Volvo Cars Australia - Sydney Institute of Marine Science 'Living Seawall'

Biodiversity Assessment

Volvo Living Seawall at Bradfield Park, Milsons Point, New South Wales, Australia. Image credit: Maria Vozzo, SIMS

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Executive Summary

The hardening of shorelines around the world with protective structures such as seawalls is a growing cause of biodiversity loss. The creation of “living” seawalls is a novel and adaptable solution involving the installation of modular habitat panels. These enhance biodiversity and could be applied along the many tens of thousands of kilometers of global seawalls. Habitat panels, mimicking mangrove roots, were installed on ~18 m^2 of seawall at Milsons Point, NSW, Australia and their benefits to biodiversity assessed.

After 24 months, a total of 91 species were observed on the Volvo Living Seawall. There were 73% more species observed on mangrove panels (90 species) than on flat panels (52 species). Forty-four percent of the species observed in this study were unique to the Volvo Living Seawall and not found on the control seawalls. Further, the Volvo Living Seawall had ~30-40 more species than two control (i.e. unmodified) sections of seawall. Between 18 and 24 months, the Volvo Living Seawall had acquired additional species, suggesting the full benefits of the Living Seawall may be yet to be realized and may further increase through time.

There were a variety of species living on the panels including sessile (i.e. non-mobile) algae (seaweeds), mussels, oysters, barnacles and sponges. Mobile species living on the wall included limpets, snails, chitons and small crustaceans. Mussels, important filter feeders, were observed on the mangrove panels, but were absent from flat panels. Similarly, the native habitat-forming kelp, *Ecklonia radiata*, was observed on the mangrove panels of the Volvo Living Seawall but not on the flat panels. Kelp, like other algae, sequesters carbon (i.e. removes it from the carbon cycle) as it grows.

There was a greater diversity of sessile species on the mangrove panels compared to flat panels at each of the intertidal heights. At the low intertidal height, algae were the most abundant sessile species on the mangrove panels. In the mid intertidal zone, barnacles and oysters were the most abundant sessile species on the mangrove panels. Similarly, the mangrove panels had greater mobile species richness than flat panels across the whole Living Seawall. Mobile species were most abundant at the high and mid intertidal heights and here the mangrove panels supported up to 5 times the number of mobile species than the flat panels.

Overall, the results demonstrate that the Volvo Living Seawall is achieving its primary goal of enhancing seawall biodiversity. They also suggest that through time, the Living Seawall may start to contribute to important ecosystem functions such as maintenance of clean water and sequestration of carbon, that could be quantified through subsequent monitoring programs.

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Introduction

Today, over 50% of Sydney Harbour's shoreline is armoured by seawalls – a figure that is similar to many urbanised estuaries elsewhere in Australia and the world. The flat and relatively featureless surface of seawalls supports reduced space for attachment and growth of marine species as compared to the natural habitats they have replaced (Chapman 2003, Chapman and Bulleri 2003, Bulleri et al. 2005). Thus, new designs for marine urban structures are urgently needed that provide habitat features to support native marine biota.

Seawalls, especially in Sydney Harbour, were typically built to reclaim land, often replacing many of the soft sedimentary habitats such as mangroves, saltmarsh and mud flats that once lined the shoreline (reviewed by Mayer-Pinto et al. 2015). In southeast Australia, habitat forming species such as mangroves support diverse marine communities. The complex root structure of mangroves provides a surface on which other sessile species, such as oysters or algae settle, which in turn, may facilitate mobile species such as snails (Bishop et al. 2012). Therefore, loss of these natural habitats can have significant implications on marine life.

For over 20 years, Sydney-based researchers have been investigating the impacts of artificial structures on marine life and developing methods to improve the ecological value of these structures. Early interventions included removing blocks in walls to serve as rock pools (Chapman and Blockley 2009), retrofitting seawalls with flowerpots (Browne and Chapman 2011, 2014, Morris et al. 2017), or attaching complex tiles to seawalls (Strain et al. 2018a, Ushiama et al. 2019; Figure 1). Such experimental interventions have found that the addition of habitat complexity to marine urban structures through the introduction of pits, grooves and water-retaining features enhances the abundance and biodiversity of invertebrates and algae (reviewed by Strain et al., 2018). In addition to biodiversity benefits, complex tiles support filter feeding communities that can exhibit up to 50% higher particle removal rates than flat tiles (Vozzo et al. 2021).

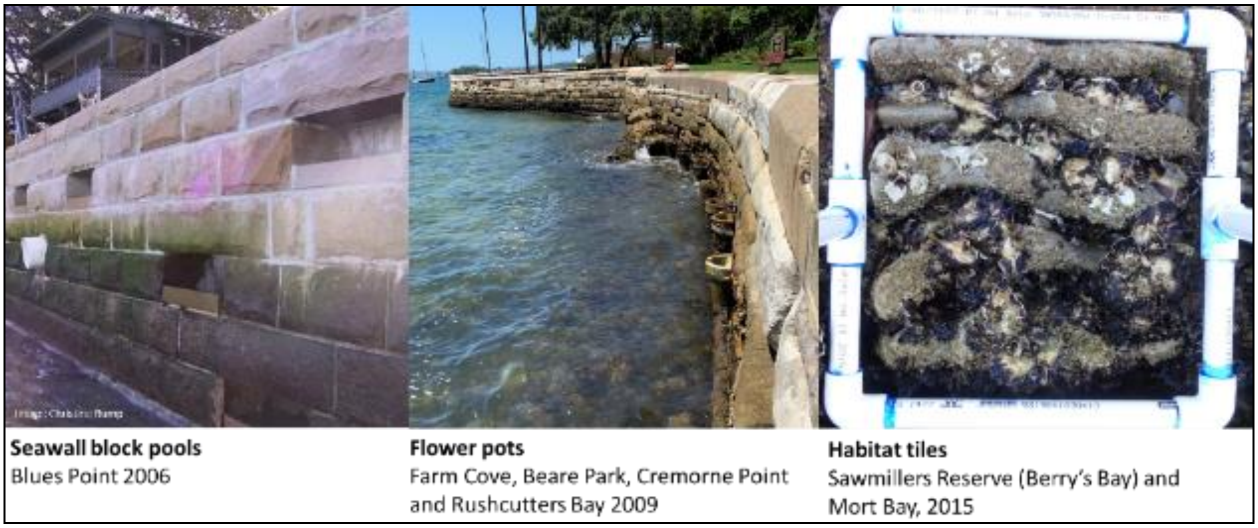

Figure 1: Evolution of early seawall "greening" initiatives in Sydney Harbour. Image credits: Christina Bump (left), Maria Vozzo (center) and Beth Strain (right).

Previous experimental work has demonstrated that seawall "greening" can enhance biodiversity on scales of tens of centimeters, but to enhance biodiversity at the scales that matter for maintenance of clean water, fisheries productivity and carbon sequestration, larger scale interventions are needed. Here, we investigate the benefits to biodiversity of the Volvo Living Seawall, a greening project that covers approximately 18 m^2 of an intertidal seawall. We expect that sections of seawall receiving habitat panels will support more biodiversity than unmodified sections of seawall, and that habitat panels containing complex features will support more biodiversity than flat panels. The data presented in this report represent findings during the first 24 months after panel installation. Biodiversity is expected to further increase over longer time scales, as communities continue to develop.

Methods

Installation

In October 2018, a total of 50 complex habitat panels with a design that mimics mangrove roots, and 9 flat (experimental control) panels were installed along a 13 m section of seawall at Milsons Point, New South Wales, Australia (33°50'59.5"S,151°12'46.4"E). The panels spanned a range of approximately 18 m^2, from the low to high intertidal elevations. We assessed benefits of the panels to marine life at high, mid and low intertidal elevations (Figure 2). The panels were installed using stainless steel rods that were drilled into the seawall such that there was an 8-10 cm gap between their back surface and the seawall. This was done to avoid disruption of the existing marine life on the seawall, which would be necessary if the panels were flush. Colonisation was assessed only the outwards facing (i.e., front) surface of the panels.

Figure 2: Volvo Living Seawall installation along the Bradfield Park seawall in Milsons Point, New South Wales, Australia. Intertidal biodiversity was sampled in the high, mid and low intertidal zones. Image credit: Maria Vozzo, SIMS.

Biodiversity surveys

Surveys were conducted to assess the benefits of mangrove panels at the site-scale (i.e. compared to unmodified seawalls) and at the panel-scale (i.e compared to flat panels). We compared invertebrate and algal (seaweed) communities between (1) the site of installation of the 50 mangrove panels and (2) two adjacent sections of seawall without panels (control seawalls) one month prior to installation (September 2018), 6 months (May 2019), 12 months (October-November 2019), 18 months (May 2020) and 24 months (October 2020) after installation (Figure 3). Within the Volvo Living Seawall, ecological communities were compared between complex mangrove panels and flat panels during the 6, 12 and 24 month sampling events.

At each site, the low- mid- and high-shore intertidal assemblages were sampled. In the intertidal environment, a distinct “zonation” of different communities often occurs within each height as a result of the tidal cycle and how much time each zone is underwater during each day. Therefore, we sampled each height as we expected the communities within these heights to be dominated by different species and respond differently to the addition of the habitat panels.

In September 2018, five quadrats (25 x 25 cm, Glossary) were positioned randomly at each intertidal height, and at least 50 cm apart, along a 10 m stretch of seawall. For each quadrat, both primary (i.e. attached directly to the substrate) and secondary (i.e. growing on top of other species) cover (growth) were recorded, separately. Mobile species within each plot were counted by species. Sessile species present in the quadrat but not counted under an intersecting point were recorded. Sessile species were classified into one of 10 groups, each of which perform different ecological functions: algae, ascidians, barnacles, bryozoans, corals, hydrozoans, mussels, oysters, sponges and tubeworms. After the 6 month (May 2019) sampling time point, we surveyed the community within 10 replicate quadrats at each intertidal height for each subsequent time point.

To assess the efficacy of the mangrove panel design in providing habitat for invertebrates and algae, we compared communities on (1) panels with the mangrove design (n=3) and (2) flat panels without the mangrove design (n=3) at each of the three intertidal heights. Mangrove and flat panels were sampled by placing one 25 x 25 cm quadrat in the center of each panels, as described above.

Figure 3: Map of study sites: Volvo Living Seawall, Control seawall 1 and Control seawall 2.

Results

Site comparisons

The total number of species living on the Volvo Living Seawall displayed some seasonal variation (generally decreasing in winter and increasing in summer), but over and above this seasonality was a trend for an increasing number of species living at this site through time (Figure 4). After 6 months, a total of 55 species were observed living on the Volvo Living Seawall. By 12 months, the total number of species on the Volvo Living Seawall was 78 and by 24 months the number of species was 91, including 23 mobile species and 68 sessile species. In contrast, the maximum number of species recorded on a control seawall (without Living Seawall panels) was 43, recorded at 24 months (site 1: 16 mobile and 27 sessile; site 2: 9 mobile and 22 sessile).

Consequently, by 24 months, at the mid intertidal height, there were significantly more species on the Volvo Living Seawall than either of the control seawalls (ANOVA: site, $F_{2,27}$ = 20.68, $p < 0.001$; Tukey tests: $p < 0.001$). Similarly, the Volvo Living Seawall had a greater species richness than the control seawalls at the low intertidal height (ANOVA: site, $F_{2,27}$ = 112.40, $p < 0.001$; Tukey tests: $p < 0.001$: Living Seawall > Control Seawall 1 > Control Seawall 2). There was no difference in species richness among sites in the high intertidal, where richness was least (ANOVA: site, $F_{2,27}$ = 0.08, $p = 0.923$).

Of the 91 species observed on the Volvo Living Seawall after 24 months, 42 were not found on the control seawalls, including algae such as *Gracillaria secundata, Pterocladia capillacea, Sargassum sp.,* and *Ulva intestinalis*; barnacles such as *Catomerus polymerus*, and other filter-feeding invertebrates such as bryozoans, hydrozoans and sycanoid sponges. Many of these species are important habitat-forming species that help facilitate other sessile and mobile species (Figure 5; Appendix 1).

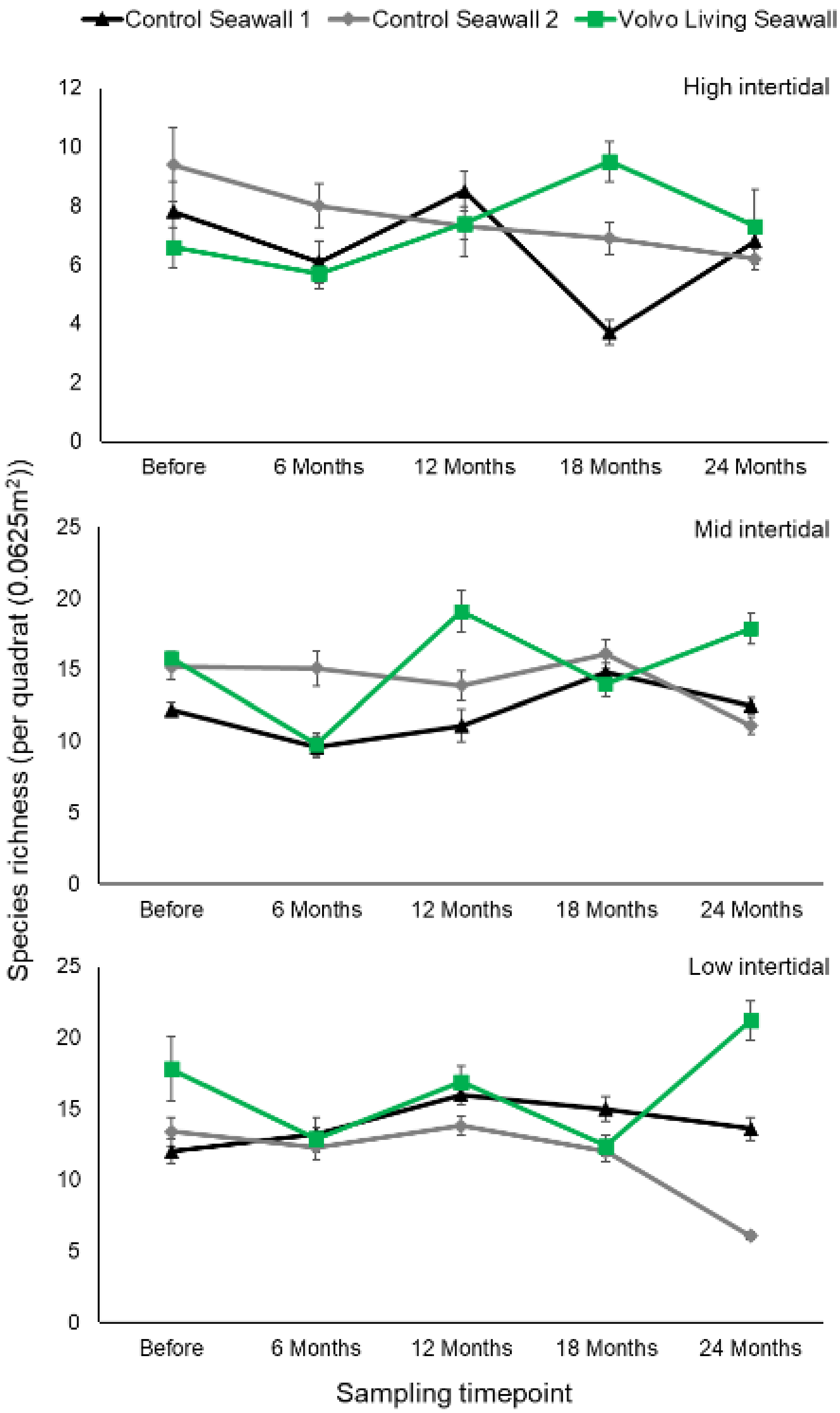

Figure 4: Mean (± SE) number of species observed per quadrat (covering an area of $0.0625m^2$) eight at each of the intertidal heights at the Control Seawall 1, Control Seawall 2 and Volvo Living Seawall during each of the sampling points. Note the high intertidal graph has a smaller y axis range than the mid and low intertidal graphs. The mean is calculated from n=15 quadrats per site during the "Before" sampling and n=30 quadrats per site during 6-24 month sampling.

Figure 5: The Living Seawall habitat panels are home to other important habitat-forming species such as the native kelp, *Ecklonia radiata*, and filter-feeding mussels, *Mytilus spp.*, that can be seen here growing on the mangrove panels. Image credit: Maria Vozzo, SIMS.

Panel design comparisons

By 24 months, the mangrove panels had greater species richness than flat panels at each of the mid (mean ± SE; mangrove: 17 ± 1; flat: 7 ± 1; ANOVA: panel, $F_{1,4}$ = 42.78, p = 0.003) and high (mangrove: 12 ± 1; flat: 2 ± 1; ANOVA: panel, $F_{1,4}$ = 88.92, p = 0.001) intertidal heights. Species richness was similarly high on both mangrove (21 ± 3) and flat (17 ± 2) panels at the low intertidal height (ANOVA: panel, $F_{1,4}$ = 5.26, p = 0.084).

Mobile species

All 23 mobile species were observed on the mangrove panels, but only 8 of the 23 mobile species were observed on the flat panels. Mobile species were most abundant on the mangrove panels at the high intertidal height followed by the mangrove panels at the mid intertidal height (Table 1). Of the mobile species observed on mangrove panels in the mid intertidal zone, false limpets (*Siphonaria denticulata*) were the most abundant, comprising 68% of the species observed, followed by the chiton *Sypharochiton pelliserpentis*, which comprised 25% of the species observed. On mangrove panels in the high intertidal zone, one snail species (*Afrolittorina acutispira*) was the most abundant species (67%) followed by three species of false limpets (*S. denticulata, S. diemensis and S. funiculata*) that comprised 21% of all mobile species observed (Table 1; Appendix 1).

Table 1: The presence (indicated with an “x”) of mobile species observed at the Volvo Living Seawall site (on mangrove and flat panels), Control Seawall 1 and Control Seawall 2 after 24 months.

		Volvo Living Seawall						**Control Seawall 1**			**Control Seawall 2**		
		Mangrove panels			**Flat panels**								
	Species	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Chitons	*Acanthochitona pilsbryi*		x			x		x					
	Acanthopleura gaimardi		x					x	x				
	Sypharochiton pelliserpentis	x	x	x	x	x		x	x	x			
Snails	*Afrolittorina acutispira*			x	x	x	x			x			x
	Astralium squamiferum			x									
	Austrocochlea porcata							x					
	Austrolittorina unifasciata			x						x			
	Bedeva paivae		x										
	Bembicium nanum			x									
	Tenguella marginalba	x	x	x	x	x		x	x		x	x	
Crustaceans	Amphipoda Caprellidae	x											
	Amphipoda spp.											x	
	Pilumnid crab											x	x
	Ligia exotica		x	x									
	Isopoda spp.		x										
Limpets	*Cellana tramoserica*		x					x	x			x	
	Montfortula rugosa		x	x				x	x				x
	Notoacmea flammea		x					x	x	x			
	Notoacmea petterdi									x			
	Patelloida latistrigata			x						x			
	Patelloida mimula		x	x		x		x	x	x			x
	Patelloida mufria		x	x					x	x			
	Patelloida saccharina			x									
False limpets	*Siphonaria denticulata*		x	x	x	x		x	x	x			
	Siphonaria diemenensis			x		x	x						
	Siphonaria funiculata		x	x		x	x					x	x
	Siphonaria morphospecies small black							x	x	x		x	x
Air breathing slug	Onchididae		x	x									

Sessile species

By 24 months, the percentage cover of sessile species was high on both flat and mangrove panels in the low intertidal environment but decreased when moving up the seawall in the mid and high intertidal zones. On average, algae were the most abundant sessile group on habitat panels in the low intertidal zone. Although in the low intertidal zone, flat, like mangrove panels were fully covered by sessile species, there was slightly greater species richness on the mangrove panels than the flat panels (Figure 6).

In the mid intertidal zone, mangrove panels had nearly six times the sessile species cover of flat panels. Barnacles were slightly more abundant than oysters on the mangrove panels with the opposite trend observed on the flat panels. This represents a slight shift in community composition from the 12 month data set where barnacles were the most abundant sessile group on habitat panels in the mid intertidal zone on both mangrove and flat panels. Mangrove panels in the mid intertidal zone had 6 different functional groups present (algae, barnacles, bryozoa, mussels, oysters and tubeworms); in contrast, only 3 functional groups were present on the flat panels (barnacles, oysters and tubeworms; Figure 6).

The percentage cover of sessile species was generally low in the high intertidal zone. flat panels were almost completely bare although brown algae were occasionally observed. On mangrove panels up to 21% of the panel surface was occupied by algae, barnacles and oysters (Figure 6).

Table 2: The presence (indicated with an "x") of algae observed at the Volvo Living Seawall site (on mangrove and flat panels), Control Seawall 1 and Control Seawall 2 after 24 months.

		Volvo Living Seawall						**Control Seawall 1**			**Control Seawall 2**		
		Mangrove panels			**Flat panels**								
	Species	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Brown algae	*Caloglossa leprieurii*		x	x						x			
	Colpomenia sinuosa	x			x					x	x		
	Dictyota dichotoma	x			x								
	Ecklonia radiata	x									x		
	Ectocarpus siliculosus	x											
	Petalonia binghamiae	x	x		x			x					
	Ralfsia verrucosa	x	x	x				x	x	x		x	
	Sargassum sp.		x										
	Morphospecies 1 (brown fuzzy)	x											
Coralline algae	*Corallina officinalis*	x	x	x	x	x		x	x		x	x	x
	Crustose coralline algae	x	x	x				x					
Green algae	*Chaetomorpha aerea*				x								
	Cladophora liebetruthii	x	x		x								
	Cladophora prolifera	x			x								
	Ulva australis	x	x		x	x		x		x	x	x	x
	Ulva intestinalis	x	x		x								
	Morphospecies 2 (green strap)	x											
	Morphospecies 3 (green filamentous)		x										
	Morphospecies 4 (green fuzzy)	x	x		x								
	Morphospecies 5 (green layer)		x	x		x		x	x	x			
Red algae	*Ceramium* sp.		x		x								
	Gelidium pusillum	x							x	x			
	Graciliaria sp.	x	x	x					x		x	x	x
	Graciliaria secundata	x											
	Hildenbrandia rubra										x	x	x
	Pterocladia capillacea	x			x								
	Pyropia pulchella		x		x			x					
	Rhodymenia sp.	x			x						x		
	Morphospecies 6 (red bubble)	x	x		x								

Table 3: The presence (indicated with an "x") of sessile invertebrates observed at the Volvo Living Seawall site (on mangrove and flat panels), Control Seawall 1 and Control Seawall 2 after 24 months.

		Volvo Living Seawall						**Control Seawall 1**			**Control Seawall 2**		
		Mangrove panels			**Flat panels**								
	Species	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Ascidians	*Pyura praeputialis*	x	x		x								
	Styela plicata	x											
Barnacles	*Amphibalanus amphitrite*	x			x								
	Amphibalanus variagatus	x			x								x
	Austrobalanus imperator	x	x		x			x			x	x	
	Austromegabalanus nigrescens	x	x		x			x			x		
	Austrominius covertus	x	x	x		x							x
	Austrominius modestus		x			x						x	x
	Catomerus polymerus		x										
	Chthamalus antennatus			x		x				x			
	Ibla quadrivalvis			x				x	x	x			
	Tesseropora rosea		x	x		x		x	x	x	x	x	x
	Tetraclitella purpurascens		x	x		x		x	x				x
	Unidentified barnacles	x						x	x				
Bryozoans	*Bugula neritina*	x	x										
	Tricellaria inopinata	x	x		x								
	Watersipora subtorquata	x	x		x			x			x	x	
	Morphospecies 1 (orange encrusting)	x											
	Morphospecies 2 (grey encrusting)	x											
Anthozoa (coral)	*Plesiastrea versipora*	x			x								
Hydrozoa	Hydroids spp.	x											
Mussels	*Mytilus* spp.	x	x		x				x				
	Trichomya hirsuta	x						x	x		x	x	
	Unidentified mussels	x						x					x
Oysters	*Crassostrea virginica*		x	x	x	x		x	x	x		x	x
	Saccostrea glomerata		x	x	x	x		x	x	x		x	x
	Morphospecies 1 (oyster)	x	x	x				x	x			x	x
Sponges	Morphospecies 1 (greenish brown)	x											
	Morphospecies 2 (grey)	x											
	Morphospecies 3 (orange)	x			x			x			x		
	Morphospecies 4 (pink)	x											
	Morphospecies 5 (purple)	x	x		x								
	Morphospecies 6 (yellow)	x											
	Syconid sponge sp.	x											
Tubeworms	*Galeolaria caespitosa*	x	x	x	x	x		x	x				
	Hydroides spp.	x			x								
	Sabellidae	x											
	Salmacina australis	x			x								
	Serpulidae	x	x		x								
	Spirorbidae	x			x								

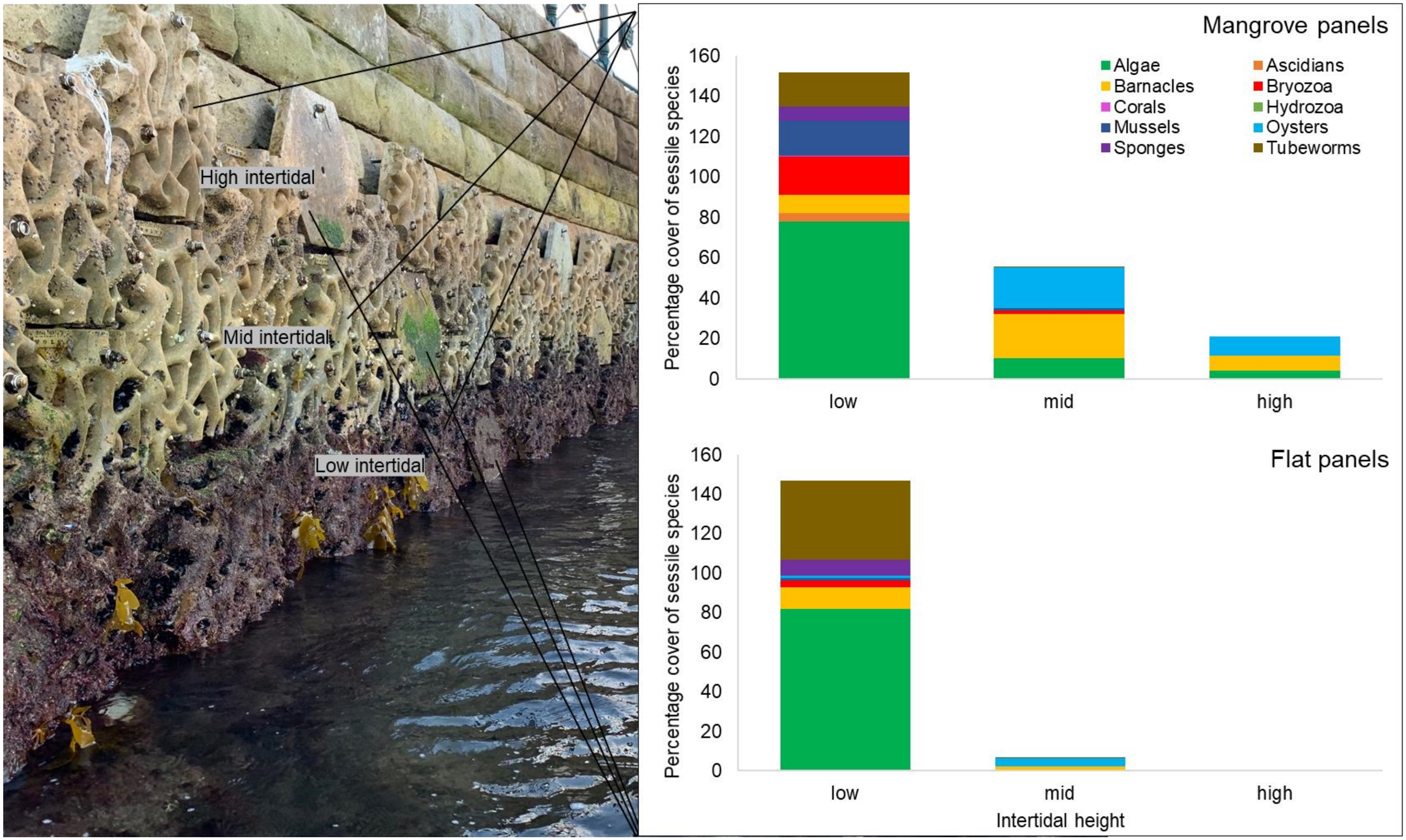

Figure 6: The percentage cover of sessile species on flat and mangrove panels at each of the three intertidal heights after 24 months. The percentage cover includes primary and secondary sessile species and as such, the sum may exceed 100%. Image credit: Maria Vozzo, SIMS.

Conclusion

We found that after 24 months, the Volvo Living Seawall supported more mobile and sessile species than adjacent control (unmodified) seawalls. By 24 months, there were 91 species observed on the Volvo Living Seawall, which was 84% higher than the 55 species that were observed at the site 6 months after installation. As expected, the complex habitat features of the mangrove panels supported a greater abundance and diversity of sessile and mobile species than flat panels at each intertidal height. This was especially pronounced at the mid and high intertidal height, where temperature and desiccation stress are greatest during low tide.

Many of the species observed in higher abundance on the mangrove than flat panels were important filter feeders (i.e. mussels, oysters and barnacles) that can help improve water quality by filtering out particulate matter or contaminants. The mangrove panels also had high abundances of algae such as the native kelp, *Ecklonia radiata*, that sequesters carbon as it grows. Further studies, directly measuring filtration rates (Glossary), carbon and nutrient cycling are required to document the extent of these likely benefits.

We observed seasonal variation in the species richness of the Volvo Living Seawall and control seawalls, and as such, long-term monitoring that captures seasonal variation is needed to determine lasting ecological benefits of this work. Even at 24 months, species were still being acquired by the Volvo Living Seawall. Consequently, additional monitoring is required to capture the full extent of ecological benefits of the Volvo Living Seawall. Overall, the results show that the Volvo Living Seawall enhanced biodiversity and suggest that benefits may also extend to important ecosystem services such as water filtration and carbon sequestration that could be quantified through subsequent, add-on monitoring programs.

Acknowledgements

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Glossary

Algae (macroalgae) – seaweed that can be red, brown, green, or calcareous. They are members of the Protista kingdom and are therefore not plants, though they photosynthesise.

Biodiversity – the variety of invertebrate and algal life in a particular habitat. Here, on seawalls and habitat panels.

Filtration rate – the measure of how much water is naturally filtered and cleaned when species such as oysters, mussels and barnacles feed.

Intertidal zone – the area on a shoreline between the low and high tide water level. This zone can often be categorised into different heights as a result of daily water exposure and the subsequent community that lives there.

Invertebrates – a group of animals that do not have a backbone. Invertebrates can be mobile (i.e. snails and crabs) or sessile (i.e. mussels and barnacles).

Mobile species – species such as chitons, limpets and snails that can move around.

Quadrat – a standardised area in which the abundance of species and composition of ecological communities is quantified. These are often strung to create intersection points under which percent cover can be estimated. Here, we use square, 25 cm x 25 cm quadrats that have 25 intersecting points made from fishing line (Figure G1).

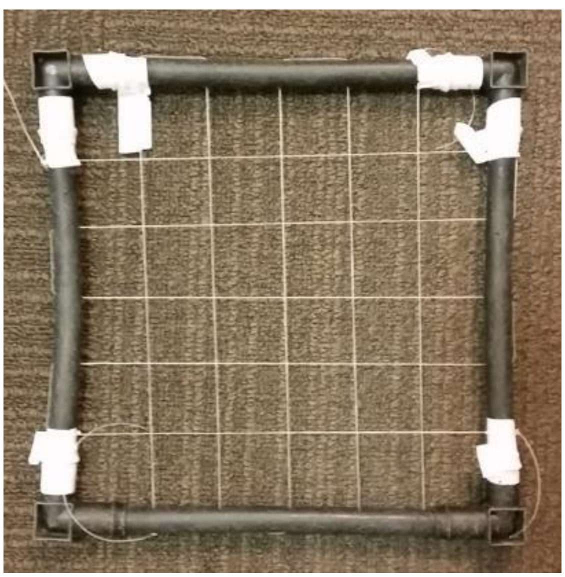


Figure G1: Example of a 25 cm x 25 cm quadrat, with 25 intersecting points, used to survey the communities in this study. Image credit: Aria Lee, SIMS

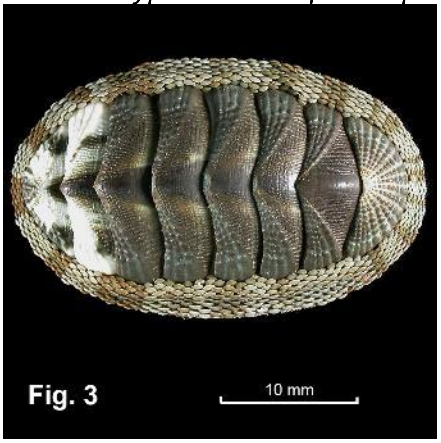
Sessile species – species such as oysters and algae (seaweed) that attach to surfaces permanently and do not move around.

Species richness – the number of different species living in an area.

Appendix 1

Table A1: The most abundant mobile species observed on the Volvo Living Seawall.

<table>
<tr><td>Snail: Afrolittorina acutispira

</td><td>Chiton: Sypharochiton pelliserpentis


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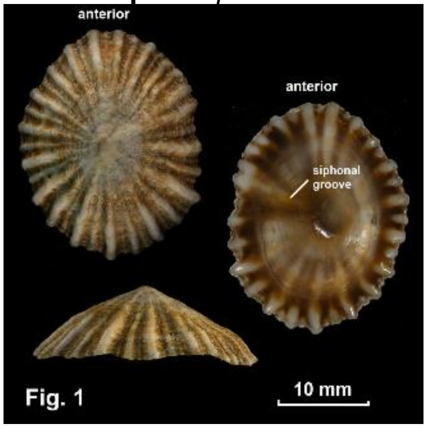

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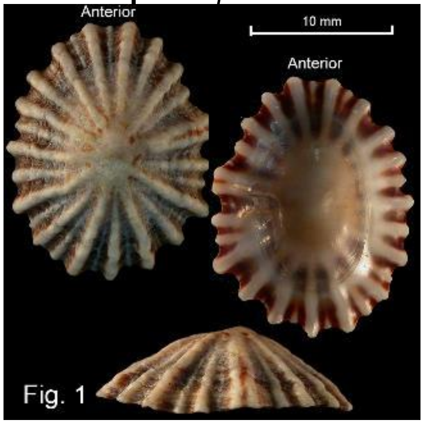

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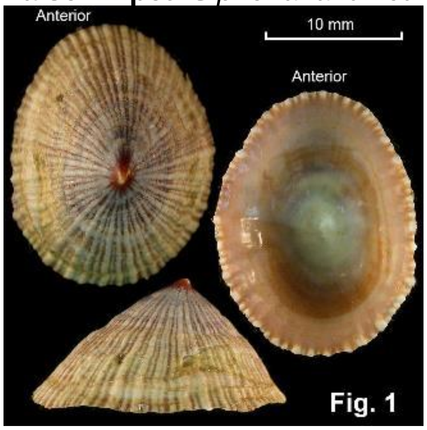
<tr><td>False limpet: Siphonaria funiculata


https://seashellsofnsw.org.au/Siphonariidae/Images/7384-1.jpg</td><td></td></tr>
</table>

Table A2: Abundant sessile species observed on the Volvo Living Seawall.

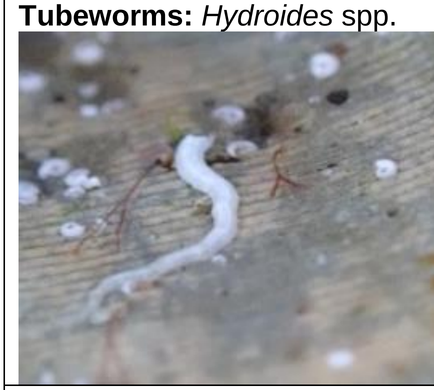
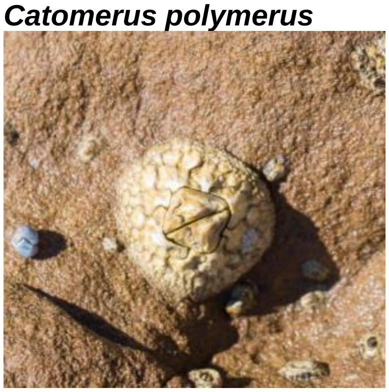
Mussels: *Mytilus spp.* 	**Oysters:** *Saccostrea glomerata*  Image: Leah Wood, SIMS
Barnacles: *Austrominius covertus* 	**Barnacles:** *Tesseropora rosea* 
Tubeworms: *Hydroides* spp. 	**Algae:** *Ulva australis* 
Algae: *Caloglossa lepriuerii* 	**Coralline algae:** *Corallina officinalis* 

Table A3: Species unique to the Volvo Living Seawall.

Gracillaria secundata 	***Pterocladia capillacea*** 
Sargassum sp. 	***Ulva intestinalis***  https://bie.ala.org.au/species/NZOR-6-124055#gallery
Catomerus polymerus  https://bie.ala.org.au/species/urn:lsid:biodiversity.org.au:afd.taxon:d72d5301-6a7e-4199-bc9c-6d90b599e867	

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