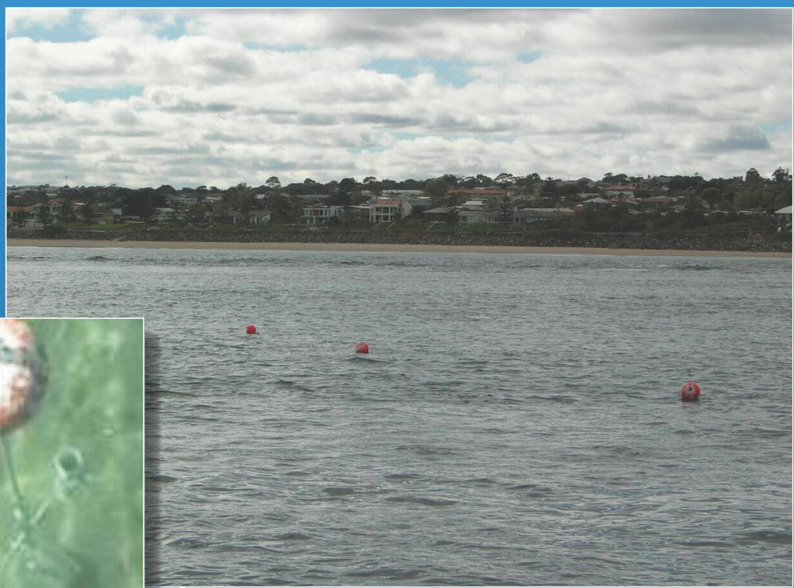
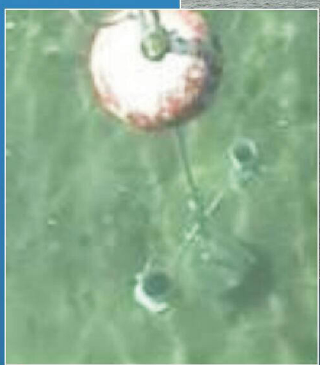
Marine Environment and Ecology

Sedimentation Surveys of Adelaide's Coastal Reefs, Part 2 (Autumn)

A report prepared for the Adelaide and Mount Lofty Ranges Natural Resources Management Board





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Milena Fernandes

SARDI Aquatic Sciences,
PO Box 120 Henley Beach SA 5022

December 2008

Government
of South Australia

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South Australian Research & Development Institute
Aquatic Sciences Centre
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.sardi.sa.gov.au

Cover page: Deployed sediment trap (left), and Horseshoe reef (right)

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Authors:	M. Fernandes
Reviewers:	Brad Page
	Sonja Venema
Approved by:	Jason Tanner
Signed:	
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EXECUTIVE SUMMARY

This work was commissioned by the Adelaide and Mount Lofty Ranges Natural Resources Management Board to determine sedimentation rates on Adelaide's coastal reefs during the start of the rainy season in autumn, and to provide information on the potential sources of these sediments. For this purpose, sedimentation rates were measured on twelve reefs between Semaphore and Aldinga in May 2008, and the composition and particle size distribution of sediments compared with those from terrestrial sources discharging into the Adelaide marine environment.

The highest rates of sedimentation along the metropolitan coast, reaching up to 1,622 grams per square metre per day (g m^{-2} d^{-1}), were measured at reefs north of the mouth of the Onkaparinga River, between Port Noarlunga and Hallett Cove. Riverine discharges and cliff-face erosion, combined with high-energy waves and negligible transport offshore, act to sustain high deposition in these nearshore systems. Reefs further south receive inputs of similar origin, albeit at rates never exceeding 11 g m^{-2} d^{-1}.

Reefs in the northern section of the metropolitan coast at Semaphore and Broken Bottom had much lower sedimentation rates (< 30 g m^{-2} d^{-1}) as a result of their increased distance offshore. Sediments reaching these reefs were similar to those from the Torrens River, but high nitrogen contents suggest additional inputs from wastewater treatment plants.

1 INTRODUCTION

The coastal zone bordering Adelaide encompasses over 50 km of temperate seagrass meadows, rocky reefs and sandy beaches. Although the climate is semi-arid with low rainfall, growing urban and agricultural development are reflected in an annual input of sediments to the marine environment on the order of 10,000 tonnes (Wilkinson et al. 2005b). Approximately 70% of this total is delivered to northern metropolitan waters between Port Gawler and Glenelg. The majority of sediments entering the system are derived from wet runoff, with only 18% delivered by dry fall and 15% from wastewater treatment plants (Wilkinson et al. 2005b). There is growing concern about the impact of these terrestrially-derived sediments on nearshore coastal ecosystems, as land-based inputs are frequently linked to the progressive deterioration of coastal reefs (Turner et al. 2007; Connell et al. 2008). The effects of high sediment loads on reef communities are numerous, with direct impacts including a reduction in light availability, smothering of surface benthic organisms and a shift in the relative composition of macroalgae that form the base of the food chain (Airoldi 2003; Connell 2005; Balata et al. 2007).

The Adelaide and Mount Lofty Ranges Natural Resources Management (NRM) Board has identified coastal water quality as a key management issue for the region, with action targets including the halt in coastal habitat decline by the reduction in the volume of discharges into the marine environment. The objective of this study was to provide baseline data on sedimentation rates on metropolitan reefs to guide management initiatives to reduce sediment loads from catchment sources. The first part of the study indicated that sedimentation rates in winter and summer are typically <220 g m^{-2} d^{-1} (Fernandes et al. 2008). The highest rates were recorded between Port Noarlunga reef and Southport, sustained by the resuspension of coastal sediments of riverine origin. In contrast, sedimentation rates on the northern reefs of Semaphore and Broken Bottom were <10 g m^{-2} d^{-1} and driven by wastewater rather than fluvial inputs. In this second part of the study, I investigated sedimentation during the period of high runoff occurring when the first rains break the summer dry season in autumn (Wilkinson et al. 2005a). Similarly to what was done for winter and summer, the geochemical composition, nutritional value and particle size distribution of sediments were examined and compared to potential terrestrial sources in an attempt to isolate the most probable sources of sediments reaching metropolitan reefs.

2 METHODS

Twelve reefs were sampled between Semaphore and Aldinga in May 2008 (Figure 1, Table 1). Sampling was generally along the landward boundary of the reefs, but for a few reefs both the seaward boundary (Outside) and the landward boundary (Inside) were sampled. Samples were collected using sediment traps moored for 1 to 2 days at a depth of 1 m above the seafloor. Each trap consisted of two PVC tubes with a height to width ratio of 4.7 (height 400 mm, diameter 85 mm), lead weighted on the bottom (40 g) to ensure vertical orientation. At each site, sediment traps were deployed at three stations 30 m apart, with two replicates per station. Upon retrieval, traps were spiked with $HgCl_2$ to a final concentration of 10 mg L^{-1} to prevent microbial degradation.

Upon return to the laboratory, the contents of sediment traps were sieved (1 mm mesh size) to remove material not part of the passive flux (e.g. mobile organisms such as zooplankton). Sieved samples were vacuum-filtered through pre-combusted (350ºC for 3 h) and pre-weighed glass-fibre filters (MFS GF-75, 0.7 μm, 47 mm diameter). Filters were placed in separate pre-combusted glass petri dishes, covered with a glass lid and oven-dried at 50ºC. Before gravimetric analysis, filters were placed in an oven at 50ºC for at least 3 h and then placed in a desiccator with silica gel for 1 h to cool. The filters were then weighed and the results corrected for salt deposition. Sediments were gently scraped off the filters with a spatula, homogenized with a mortar and pestle, and combined to provide one sample per station. For the determination of particle size distribution and elemental composition, samples were further combined to provide one sample per site.

We also collected samples from the main rivers discharging into the metropolitan coast (Wilkinson 2005; Wilkinson et al. 2005a) and from the cliffs bordering the Onkaparinga estuary (Figure 1, Table 1). Riverine sources included the Torrens River (above the weir at Military Road), the Patawalonga lacustrine-riverine system (above the Barcoo Outlet), the Field River and Christies Creek (above the high tide mark) and the Onkaparinga River (in the township of Old Noarlunga). For each river, two 20 L carboys were filled with water as close as possible to the middle of the river channel. These samples were spiked with $HgCl_2$ to a final concentration of 10 mg L^{-1} to prevent microbial degradation. Upon return to the laboratory, the carboys were left to settle for at least 1 night and approximately 15 L of the overlying water was carefully siphoned off with a rubber hose. The remaining water was sieved through a 1 mm mesh to remove large particles, and vacuum filtered through pre-combusted and pre-weighed glass-fibre filters (MFS GF-75, 0.7 μm, 47 mm diameter). Filters were placed in separate pre-combusted glass petri dishes, covered with a glass lid and oven-dried at 50 ºC. These filters were treated and weighed in the same way as the sediment trap samples. Replicates were combined to provide one sample per site. Samples from the Onkaparinga cliffs were collected by scraping the bottom edge of the cliff-face at a level where wave action was evident.

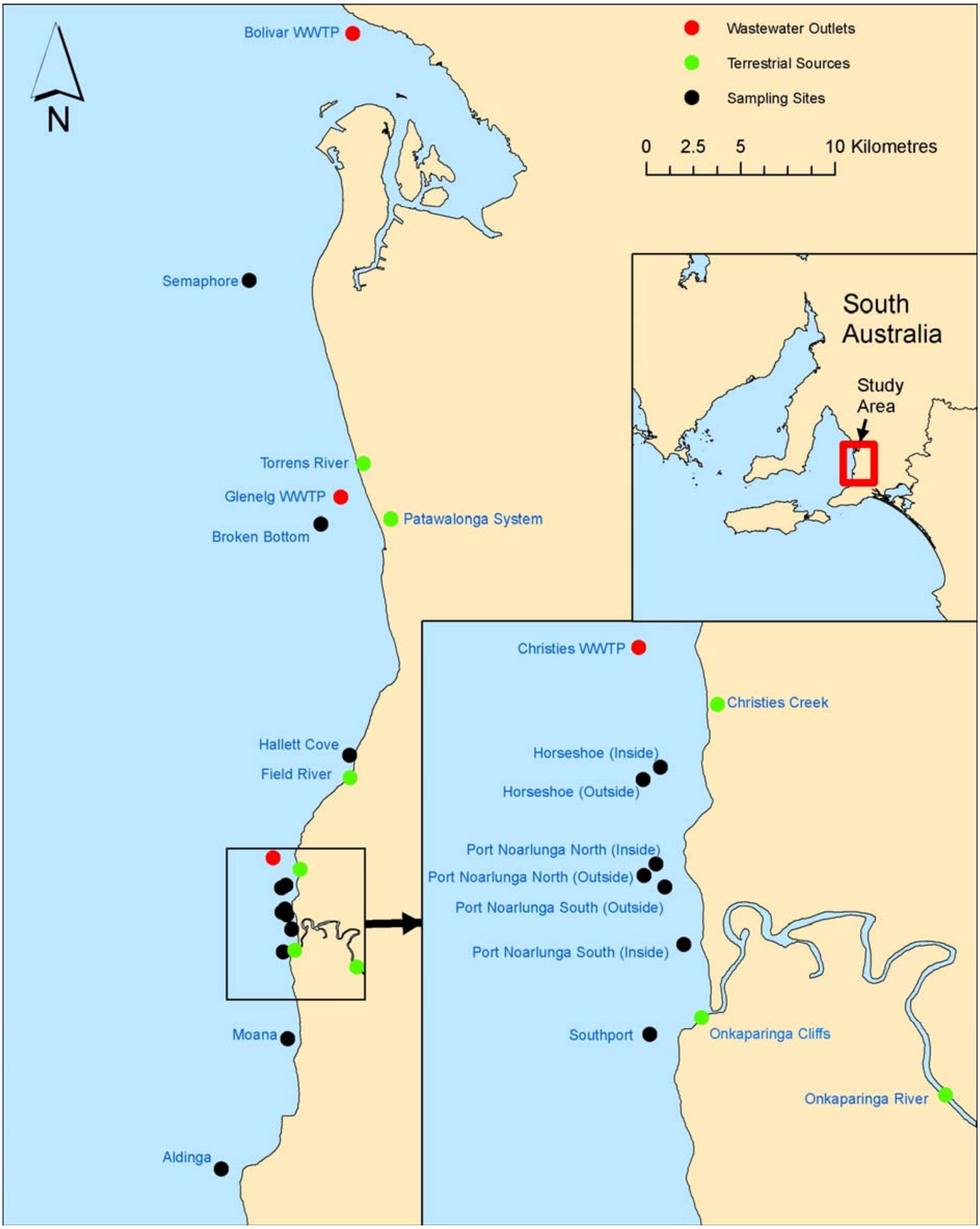

Figure 1. Map of the study area showing the location of sampling sites, potential terrestrial sources and wastewater outlets.

Table 1. Coordinates of sampling sites (WGS84), depth and dates of deployment.

Sampling site	Code	Latitude	Longitude	Depth (m)	Date deployed[1]
Reefs					
Semaphore	SE	34^o 50.826'	138^o 26.757'	10	05-May-2008
Broken Bottom	BB	34^o 57.801'	138^o 28.817'	10	05-May-2008
Hallett Cove	HC	35^o 04.422'	138^o 29.641'	5	05-May-2008
Horseshoe (Inside)	HI	35^o 08.154'	138^o 27.811'	3	05-May-2008
Horseshoe (Outside)	HO	35^o 08.242'	138^o 27.688'	4	05-May-2008
Pt Noarlunga North (Inside)	NNI	35^o 08.896'	138^o 27.854'	4	08-May-2008
Pt Noarlunga North (Outside)	NNO	35^o 08.849'	138^o 27.782'	7	05-May-2008
Pt Noarlunga South (Inside)	NSI	35^o 09.420'	138^o 27.979'	3	08-May-2008
Pt Noarlunga South (Outside)	NSO	35^o 09.014'	138^o 27.843'	5	08-May-2008
Southport	SP	35^o 10.065'	138^o 27.736'	5	08-May-2008
Moana	MI	35^o 12.551'	138^o 27.863'	7	08-May-2008
Aldinga	AL	35^o 16.254'	138^o 25.971'	6	08-May-2008
Terrestrial sources					
Torrens River	---	34^o 56.084'	138^o 30.025'	---	06-May-2008
Patawalonga system	---	34^o 57.662'	138^o 30.817'	---	06-May-2008
Field Creek	---	35^o 05.069'	138^o 29.658'	---	06-May-2008
Christies Creek	---	35^o 07.709'	138^o 28.212'	---	06-May-2008
Onkaparinga River	---	35^o 10.486'	138^o 29.846'	---	06-May-2008
Onkaparinga Cliffs	---	35^o 09.899'	138^o 27.924'	---	14-May-2008

[1]For the samples from terrestrial sources, this is the date collected.

Al, Cr, Cu, Fe, Ni, P, Pb, Sr and Zn contents were determined in a Varian Vista Axial Inductively Coupled Plasma-Atomic Emission Spectrometer (ICP-AES) after digestion with nitric and hydrochloric acids (Standards Australia 1997). The sample from the reef at Moana was not analysed due to breakage during transport. The only terrestrial samples that had enough material for ICP analysis were those from the Torrens, Onkaparinga and Field Rivers, as well as those from the cliffs in the vicinity of the Onkaparinga estuary. N content was determined in a LECO TruSpec elemental analyser.

Particle size distribution was determined in a Malvern Mastersizer 2000 laser diffraction analyser. Samples were dispersed with a 50 g L^{-1} sodium hexametaphosphate solution in an ultrasound bath for 15 min, then left to soak overnight, and sonicated again for 15 min. Dispersed samples were wet sieved to 1 mm just before analyses to remove possible contamination from filter fibres. Samples from Aldinga Reef and from riverine sources did not contain enough material for analysis. Particle size distributions were analysed with the Folk and Ward graphical method in the software package GRADISTAT (Blott and Pye 2001). Parameters used to describe distributions included the mean grain size, the spread of sizes around the mean (sorting), the symmetry or preferential spread of the distribution to one side of the mean (skewness), and the degree of concentration of the grains relative to the average (kurtosis).

Results were analysed with the software package STATISTICA (StatSoft, Tulsa, OK). Hierarchical cluster analysis (single linkage, Euclidean distances) was used as an exploratory technique to extract relationships between variables and sample groupings. The results from ICP-AES analysis were standardized before cluster analysis, with reef samples standardized separately from samples of terrestrial sources. Mineral grain size parameters (mean, sorting, skewness and kurtosis) were not standardized before cluster analysis.

3 RESULTS

The sedimentation rates measured on Adelaide's coastal reefs during autumn were the highest recorded as part of this program (Figure 2). Deposition was 3-8 times higher between Semaphore and Broken Bottom, and 25-50 times between Hallett Cove and Port Noarlunga, when compared to either winter or summer. Sedimentation rates were particularly enhanced to the north of the Onkaparinga estuary, with values >650 g m^{-2} d^{-1} measured on the reefs of Horseshoe and Port Noarlunga North (Table 2). In contrast, rates measured in the north at Semaphore and Broken Bottom, and in the south at Moana and Aldinga, were an order of magnitude lower, typically below 30 g m^{-2} d^{-1}. Intermediate values were found at Hallet Cove and between Port Noarlunga South and Southport, varying in the range 70-200 g m^{-2} d^{-1}. Sedimentation rates were also influenced by the location of sampling sites in relation to the reef structure, with sites on the seaward boundary generally receiving higher sediment loads than sites on the landward boundary (Figure 2).

The intense deposition observed between Hallett Cove and Port Noarlunga North was a result of the influx of nitrogen- and phosphorus-depleted sediments (Figure 3a,b). Despite low nutrient contents, high deposition of sediments ensured high sedimentation rates for both nitrogen and phosphorus at these sites (Table 2). The molar ratio between these nutrients (N:P) remained similar to winter and summer (Figure 3c), suggesting that the increased sedimentation was not a reflection of a change in the source of sediments. Although sedimentation rates were comparatively lower in the north of the study area throughout the year, sediments from the reefs at Semaphore and Broken Bottom were consistently nitrogen-enriched (Figure 3a,c).

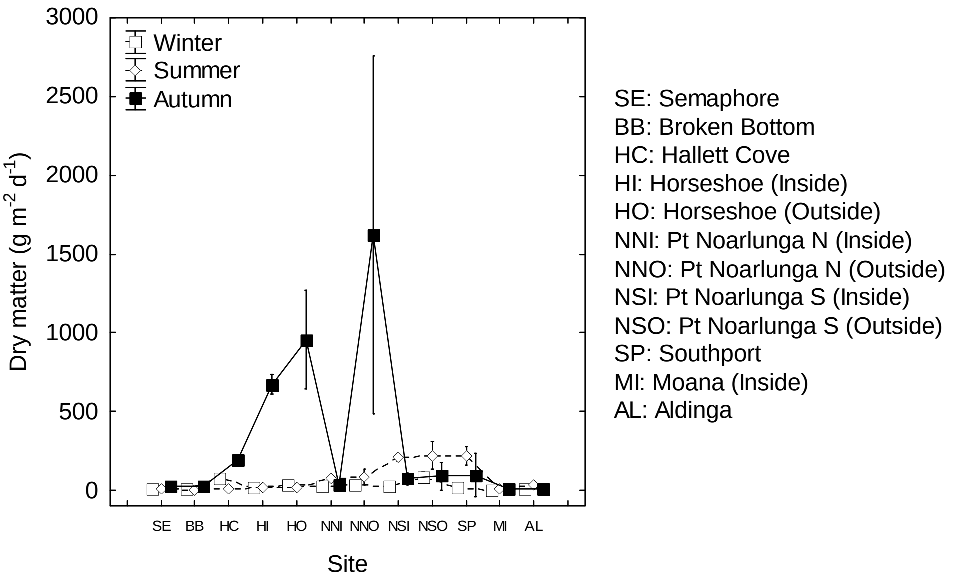

Figure 2. Dry matter sedimentation rates (mean ± SD) in winter and summer (data from Fernandes et al., 2008) versus autumn.

Table 2. Mean dry matter, nitrogen and phosphorus sedimentation rates in autumn (SD).

Site	Dry matter ($g\ m^{-2}\ d^{-1}$)	Nitrogen ($mmol\ m^{-2}\ d^{-1}$)	Phosphorus ($mmol\ m^{-2}\ d^{-1}$)
Semaphore	24.7 (2.2)	11.9 (1.1)	0.5
Broken Bottom	26.9 (3.9)	13.7 (1.5)	0.6
Hallett Cove	192.3 (16.7)	28.3 (0.1)	2.0
Horseshoe (Inside)	670.7 (61.4)	53.3 (15.3)	5.0
Horseshoe (Outside)	953.4 (313.2)	75.4 (1.2)	7.1
Port Noarlunga North (Inside)	34.6 (9.5)	---	0.7
Port Noarlunga North (Outside)	1,621.9 (1,138.9)	96.7 (62.8)	9.9
Port Noarlunga South (Inside)	71.8 (36.9)	18.7 (5.6)	1.0
Port Noarlunga South (Outside)	89.0 (87.8)	10.7 (5.4)	0.9
Southport	93.4 (137.5)	27.4 (28.4)	1.2
Moana	10.9 (4.6)	---	---
Aldinga	9.5 (3.0)	---	0.1

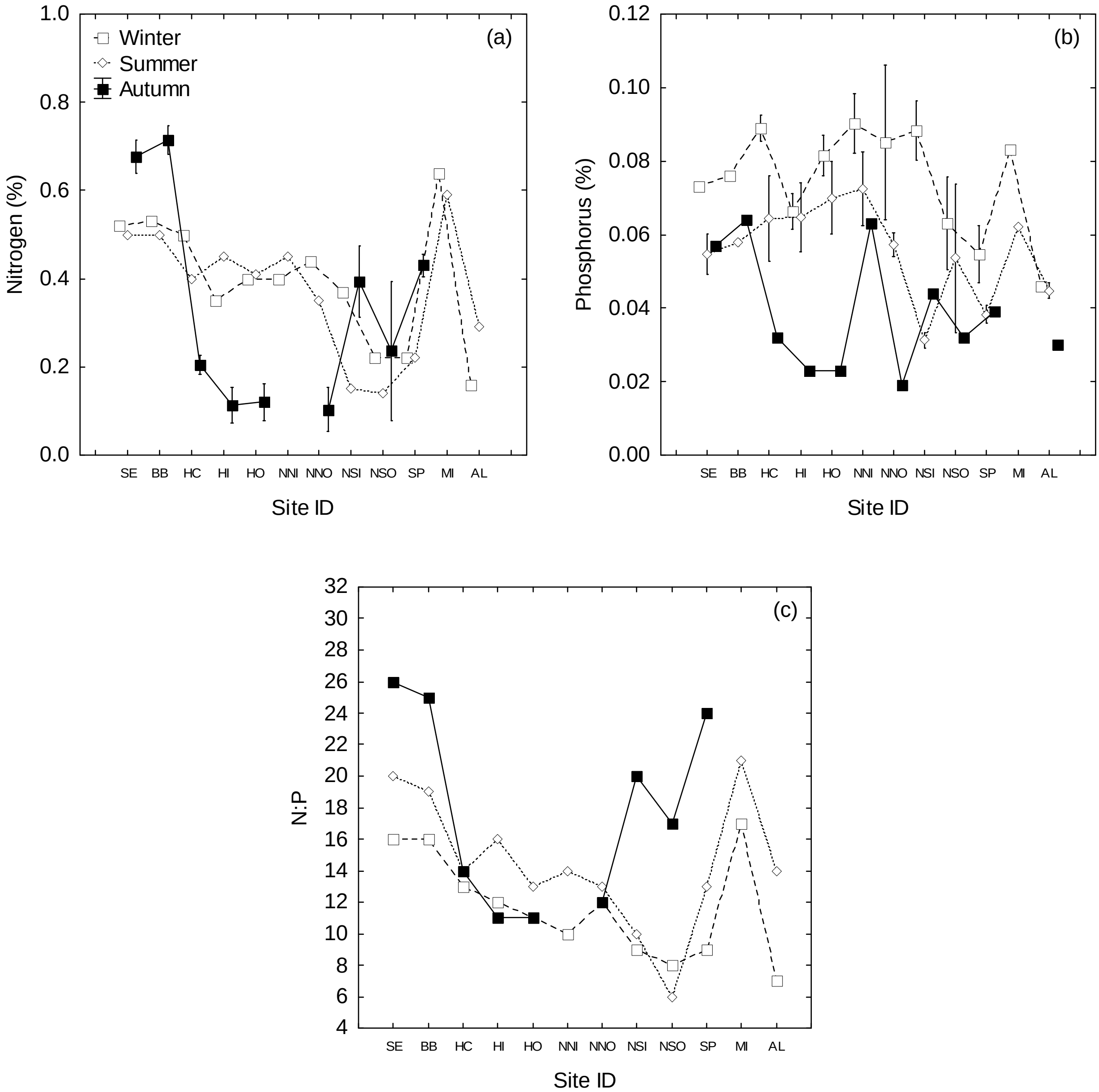

Figure 3. Content of (a) nitrogen and (b) phosphorus of sinking sediments (mean ± SD), and (c) N:P molar ratios during winter and summer (data from Fernandes et al., 2008) versus autumn. Missing values correspond to sites where the quantity of sediments collected was not enough for analysis.

The nutrient content of sediments from the coastal cliffs in the estuary of the Onkaparinga River was low: 0.04% nitrogen, 0.01% phosphorus, with a N:P molar ratio of 10. These values are similar to those measured in the nutrient-depleted sediments reaching reefs between Hallett Cove and Port Noarlunga North. Phosphorus contents in riverine suspended matter were comparatively higher, reaching 0.06% in the Onkaparinga and Field rivers, and 0.11% in the Torrens River. The riverine sources had different loads of suspended matter, with approximately 3 mg L^{-1} in the Field River and Christies Creek, 4 mg L^{-1} in the Patawalonga system, 7 mg L^{-1} in the Torrens River and 11 mg L^{-1} in the Onkaparinga River. These concentrations are generally lower than median values from long-term monitoring programs (Wilkinson et al. 2005b), suggesting that runoff was still minor at the beginning of the rainy season.

The elemental composition of sediments suggests that metropolitan reefs can be separated into two major clusters, with the Semaphore and Broken Bottom reefs grouping with the Torrens River, and reefs further south grouping with the Onkaparinga River and Onkaparinga Cliffs (Figure 4). The landward site at Port Noarlunga North was different from the other reefs as a result of comparatively high lead and zinc concentrations (Table 3). Sediments from the Field River were similar to those from the Torrens River, but are unlikely to reach the northern reefs they group with, given the location of the estuary, >10 km to the south. The majority of reefs between Hallet Cove and Aldinga had sediment compositions similar to suspended matter from the Onkaparinga River. However, the composition of sediments in the area of high deposition between Horseshoe and Port Noarlunga North indicates that the erosion of coastal cliffs might also significantly contribute to nearshore sedimentation in the vicinity of the Onkaparinga estuary. Sediments in this area were depleted of all elements tested with the exception of strontium (Table 3).

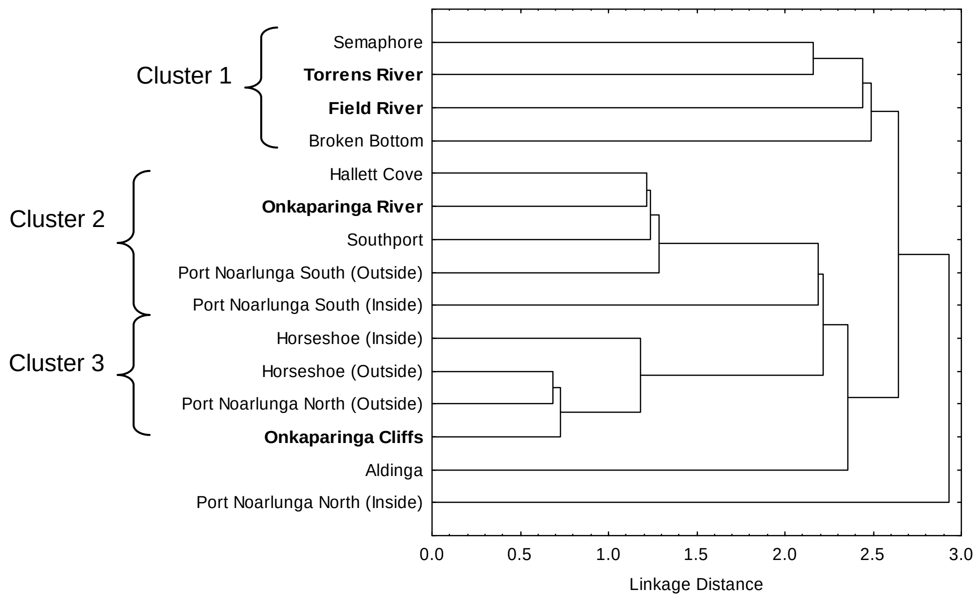

Figure 4. Dendrogram using single linkage (Euclidean distances) highlighting the spatial separation of terrestrial sources (in bold) and reefs based on the elemental composition of sediments. The linkage distance is a measure of how dissimilar the sediments at any two sites are, and thus the clusters group sites of similar elemental composition. For example, Semaphore and Torrens River join together with a linkage distance of ~2.2, so are less similar to each other than the Onkaparinga Cliffs are to Port Noarlunga North (Outside) with a linkage distance of ~0.7.

Particle size distributions corroborated some of the evidence inferred from the elemental composition of samples: sediments reaching the Semaphore and Broken Bottom reefs were fine and similar to suspended matter from the Torrens River, whereas sediments reaching reefs further south were comparatively coarser, and more closely aligned with suspended matter from the Onkaparinga River (Figures 5 and 6; Table 4). The sediments reaching sites where deposition was particularly high between Horseshoe and Port Noarlunga North were coarse compared to other reefs (Figure 6b). Sediments collected from the cliffs in the vicinity of the Onkaparinga estuary were considerably finer, but these had a tail of coarse particles that could be linked to sedimentation in the area.

Table 3. Mean elemental concentrations (SD) for sediments from reefs in the clusters of Figure 4, and for sediments from terrestrial sources. Reefs are grouped according to their most likely source of sediments based on cluster analysis, except for the reef at Port Noarlunga North (Inside).

	Al	Cr	Cu	Fe	Ni	P	Pb	Sr	Zn
Reefs (source of sediments)									
Cluster 1 (Torrens River)	6800(566)	25(2)	29(16)	10850(1626)	11(2)	605(49)	35(4)	450(14)	100(0)
Cluster 2 (Onkaparinga River)	3550(404)	14(4)	7(2)	8600(1117)	6(2)	368(59)	17(5)	453(42)	36(10)
Cluster 3 (Onkaparinga Cliffs)	1833(289)	7(1)	2(0)	5567(1201)	3(0)	217(23)	5(1)	467(21)	13(2)
Port Noarlunga North (Inside)	6900	25	24	12000	11	630	90	460	300
Terrestrial sources									
Field River	14000	32	40	19000	18	580	73	330	250
Torrens River	11000	33	37	18000	11	1100	110	72	630
Onkaparinga River	8700	26	16	15000	11	580	32	53	160
Onkaparinga Cliffs	5800	13	3	12000	9	80	5	120	13

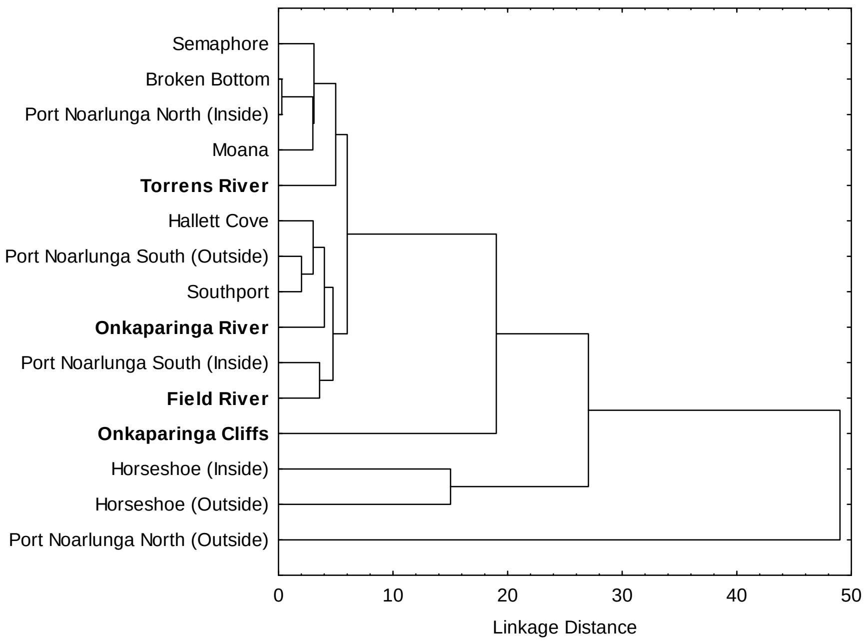

Figure 5. Dendrogram using single linkage (Euclidean distances) highlighting the spatial separation of terrestrial sources (in bold) and reefs based on particle size characteristics (mean, sorting, skewness, kurtosis). The clusters group sites of similar particle size distribution.

Table 4. Mean, sorting, skewness and kurtosis of particle size distributions for potential terrestrial sources (data from Fernandes et al., 2008, except for the Onkaparinga Cliffs, this study), and for reef sediments in autumn.

Site	Mean (µm)	Sorting (µm)	Skewness	Kurtosis
Reefs				
Semaphore	34	3.32	-0.15	0.97
Broken Bottom	40	3.68	-0.17	0.96
Hallett Cove	58	3.54	-0.35	1.14
Horseshoe (Inside)	94	2.90	-0.43	1.50
Horseshoe (Outside)	109	3.47	-0.47	1.78
Port Noarlunga North (Inside)	40	3.98	-0.14	0.97
Port Noarlunga North (Outside)	158	2.53	-0.26	1.71
Port Noarlunga South (Inside)	51	4.13	-0.23	0.90
Port Noarlunga South (Outside)	63	4.17	-0.33	1.00
Southport	61	3.92	-0.25	1.05
Moana	37	4.09	-0.27	0.97
Aldinga	---	---	---	---
Terrestrial sources				
Torrens River	45	4.02	-0.09	0.86
Field Creek	54	6.10	-0.11	0.87
Onkaparinga River	67	4.51	-0.42	1.05
Onkaparinga Cliffs	15	3.96	-0.09	0.85

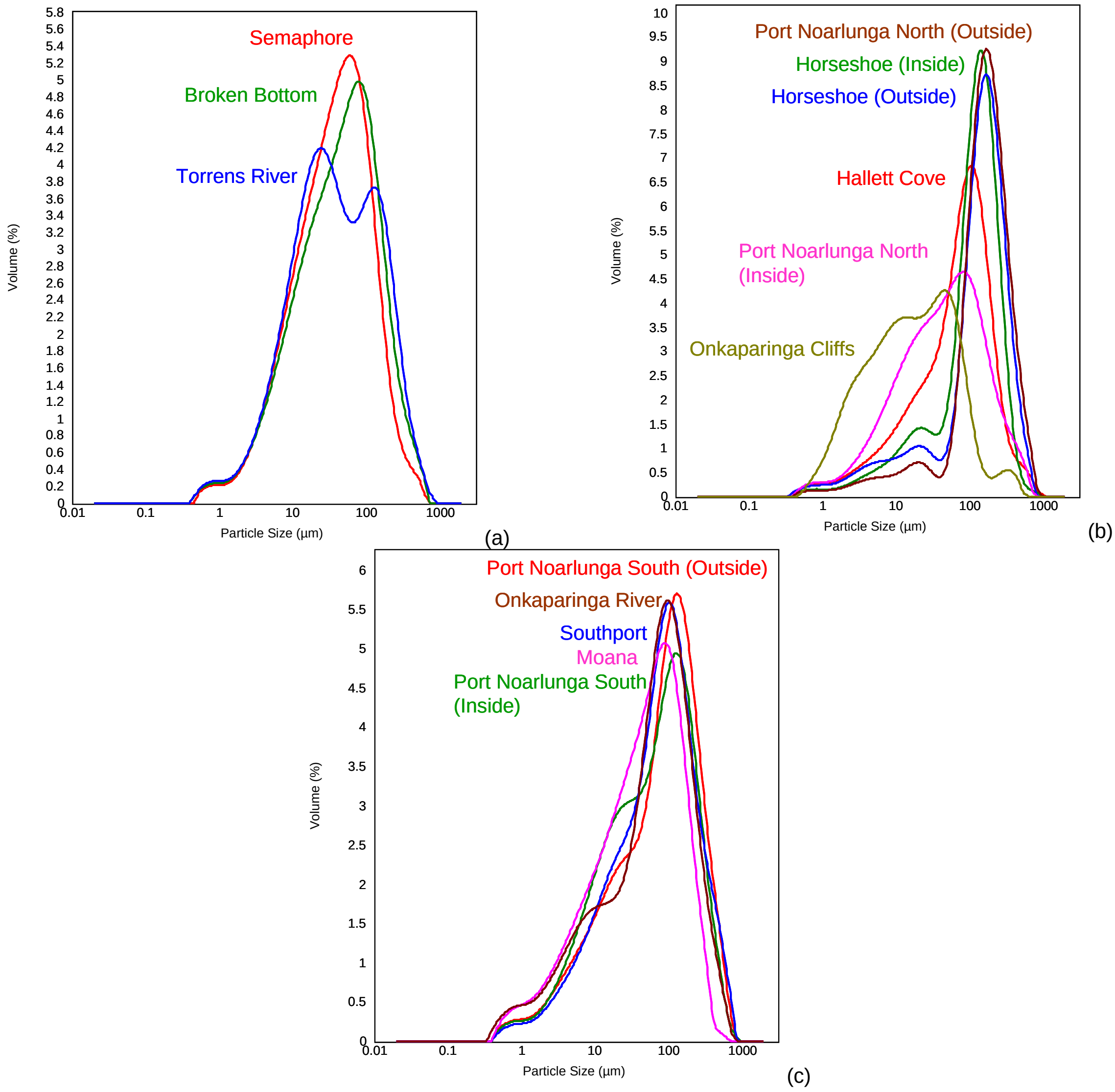

Figure 6. Particle size distributions of sediments from coastal reefs in autumn and potential terrestrial sources in (a) the north of the study area, (b) the area of high deposition between Hallet Cove and Port Noarlunga North and (c) near the mouth or south of the Onkaparinga River. Data for terrestrial sources are from Fernandes et al. (2008) except for the Onkaparinga Cliffs (this study).

4 DISCUSSION

The largest inputs of sediments to reefs along the Adelaide metropolitan coast are likely to derive from the Onkaparinga River and coastal cliffs in the vicinity of its mouth. The Onkaparinga River discharges an estimated 758 tonnes of sediments per year into the marine environment (Wilkinson et al. 2005b), leading to enhanced dry matter, nitrogen and phosphorus sedimentation rates at reefs close or immediately north of its estuary during autumn. Sediments reaching these reefs were coarser and nutrient-depleted compared with other sites along the coast. This riverine signature is observed as far north as Hallett Cove, and as far south as Aldinga, although dry matter sedimentation rates drastically decrease south of Southport.

The high sedimentation rates in the vicinity of the Onkaparinga estuary in autumn were measured after major rainfall occurring in early May (Figure 7). However, the Onkaparinga River has a predominantly rural catchment and extreme soil moisture deficit restricts significant runoff to the wetter months of the year, between June and October (Wilkinson 2005; Wilkinson et al. 2005a). As a consequence, the water level recorded in the Onkaparinga River between January and mid-May was below the limit of 0.8 m required to make the river flow. The most plausible scenario is that direct inputs from the river were negligible in the initial 5 months of the year, but stormy conditions resulted in resuspension and transport of river-derived coastal sediments deposited during winter, when flows typically peak (Wilkinson et al. 2005a). The area is characterized by an energetic wave climate, capable of mobilising fine to medium-sized sand for over 90% of the time, but is poorly flushed, with minimal cross-shore advection (Petrusevics 2005; Pattiaratchi et al. 2007).

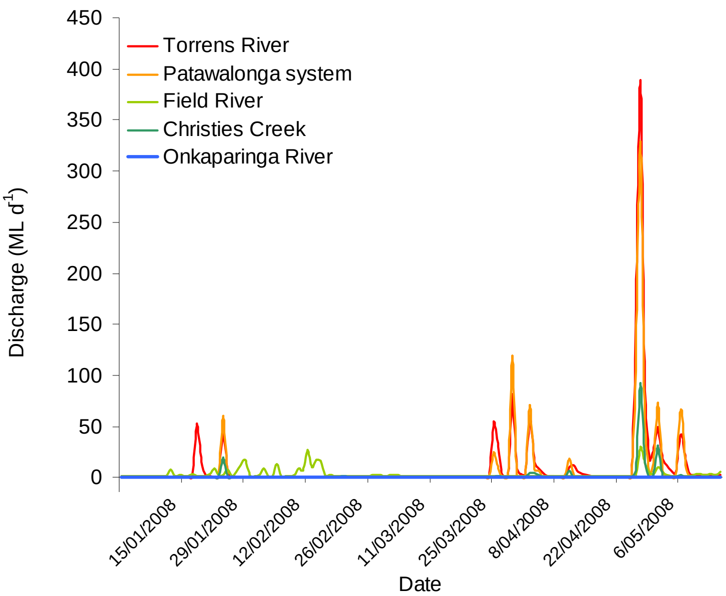

Figure 7. Daily mean river flows between January and May 2008 (Department for Water, Land and Biodiversity Conservation). Flows from the Patawalonga system were estimated as the sum of flows from the Brownhill Creek and Sturt River.

The sea breezes occurring during the warmer months of the year force circulation towards the north (Pattiaratchi et al. 2007), potentially explaining the very high sedimentation rates measured at Port Noarlunga North and Horseshoe. The composition of sediments at these sites suggests that riverine inputs are further enhanced by the erosion of limestone cliff-faces in the vicinity of the estuary. Sediments here are depleted of all major elements when compared to other sites, most likely a consequence of dilution by limestone. Although cliff sediments are mostly fine, these are likely to undergo sorting during transport, so that fine fractions remain in suspension for longer and spread over a large area, with coarser sediments preferentially depositing on nearby reefs. These sites where very high sedimentation was recorded in autumn have shown a decline in condition over the past decade, as indicated by the loss of large brown macroalgae, development of mussel mats, and expansion of the areas characterized by bare substrate (Turner et al. 2007). The loss of large brown species might be related to the competitive advantage of turf-forming algae, poor recruitment and survival under these conditions (Andrew Irving, personal communication). However, the increase in bare substrate cover suggests that the high rates of sediment deposition are also having a detrimental effect on the more resilient turf-forming species (Irving and Connell 2002).

Further north, deposition at Semaphore and Broken Bottom responded to increased flows from the Torrens River and Patawalonga system, with sedimentation rates reaching values >3 times those in winter or summer. Despite this seasonal increase, sedimentation rates are generally low in the area when compared to the southern reefs between Southport and Hallett Cove. The fine sediments reaching Semaphore and Broken Bottom were similar to suspended matter collected from the Torrens River, but the high nitrogen and N:P ratios suggest that these sites might also receive inputs from wastewater treatment plants (Fernandes et al. 2008). To put these data in perspective, the annual load of suspended matter from the Torrens River and Patawalonga system is estimated at 1,826 tonnes, against values for the Bolivar and Glenelg wastewater treatment plants of 1,495 tonnes (Wilkinson et al. 2005b). The deposition of nutrient-rich sediments might be linked to the poor condition of these northern reefs, where small foliaceous and turfing red macroalgae are predominant (Gorgula and Connell 2004; Turner et al. 2007).

5 CONCLUSIONS

Our results suggest that sedimentation on Adelaide's coastal reefs is greatly enhanced by the first rains to break the summer drought, generally occurring in autumn. Deposition of terrestrial sediments decreases with distance from shore, peaking in the nearshore reefs north of the mouth of the Onkaparinga River. The hydrodynamic setting of the area results in strong remobilization of river-derived coastal sediments by waves, erosion of limestone cliffs and minimal cross-shore transport of sediments. The reefs in this area have been flagged as being in poor ecological condition in previous investigations, with loss of large brown macroalgae, development of mussel mats, and expansion of the areas characterized by bare substrate. Although direct riverine inputs are evident in the north of the Adelaide coast on Semaphore reef and Broken Bottom, the area is subject to comparatively lower sedimentation rates. The poor condition of these northern reefs, where small foliaceous and turfing red macroalgae are predominant, might be alternatively linked to the fact that sedimentation in the area is distinctively nutrient-enriched. The limitations of this preliminary work are many, including failure to capture short-term dynamics of nearshore deposition and to comprehensively evaluate terrestrial fingerprints (see discussion in Fernandes et al., 2008). Future studies will need to close knowledge gaps related to these points, and would benefit from more targeted monitoring strategies aimed at unravelling short-term temporal patterns.

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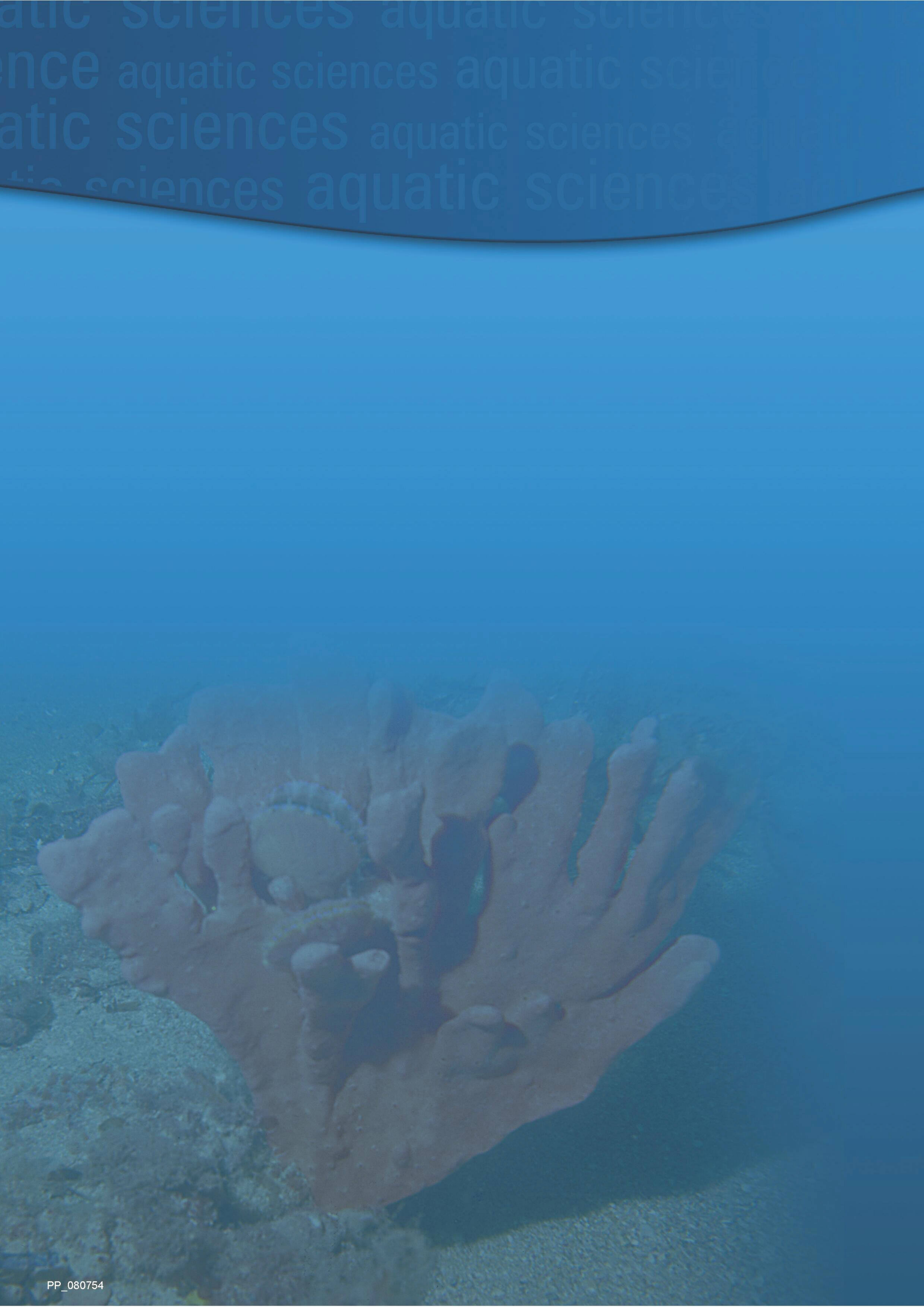

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