rank	Outfall	State	Total nutrients load (kg)
51	Fairfield	Queensland	10916
52	Narooma	New South Wales	11378
53	Millbank	Queensland	11628
54	Coolum	Queensland	11659
55	McGaurans Beach	Victoria	12342
56	Port Lincoln	South Australia	13924
57	Skennars Head (Lennox Head)	New South Wales	14263
58	Carole Park	Queensland	14311
59	Margate	Tasmania	14917
60	East Rockingham	Western Australia	15277
61	George Town	Tasmania	16777
62	Batemans Bay	New South Wales	17424
63	West Rockhampton	Queensland	18567
64	Goodna	Queensland	19250
65	Wynnum	Queensland	20071
66	Alkimos	Western Australia	20791
67	Coffs Harbour	New South Wales	23049
68	Hoblers Bridge	Tasmania	23548
69	Murrumba Downs	Queensland	23993
70	Port Pirie	South Australia	24216
71	Port Sorell	Tasmania	24353
72	Burpengary East	Queensland	24591
73	Sandgate	Queensland	25147
74	Port Augusta East	South Australia	26560
75	Bombo	New South Wales	29186
76	Caboolture South	Queensland	29846

Rank	Outfall	State	Total nutrients load (kg)
77	Mt St John	Queensland	32813
78	Southern WWTP (Woree)	Queensland	33058
79	Round Hill	Tasmania	33308
80	Baxter's Beach	Victoria	33588
81	Selfs Point	Tasmania	33918
82	Beenleigh	Queensland	36244
83	Riverside	Tasmania	36266
84	Wacol	Queensland	37907
85	Delray Beach	Victoria	44140
86	Bundamba	Queensland	45715
87	Phillip Island	Victoria	46353
88	Innisfail	Queensland	50837
89	Wynyard	Tasmania	51210
90	Ulverstone	Tasmania	51259
91	South Rockhampton	Queensland	51701
92	Finger Point	South Australia	53315
93	Rosny	Tasmania	53888
94	Portland	Victoria	54942
95	Redcliffe	Queensland	56528
96	Altona	Victoria	57375
97	Merrimac	Queensland	60557
98	Cameron Bay	Tasmania	61899
99	Cleveland Bay	Queensland	64672
100	Newnham	Tasmania	67192
101	Maroochydore	Queensland	76814
102	Christies Beach-Northern	South Australia	81176

Rank	Outfall	State	Total nutrients load (kg)
103	Elanora	Queensland	82509
104	Bunbury	Western Australia	95601
105	Port Fairy Domestic	Victoria	103619
106	North Rockhampton	Queensland	104646
107	Gibson Island	Queensland	108970
108	Loganholme	Queensland	113088
109	Smithton	Tasmania	122576
110	Coombabah	Queensland	132233
111	Blackmans Bay	Tasmania	137078
112	Boags Rock (Boneo)	Victoria	151645
113	Ti-tree Bend	Tasmania	178405
114	Prince of Wales Bay	Tasmania	180990
115	Oxley	Queensland	193897
116	Macquarie Point	Tasmania	238933
117	Shellharbour	New South Wales	240151
118	Palmerston	Northern Territory	242436
119	Black Rock	Victoria	245826
120	Leanyer Sanderson	Northern Territory	252787
121	Winney Bay (Kincumber)	New South Wales	261452
122	Ludmilla	Northern Territory	267783
123	Pardoe	Tasmania	305653
124	Warrnambool WRP	Victoria	307302
125	Glenelg	South Australia	383036
126	Warriewood	New South Wales	429849
127	Subiaco	Western Australia	573772
128	Bolivar High Salinity	South Australia	604478

Rank	Outfall	State	Total nutrients load (kg)
129	Bolivar WWTP	South Australia	685004
130	Point Peron	Western Australia	692652
131	Potter Point (Cronulla)	New South Wales	911183
132	Luggage Point	Queensland	925360
133	Coniston Beach (Wollongong)	New South Wales	1186472
134	Beenyup	Western Australia	1514724
135	Woodman Point	Western Australia	2345688
136	Boags Rock (ETP)	Victoria	3669779
137	Bondi	New South Wales	4527083
138	Werribee (WTP)	Victoria	7988464
139	North Head	New South Wales	12005094
140	Malabar	New South Wales	14324559

Note:

= Top quartile

= 50th quartile

= 75th quartile

= Bottom quartile

APPENDIX B – OUTFALLS CLUSTERS

Table 8. The clusters of Australian coastal outfalls.

Cluster	State	Location
1	New South Wales	Bombo
1	New South Wales	Coniston Beach (Wollongong)
1	New South Wales	Narooma
1	New South Wales	Potter Point
1	New South Wales	Shellharbour
1	New South Wales	Tomakin
1	New South Wales	Ulladulla
1	New South Wales	Warriewood
1	Northern Territory	Ludmilla
1	Queensland	East Bundaberg
1	Queensland	Eli Creek
1	Queensland	Gladstone
1	Queensland	Karana Downs
1	Queensland	Maryborough
1	Queensland	South Rockhampton
1	Queensland	South Trees Inlet
1	Queensland	West Rockhampton
1	South Australia	Port Augusta
1	South Australia	Christies Beach-Southern outfall
1	South Australia	Whyalla
1	Tasmania	Bicheno
1	Tasmania	Blackmans Bay
1	Tasmania	Boat Harbour
1	Tasmania	Bridgewater

Cluster	State	Location
1	Tasmania	Bridport
1	Tasmania	Cameron Bay
1	Tasmania	Currie
1	Tasmania	Cygnet
1	Tasmania	George Town
1	Tasmania	Hoblers Bridge
1	Tasmania	Macquarie Point
1	Tasmania	Margate
1	Tasmania	Midway Point
1	Tasmania	Newnham
1	Tasmania	Orford
1	Tasmania	Port Arthur
1	Tasmania	Port Sorell
1	Tasmania	Prince of Wales Bay
1	Tasmania	Richmond
1	Tasmania	Riverside
1	Tasmania	Rosny
1	Tasmania	Smithton
1	Tasmania	Sorell
1	Tasmania	Stanley
1	Tasmania	East Strahan
1	Tasmania	Ti-tree Bend
1	Tasmania	Triabunna
1	Tasmania	Turners Beach
1	Tasmania	Wynyard
1	Victoria	Baxters Beach

Cluster	State	Location
1	Victoria	Boags Rock (ETP)
1	Victoria	Phillip Island
1	Victoria	Foster
1	Victoria	Port Fairy Ind
1	Victoria	Portland
1	Victoria	Toora
1	Victoria	Warrnambool
1	Victoria	Werribee (Port Phillip Bay)
1	Western Australia	Beenyup
1	Western Australia	Subiaco
1	Western Australia	Woodman Point
2	Tasmania	Pardoe
2	Tasmania	Ulverstone
3	New South Wales	Bondi
3	New South Wales	Malabar
3	New South Wales	North Head
3	Tasmania	Electrona
3	Western Australia	Point Peron
4	Northern Territory	Berrimah
4	Northern Territory	Leanyer Sanderson
4	Northern Territory	Palmerston
4	South Australia	Port Pirie
4	South Australia	Bolivar WWTP
5	New South Wales	Batemans Bay
5	New South Wales	Belmont
5	New South Wales	Bermagui

Cluster	State	Location
5	New South Wales	Boulder Bay
5	New South Wales	Burwood Beach
5	New South Wales	Camden Head
5	New South Wales	Coffs Harbour
5	New South Wales	Crescent Head
5	New South Wales	Eden
5	New South Wales	Forster
5	New South Wales	Kincumber
5	New South Wales	Merimbula
5	New South Wales	Penguin Heads
5	New South Wales	Skennars Head
5	New South Wales	Toukley
5	New South Wales	Wonga Point
5	Queensland	Beenleigh
5	Queensland	Bowen
5	Queensland	Bundamba
5	Queensland	Burpengary East
5	Queensland	Caboolture South
5	Queensland	Cannonvale
5	Queensland	Capalaba
5	Queensland	Carole Park
5	Queensland	Cleveland Bay
5	Queensland	Coolum
5	Queensland	Coombabah
5	Queensland	Edmonton
5	Queensland	Elanora

Cluster	State	Location
5	Queensland	Fairfield
5	Queensland	Gibson Island
5	Queensland	Goodna
5	Queensland	Innisfail
5	Queensland	Kawana
5	Queensland	Landsborough
5	Queensland	Loganholme
5	Queensland	Lucinda
5	Queensland	Luggage Point
5	Queensland	Mackay North
5	Queensland	Mackay Southern
5	Queensland	Marlin Coast
5	Queensland	Maroochydore
5	Queensland	Merrimac
5	Queensland	Millbank
5	Queensland	Mt St John
5	Queensland	Murrumba Downs
5	Queensland	Nambour
5	Queensland	North Rockhampton
5	Queensland	Oxley
5	Queensland	Port Douglas
5	Queensland	Redcliffe
5	Queensland	Sandgate
5	Queensland	Thorneside
5	Queensland	Victoria Point
5	Queensland	Wacol

Cluster	State	Location
5	Queensland	Woree
5	Queensland	Wynnum
5	South Australia	Bolivar
5	South Australia	Finger Point
5	South Australia	Glenelg
5	South Australia	Christies Beach-Northern outfall
5	South Australia	Port Lincoln
5	Tasmania	Cambridge
5	Tasmania	Dover
5	Tasmania	Risdon
5	Tasmania	Rokeby
5	Tasmania	Round Hill
5	Tasmania	Selfs Point
5	Tasmania	Sisters Beach
5	Tasmania	Somerset
5	Tasmania	St Helens
5	Victoria	Anglesea
5	Victoria	Apollo Bay
5	Victoria	Altona
5	Victoria	Black Rock
5	Victoria	Boneo
5	Victoria	Delray Beach
5	Victoria	Lorne
5	Victoria	McGaurans
5	Victoria	Port Fairy Dom
5	Victoria	Port Welshpool

Cluster	State	Location
5	Western Australia	Alkimos
5	Western Australia	Bunbury
5	Western Australia	Christmas Island
5	Western Australia	East Rockingham
5	Western Australia	Home Island
5	Western Australia	Busselton - North Wetlands
5	Western Australia	Busselton - South Wetlands
5	Western Australia	Wickham

www.nespmarine.edu.au

Contact:

John Gemmill
CEO Clean Ocean Foundation

johng@cleanocean.org
www.cleanocean.org