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DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Towards safer swimming – Terrigal region

Terrigal Bay sediment contaminants report

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Authorship and citation

This document was prepared by Colin Johnson, Jaimie Potts and Marco Giardina.

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Environment, Energy and Science
Department of Planning, Industry and Environment
4 Parramatta Square, 12 Darcy Street, Parramatta NSW 2150
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (Environment, Energy and Science enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
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Summary

Concern has been expressed about the possibility that stormwater runoff may transport common urban pollutants into the waters of Terrigal Bay. This study looks at pollution levels in seafloor sediments as a measure of the input of contaminants. Sediments play an important role in the aquatic environment and accumulate and store a significant proportion of many nutrients and contaminants coming in from the catchment.

Forty-two sediment sampling sites were selected along 14 transects and three depths (1, 5 and 10 metres) between Avoca Beach to the south and Jewy Bay Beach to the north. Sediments were collected from each site and the concentrations of a wide range of possible contaminants were measured.

Of the 73 contaminants assessed in sediment across the study area, only 33 were able to be detected. The contaminants that were detected were polycyclic aromatic hydrocarbons (PAHs), metals or metalloids. There were no PCBs, pesticides or polychlorinated benzene compounds detected. None of the contaminants were present at concentrations that are likely to cause ecological harm, based on national guidelines.

The only analyte that exceeded ‘low’ guideline concentrations was arsenic, at just two sites at the 5 metre water depth contour in Avoca Bay.

Arsenic is a naturally occurring mineral and is commonly found at slightly elevated levels due to natural processes and localised geology. There were also slightly elevated levels of other metals/metalloids that typically show no enrichment from anthropogenic sources found at these sites. Based on this it is concluded that the arsenic detected here is of a natural, geologic source and as such is not indicative of pollution, nor does it pose any health risks.

The samples were also analysed for microplastics and none were found by the detection methods used. The only plastics found was discarded fishing line at one site.

This study found no evidence of potentially harmful contaminants accumulating in the sediments of Terrigal Bay. In addition, no contaminants were found at levels posing a risk to human or ecological health. The higher level of fine sediment deposition in the Haven and southern Terrigal Bay observed in this study may play a contributory role in the increased turbidity observed in this location relative to surrounding areas.

Terrigal beach. Photo: Central Coast Council

Background

Central Coast Council, in partnership with Beachwatch, monitors and reports on recreational water quality along the NSW Central Coast in accordance with the National Health and Medical Research Council's *Guidelines for Managing Risks in Recreational Waters* (NHMRC 2008). Waters are tested for enterococci bacteria as an indicator of faecal contamination and graded to provide a guide to potential risk to human health from swimming.

During the past decade, Terrigal Beach has been routinely graded as Poor in the annual NSW State of the Beaches Report (DPIE 2019). This has led to considerable concern by local and state governments as well as beach goers, recreational swimmers, surfers, fishers and the broader community.

In January 2019, Central Coast Council commenced a water quality audit, expanding Beachwatch enterococci sampling at a single site (Terrigal Surf Club) to include 10 additional sites along Terrigal Beach from the Terrigal Lagoon mouth to the Haven, as well as sites at Forresters Beach to the north and North Avoca Beach to the south. Enterococci sampling was also undertaken at the major stormwater drain outlets discharging to Terrigal Beach and the Haven to assess their potential as sources of enterococci.

In February 2019, the NSW Government committed $500,000 to address water quality issues at Terrigal Beach and the Central Coast lagoons by undertaking a detailed, scientific audit and analysis of the microbial pollution sources to find solutions to improve water quality.

In April 2019, scientists from the NSW Department of Planning, Industry and Environment (DPIE) and Central Coast Council developed a detailed work program to expand council's water quality audit. Specific objectives of the NSW Government and council's joint water quality audit were to:

- determine if microbial contamination in nearshore waters and stormwater outlets along Terrigal Beach and the Haven and in Terrigal Lagoon was from human sewage or other animal (e.g. bird, dog) faeces
- determine if microbial contamination of Terrigal Beach and the Haven nearshore waters extended into deeper waters of Terrigal Bay
- determine how long contaminated stormwater remained in the bay
- assess pollutants in sediments at Terrigal Beach and the Haven
- assess the spatial extent and temporal persistence of water quality issues in Central Coast lagoons
- identify and prioritise major microbial source locations in Terrigal Beach, the Haven, Terrigal Lagoon and Avoca Lagoon catchments.

Extensive field work was conducted by the NSW Government and Central Coast Council in conjunction with University of Technology Sydney. This is Report #5 and is one of nine technical reports that describe the results of the NSW Government's Terrigal Water Quality Audit research. Additional reports will be provided by Central Coast Council on council's components of the research.

This research has led to the identification of the major biological sources of faecal bacteria and points in the sewage/stormwater drainage system where cross contamination occurs. Central Coast Council can now focus on remediation of these priority areas, and has commenced works in Terrigal Beach, the Haven and lagoon catchments to improve water quality.

Due to the size and complexity of the task the entire work program could take up to six years to complete. If routine monitoring continues to detect unacceptable contamination, further investigation and remediation works may be required.

Why survey sediments? Sediments play an important role in the aquatic environment and are responsible for storing a significant proportion of many nutrients and contaminants coming in from the catchment. They also mediate contaminant uptake, release and transfer between environmental compartments. Many anthropogenically derived materials enter waterbodies through atmospheric deposition, diffuse runoff, or direct discharge into the water. Most hydrophobic organic contaminants, metal compounds and nutrients that enter the water become associated with particulate matter. This particulate matter then settles and accumulates in the bottom sediments, making these sediments an ideal medium in which to detect chronic pollutants that may be highly transient in the water column and thus easy to miss.

Under certain conditions the contaminants in the bottom sediments may be released back into water by diffusive processes or resuspension and enter the food chain. Consequently, bottom sediments are a sink as well as a source of contaminants in the aquatic environment. These contaminants may pose a high risk to the environment and hence need to be assessed.

Objectives

The main objectives of this project are to assess:

- if nearshore sediments along Terrigal Beach and the Haven have accumulated greater concentrations of biotic and abiotic contaminants than sediments along adjacent beaches to the north and to the south
- if contaminant concentrations in Terrigal Bay exceed sediment guidelines for ecological risk for marine environments
- whether increased concentrations of fine grain sediments in Terrigal Bay are potentially causing perceived increases in turbidity
- sediment enterococci levels to determine if the sediments may be contributing to poor swimming water quality.

Collecting samples to test sediment at Terrigal. Photo: DPIE

Materials and methods

Site selection

Forty-two sediment sampling sites were selected along 14 transects at three depth contours at 1, 5 and 10 metres between Avoca Beach to the south and Jewy Bay Beach to the north (Figure 1) from LiDAR bathymetry maps produced by DPIE.

Sediment sampling

Sediments were sampled by two methods. At the near shore sites (~1 m depth), sediments were collected by hand in the surf zone using polycarbonate cores. Cores were pushed into the sediment, capped and retrieved. At the 5 and 10 metre depth sites, sediments were collected from the DPIE research vessel Badoo using a Shipek grab sampler. This heavy weight sampler (about 50 kg) is designed to collect an approximately three-litre sample from a sampling area of about 20 centimetres × 20 centimetres. The grabs were lowered and retrieved from the boat using a davit and capstan. Once retrieved, 50 millilitres of the top 2 centimetres of sediment in each core and grab were sub-sampled and placed in a sterile vial for genomic testing. A further 10 millilitres of this top 2 centimetres was mixed with 100 millilitres of filtered ocean water before the supernatant was collected (Boehm et al. 2009), chilled to <4°C and retained for enterococci assessment at Kincumber wastewater treatment plant (Enteroalert™). The remainder of the sediment sample was homogenised and placed into separate glass and plastic containers for contaminant analysis. Genomic samples were placed in an onboard cryogenic Dewar and immediately frozen. Glass and plastic containers for contaminant analysis were placed on ice in an esky and transported to DPIE laboratories for analysis.

Analytical methods

Sediment samples were analysed for a range of potential contaminants typically found in urban catchments, including heavy metals, metalloids, semi-volatile organic compounds and microplastics (Table 1). Particle size distribution and total organic carbon were also measured. To measure metals and metalloids, samples were digested with aqua regia (a mixture of nitric acid and hydrochloric acid) and analysed by inductively coupled plasma atomic emission spectroscopy (ICPAES). To measure mercury, samples were digested with acid and analysed by cold vapour atomic absorption spectroscopy (CVAAS). To measure semi-volatile organic compounds, samples were extracted with dichloromethane. Extracts were concentrated under a nitrogen gas stream and analysed by gas chromatography–mass spectrometry (GC–MS). To measure microplastics, solvent was used to dissolve the plastic in the sample. The solvent was evaporated under nitrogen, leaving a plastic residue that was weighed (Fuller & Gautam 2016). To analyse particle size distribution, samples were suspended in water and analysed with a laser particle size analyser (LA-960, Horiba, Kyoto, Japan). Total organic carbon was analysed by reacting the sample with acid to remove inorganic carbonates and then analysing with an elemental analyser to measure total organic carbon. Sediment samples were analysed at the DPIE Environmental Forensics Laboratory (Lidcombe) and DPIE Soil and Water Environmental Laboratory (Yanco).

Figure 1 **Sediment sampling sites across the 14 transects from Avoca Beach to Jewy Bay**

Site codes TBS X.Y refer to transect #X numbered from south to north and .Y refers to distance offshore with TBSX.1 a shoreline sample (~1 m depth), TBSX.2 at ~5 m depth and TBSX.3 at ~10 m depth.

Table 1 List of sediment contaminants assessed from Avoca Beach to Jewy Bay

PAH*	Other organic	Pesticides	Metals/metalloids
Acenaphthene	**PCB***	Chlorpyrifos	Antimony*
Acenaphthylene	Aroclor	**Banned pesticides**	Arsenic*
Anthracene	**Chlorophenols**	Aldrin	Barium
Benzo(a)anthracene	2,3,4,6-Tetrachlorophenol	BHC	Beryllium
Benzo(a)pyrene	2,4,5-Trichlorophenol	Chlordane*	Boron
Benzo(b)fluoranthene	2,4,6-Trichlorophenol	DDT*	Cadmium*
Benzo(ghi)perylene	2,4-Dichlorophenol	Dieldrin*	Chromium*
Benzo(k)fluoranthene	2,6-Dichlorophenol	Endosulfan	Cobalt
Chrysene	2-Chlorophenol	Endrin*	Copper*
Dibenzo(ah)anthracene	**Phenols**	Heptachlor	Lead*
Fluoranthene	2-Methylphenol	Methoxychlor	Lithium
Fluorene	2-Nitrophenol		Manganese
Indeno[1,2,3-cd]pyrene	3+4-Methylphenol		Mercury*
Naphthalene	Phenol		Molybdenum
Perylene	**Polychlorinated Benzene**	**Others**	Nickel*
Phenanthrene	1,2,3,4-Tetrachlorobenzene	Microplastics	Phosphorus
Pyrene	1,2,4,5-Tetrachlorobenzene	Organic carbon	Selenium
	1,2,4-Trichlorobenzene	Grain size	Silver*
	1,2-Dichlorobenzene	Enterococci	Strontium
	1,4-Dichlorobenzene		Sulfur
	2,4-Dinitrotoluene		Thallium
	Phalate plasticisers		Tin
			Titanium
			Vanadium
			Zinc*

* guideline values exist

Results

Contaminants

Of the 73 analytes assessed in sediment across the study area, 33 were detected (Table 2), with the remainder below detection limits indicating they were well below ANZG (2018) guideline thresholds (Figure 2). All detected contaminants were PAHs, metals or metalloids with no PCBs, pesticides or polychlorinated benzene compounds detected. Of those that were detected, and for which trigger values are available, maximum concentrations were mainly well under the lowest ANZG (2018) trigger values (Figure 3). The only exception was arsenic, which had a maximum concentration of 21 milligrams per kilogram at sites TBS 3.2 and TBS 4.2 in Avoca Bay, slightly higher than its lowest guideline value (20 mg kg^{-1}). Arsenic showed a similar concentration distribution to metals that are not associated with anthropogenic sources such as manganese and vanadium, with which it shares geochemical properties (Figure 4).

Table 2 Sediment contaminants detected in Terrigal Bay

PAH	Metals/metalloids	Others
Acenaphthene	Arsenic	Microplastics
Acenaphthylene	Barium	Organic carbon
Anthracene	Boron	Grain size
Benzo(a)anthracene	Chromium	Enterococci
Benzo(a)pyrene	Copper	
Benzo(b)fluoranthene	Lead	
Benzo(ghi)perylene	Lithium	
Benzo(k)fluoranthene	Manganese	
Chrysene	Nickel	
Dibenzo(ah)anthracene	Phosphorus	
Fluorene	Strontium	
Indeno(1,2,3-cd)pyrene	Sulfur	
Perylene	Titanium	
Phenanthrene	Vanadium	
	Zinc	

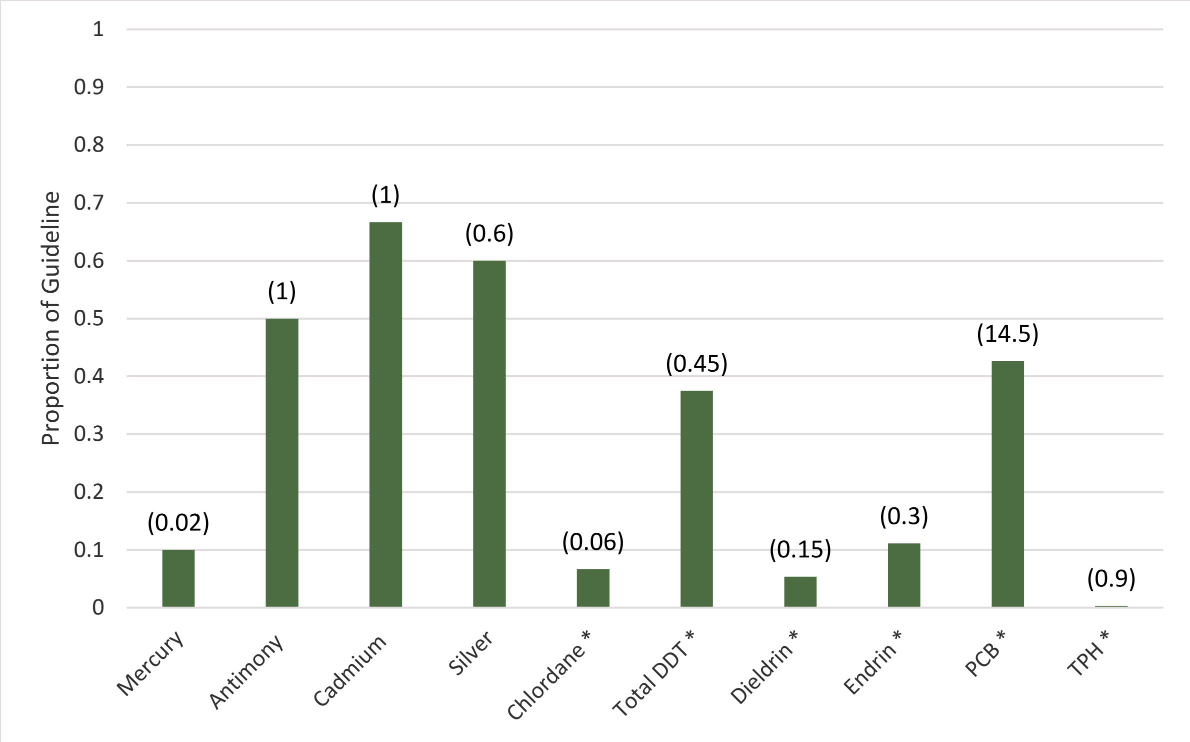

Figure 2 **Limits of detection (LOD) as a proportion of guideline 'low' threshold (ANZG 2018)**

LOD in brackets, mercury in µg/kg, remainder in mg/kg. * denotes concentrations normalised to 1% of total organic carbon as per guidelines.

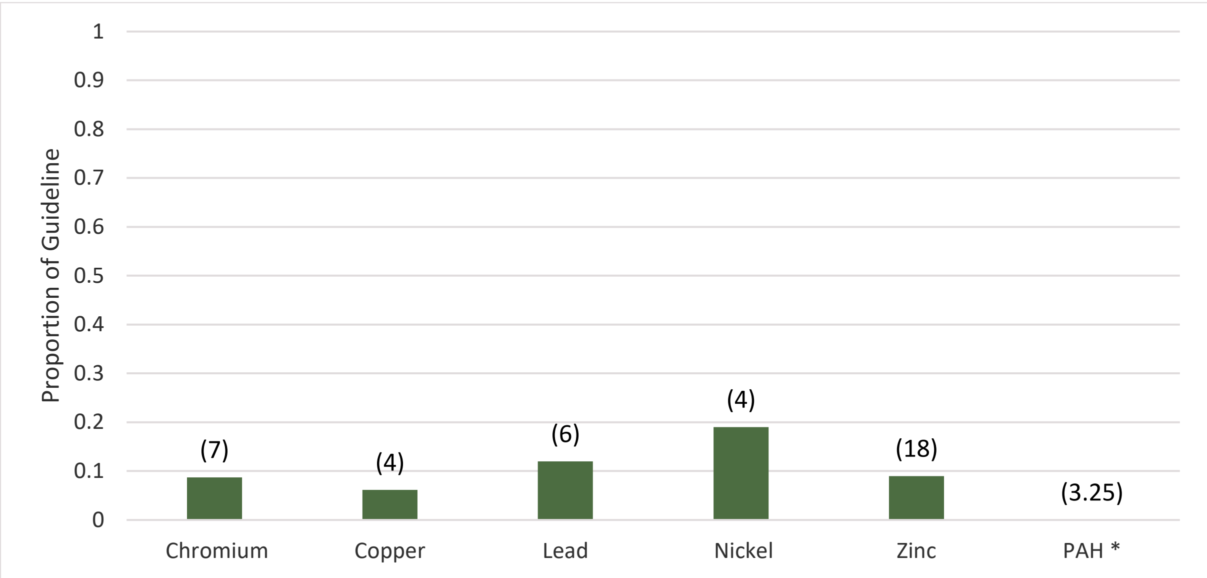

Figure 3 **Maximum concentration found as a proportion of 'low' guideline value (ANZG 2018)**

Maximum detected concentration (mg/kg) in brackets. * denotes concentrations normalised to 1% total organic carbon as per guidelines.

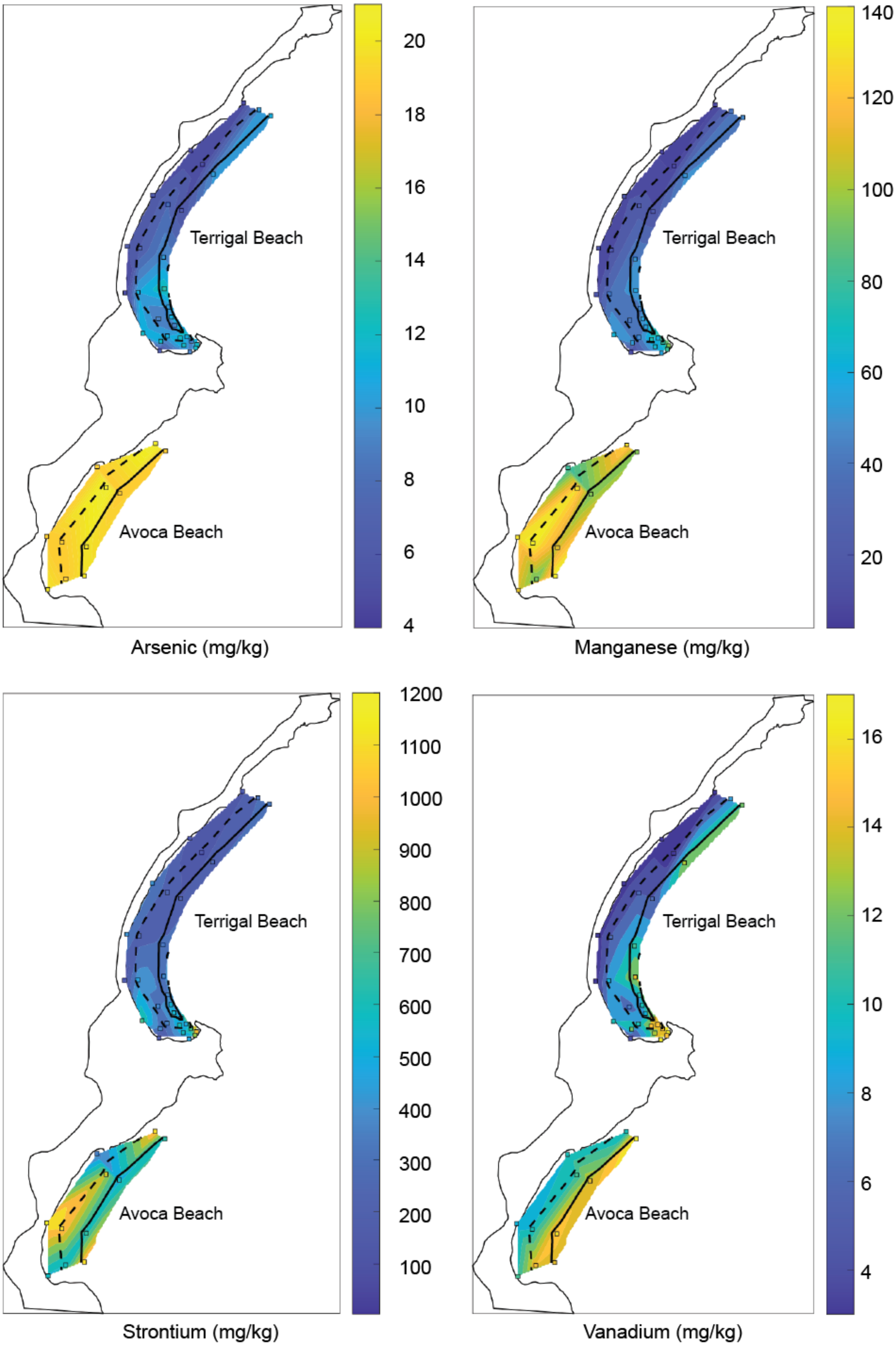

Figure 4 **Sediment concentration (mg/kg) contour maps for arsenic, manganese, strontium and vanadium in Terrigal and Avoca bays**

Dashed line: 4 m depth; solid line: 9 m depth.

The concentration of total organic carbon was very low across all sites, ranging from <0.01% (LOD) to 0.3% with greatest values within the Haven (Figure 5a). Enterococci levels in sediment were likewise low in most areas, with greatest levels found in the Haven (Figure 5b). Microplastics, in the form of fishing line fragments, were only detected at one site off Avoca Beach.

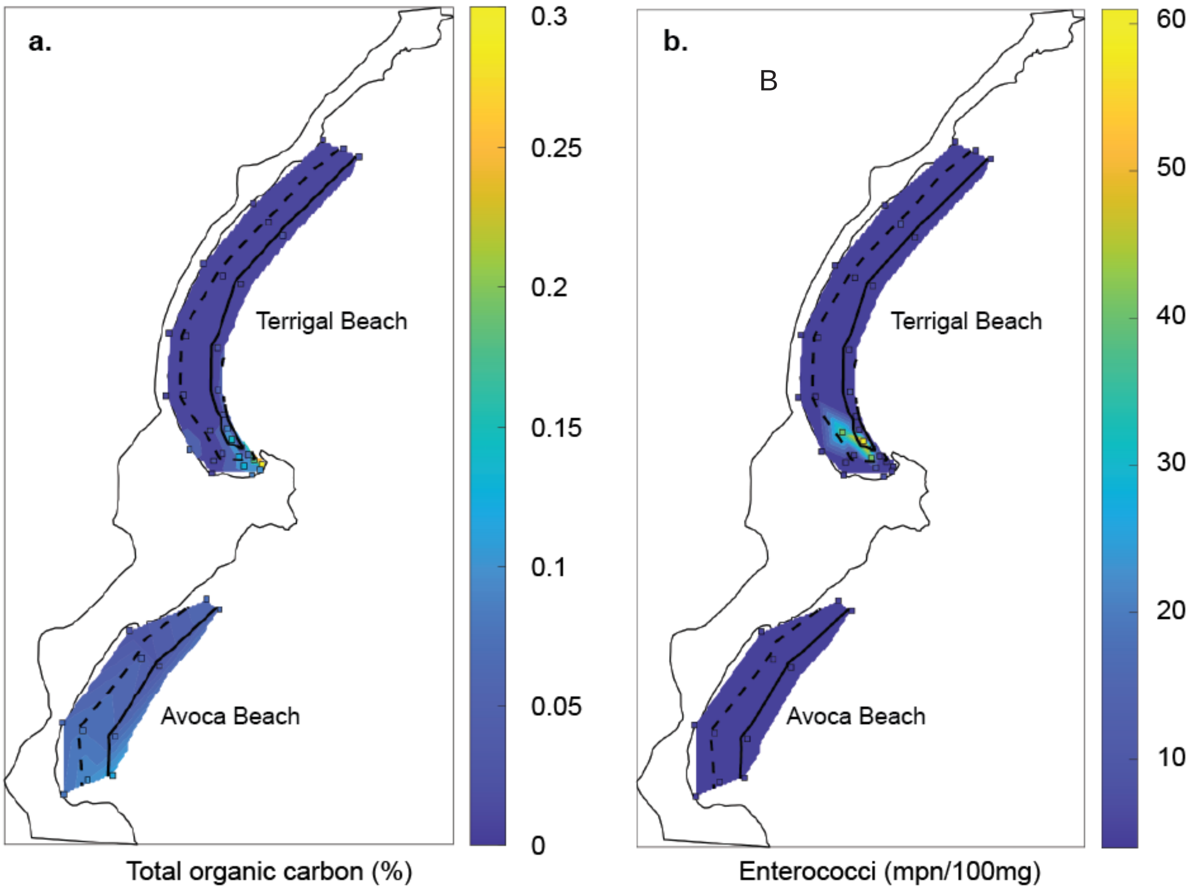

Figure 5 **Maps of sediment distribution of total organic carbon (A) and enterococci concentrations (B) in Terrigal and Avoca bays**

Dashed line: 4 m depth; solid line: 9 m depth.

Sediment grain size

Sediment grain size analysis was undertaken to assess if fine grain sediments were greater in Terrigal Bay compared to sites to the north and south. Both Terrigal Bay and Avoca Beach are dominated by coarse and medium sands (250–1000 µm) (Figure 6). In Avoca Bay, coarse sand (500–1000 µm) represents about 25–42% of sediment in both the shoreline and 10 metre depths. This is reduced at 5 metres depth to 3–20%, except in the north of the bay where coarse sand comprises 13–62% at 5 metres depth. Medium sand is highest at the northern and southern extremities of Avoca Beach along the shoreline, and minimal at 5 metres depth in the centre of the bay (<10%).

In Terrigal Bay a gradual change of sediment composition from the shore to up to 10 metres depth is evident. In the area from the shore to up to 5 metres depth, coarse sand (500–1000 µm) makes up 33–78% of sediment volume. In the same area, medium sand (250–500 µm) comprises 6–44% of the sediment volume. As depth increases from 5 metres to 10 metres, a noticeable reduction in coarse sand occurs simultaneously with an increase in medium sand, with the first constituting between 18 and 69% and the second between 15 and 51% of the total volume of the sediment.

Southern Terrigal Bay and the Haven are the only areas where substantial sediment fractions of fine sand (125–250 µm) and silt mud (<63 µm) were found (Figure 7). Here, fine sand (125–250 µm) constituted between 20 and 48% of the total volume of sediment, while silt mud (<63 µm) ranged between 31 and 40%.

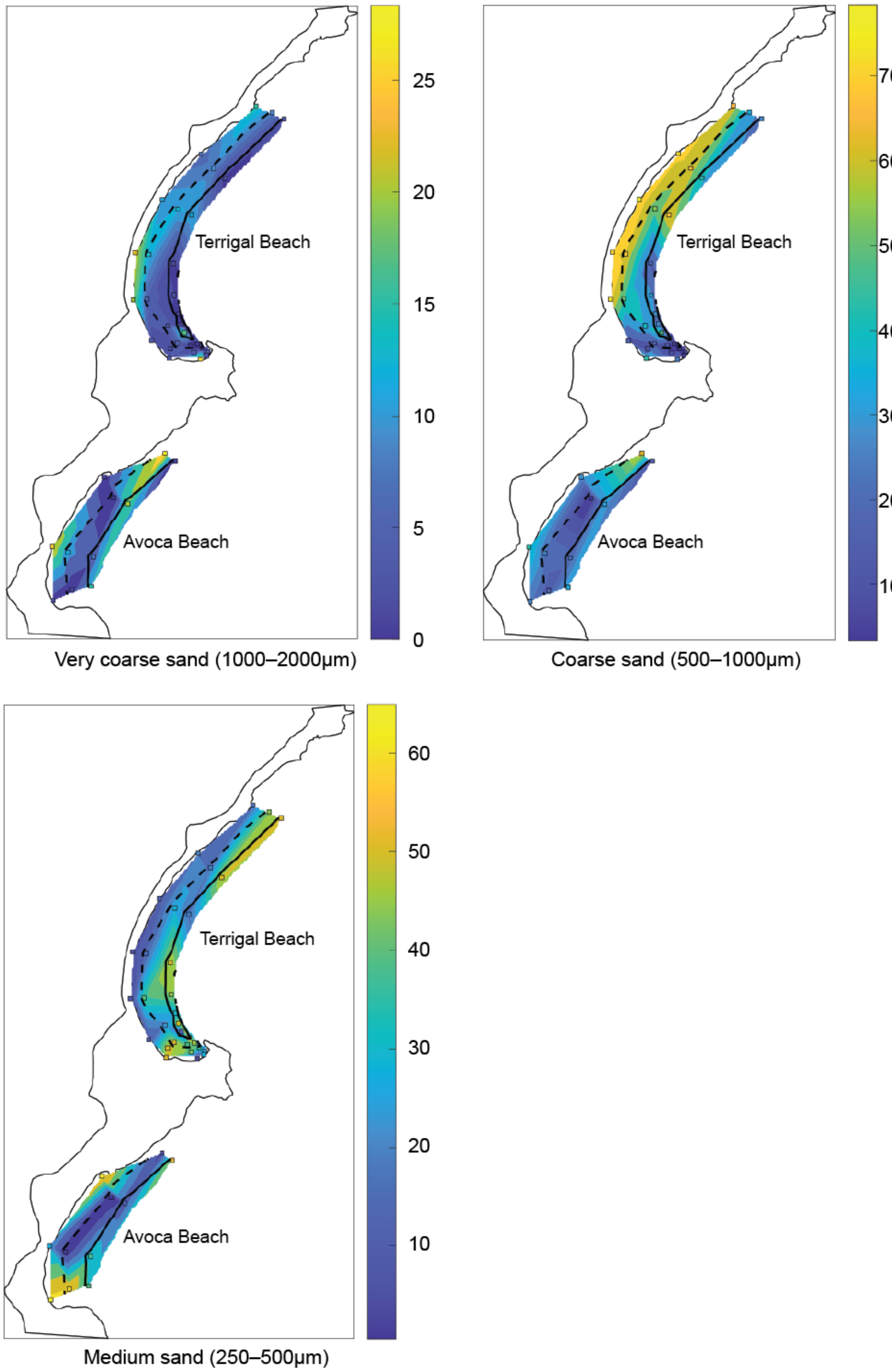

Figure 6 **Course particle size distribution of the Terrigal and Avoca bays' seafloors**
Dashed line: 4 m depth; solid line: 9 m depth.

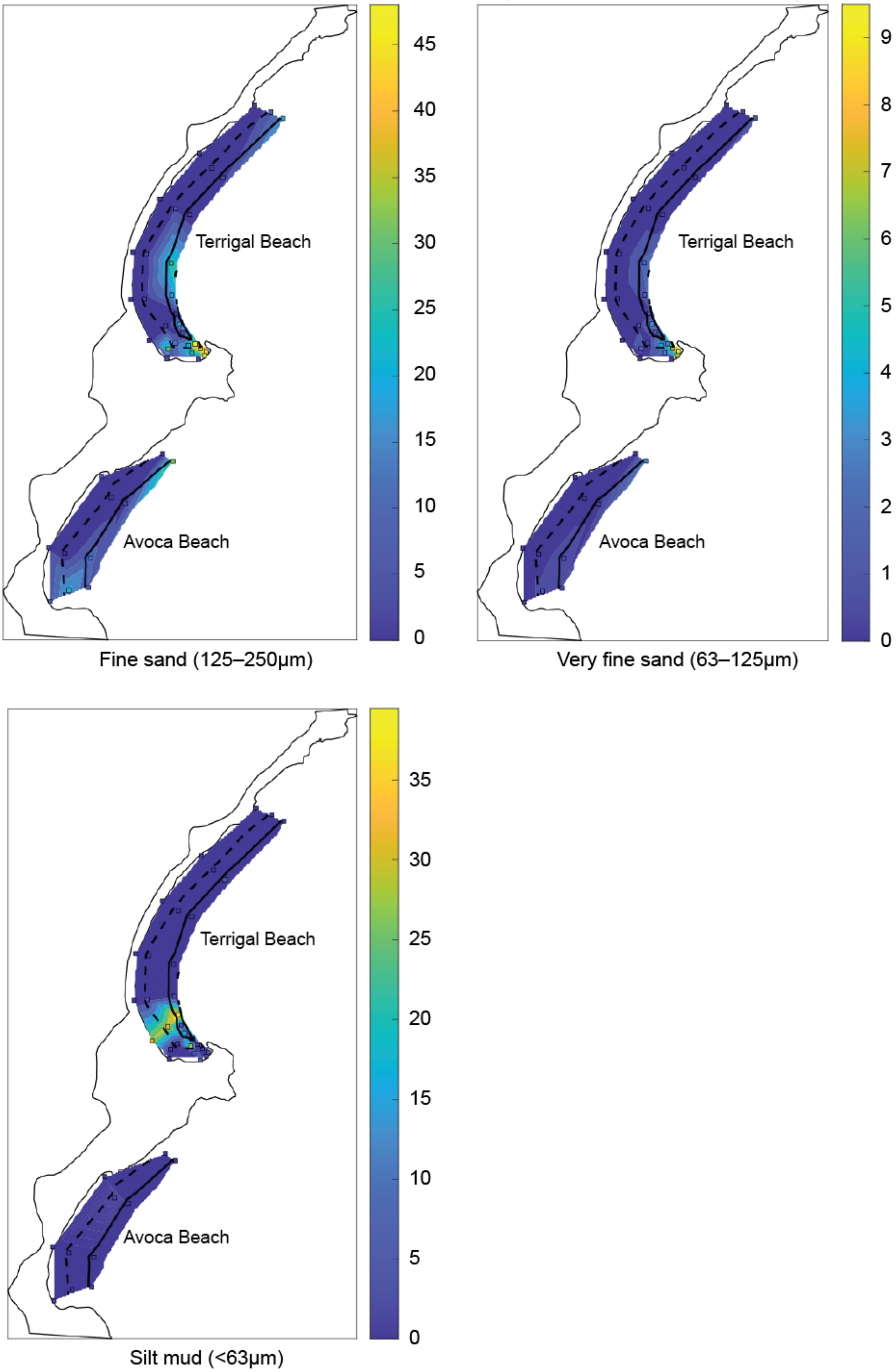

Figure 7 **Fine particle size distribution of the Terrigal and Avoca bays' seafloors**
Dashed line: 4 m depth; solid line: 9 m depth.

Discussion

This study found no indication that sediments in Terrigal Bay are accumulating contaminants that would pose a risk to either human or ecological health. Contaminant concentrations in sediments in Terrigal Bay and in sites to the north and south measured in this study were well below ANZG trigger values (ANZG 2018) and in many cases below analytical detection limits. The only analyte that exceeded 'low' ANZG guideline concentrations was arsenic, with these exceedances confined to two sites on the 5 metre depth contour in Avoca Bay.

Although arsenic enrichment can result from anthropogenic causes, it is also commonly found at elevated levels due to natural processes and localised geology (Duker et al. 2005). For this reason, localised background levels are required to determine if any detected exceedances are in fact due to pollution or are just a natural feature of the environment in the examined area (Warne et al. 2018). In addition, there is a marked difference in the toxicology of the two main species of arsenic present in the environment. The arsenic (V) species is the major contributor to total arsenic in sediments (Manning & Goldberg 1997), and is far less toxic than arsenic (III) (Neff 1997; Duker et al. 2005), such that the sediment levels found offshore from Avoca Beach do not pose threats to human or ecological health. These Avoca transects sampled in this study were localised background samples to aid in interpretation of Terrigal Bay samples and reinforce a lack of accumulation in Terrigal Bay. The close conformity between arsenic and other metals/metalloids that typically show no enrichment from anthropogenic sources and for which arsenic can substitute in mineralogy, indicates that the arsenic detected here is of a natural, geologic source and as such is not indicative of pollution nor does it pose any health risks.

In contrast to these potential toxicants, there is evidence that the southern section of Terrigal Bay and the Haven accumulate fine sediments (size <125 μm) at higher rates than in surrounding areas, with a corresponding minor increase in organic carbon in this area. This deposition is likely driven by the influence of coastal morphology on current circulation patterns in this area (see Report #5), with the slower though transient eddies prevalent in the Haven reducing the carrying capacity of the water column and thus allowing smaller and lighter particles to fall out of suspension and accumulate on the seabed in this location. The localised peaks in enterococci found in this area are equally likely a result of this reduced current velocity and increased deposition, with bacteria persisting in sediments long enough for detection. The levels detected here are insufficient to have adverse impacts on swimming water quality however.

One impact of fines accumulation in sediments in southern Terrigal Bay and the Haven is increased turbidity due to wind and/or wave driven resuspension. This is a major potential driver of the relatively high turbidity in the Haven and southern Terrigal Bay observed periodically by the community (see Report #6).

Conclusion

This study found no evidence of potentially harmful contaminants accumulating in the sediments of Terrigal Bay. In addition, no contaminants were found at levels posing a risk to human or ecological health.

However, the higher level of fine sediment deposition in the Haven and southern Terrigal Bay observed in this study may play a contributory role in the increased turbidity observed in this location relative to surrounding areas.

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