Anti-fouling for NSW Coastal Pools and Platforms

The final report for a research project (Dec 2008 – Mar 2010) on new anti-fouling coatings and alternative cleaning methods to control the growth of algae on coastal pools and platforms

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Executive summary

Algae growing on the walls of ocean pools and adjacent steps, ramps and platforms can make these surfaces slippery and degrade the water quality of the pools. Despite considerable resources deployed by Local Councils for cleaning of these areas the rapid growth of algae makes it difficult to maintain safe access to pools and ocean platforms for the community.

The Randwick City and Sutherland Shire Councils participated in a trial with the University of New South Wales (Centre for Marine Bio-Innovation) under a contract with the Sydney Coastal Councils Group to identify improved methods to control fouling of the pools and surrounding platforms.

The current methods involve the regular application of high pressure water with a "jet-blaster" often as frequently as every fortnight during Summer and monthly during Winter. This needs to be scheduled with a low tide to empty the pools and expose the fouled surfaces. The rapid growth of algae on the coastal platforms can cause the pool steps, ramps and surrounding platforms to become slippery before the next scheduled clean. Cleaning can be further complicated by rough sea conditions and periods of high community usage of the ocean pools.

Coatings from three commercial suppliers and UNSW were assessed over three separate periods (Mar-June 2009, August-Sept 2009 and Dec 2009-Feb 2010). Key specifications for the coatings were:

- Non-toxic
- Effective control of marine fouling for at least 1 to 6 months
- Suitable for on-site application to concrete surfaces.

The main test sites were Clovelly Bay (concrete steps and promenade), Malabar Rock Pool (steps and ramp), Cronulla Rock Pool (steps, ramp and the top of the pool wall).

Two coatings (White-X8 and SW-Mats) in combination with modified cleaning practices are recommended for commercial scale trials on pedestrian access points anticipating subsequent take up of these technologies (**Table**).

When these coatings are combined with the recommended modified cleaning practices the following improvements are expected:

- For submerged steps and ramps:
    - Algae prevented from growing for at least 2 - 4 weeks compared to the current 2-7 days after cleaning.
    - Algae can be easily cleaned from the SW-Mat by hand without emptying pool water compared to the current requirement to emptying the pool and cleaning with a truck-mounted high pressure jet blaster.
    - The risk of slipping is significantly reduced.

- For exposed platforms and walkways (such as Clovelly promenade):
    - Algae prevented from growing for at least 12 weeks compared to the current 3-4 weeks after cleaning.
    - The requirement for a truck-mounted water 'jet-blast' is significantly reduced.
    - The risk of slipping is significantly reduced.

In our view, although a more extensive commercial trial is recommended, the tests done to date show the selected coatings and associated cleaning regimes represent significant environmental and public benefits that are cost effective for management of algal fouling on coastal platforms and ocean pools.

Coating[1]	Performance					Coating Improvements
	Anti-fouling :Min.[2] (wks)	:Site	Cleaning : Method	: Frequency (wks)	Coating Adhesion	
White-X8	2-4	Submerged surfaces - pool steps/ramps - pool walls	1. Expose surface 2. Medium pressure water jet	4-6	New concrete - good Old concrete/aggregate - poor	Improve adhesion for older concrete and aggregate. Tint coating to blend with surrounding environment.
	>12	Exposed surfaces - promenades - top of pool walls	Medium pressure water jet	>12		
SW-Mat	2-4	Submerged surfaces in protected areas - pool steps/ramps	Submerged or exposed surfaces Plastic scouring pad Wax block.	4-6	Sand-wax adhesion to mat - 6-8 weeks.	Increase adhesion of sand-wax mix to the rubber mat. Level surface to improve ease of cleaning.

Table. Recommended Coatings and Cleaning Methods - Site characteristics and recommended coating improvements.

Notes:

1. The coatings have been coded to allow a wider distribution of the report findings. Access to the suppliers can be obtained through the Chief Executive Officer (Sydney Coastal Councils Group) or Prof Peter Steinberg (University of New South Wales).
2. The minimum period is based on the Summer 2009-10 Trial. Effectiveness is likely to be longer at other times of the year when the water is cooler and there is less sunlight.

Contents

Attachments

1. Project outline and specifications, February 2009
2. Final Report on Field Trial March-June 2009
3. T. Walton Hons Thesis 2009 - Antifouling technologies for coastal pools and platforms

1. Introduction

The ocean pools and adjacent platforms along the NSW coast can become rapidly fouled with algae. This makes the surfaces a slip hazard for pedestrians and degrades the water quality of ocean pools. Local Councils find it difficult to control algal growth with current cleaning methods. The Sydney Coastal Councils Group contracted the Centre for Marine Bio-Innovation (University of New South Wales) to identify coatings and cleaning methods that would provide non-toxic and more effective control of the of the fouling on these coastal platforms.

Fouling of the trial surfaces and the surrounding areas was dominated by algae; the green algae *Ulva* and (uncharacterised) brown algae. The green algae grew as long filaments or strands in protected areas such as Malabar Pool and as short strands in areas subjected to wave action such as the steps at Clovelly. The brown algae occurred primarily on areas that were only intermittently exposed to seawater (such as the Clovelly promenade and Cronulla pool ramp) or on surfaces that were constantly damp (such as top sections of the wall for the Cronulla Pool).

Both types of algae caused the steps, ramps and other surfaces to become extremely slippery. The green algae grew rapidly, especially in summer, with growth being observed on concrete as soon as 2-3 days after cleaning with a 'jet-blaster'. More commonly, algal growth was observed 1-2 weeks after cleaning.

Both the green and brown algae are currently removed with high-pressure water from a 'jet-blaster'. For enclosed areas such as pools a valve is opened to allow the water to be released on an ebb tide. For non-enclosed surfaces, such as the steps at Clovelly, cleaning needs to coincide with low tides of 0.5m (or less) during daylight hours. Further, sites need to be accessed by a truck-mounted 'jet-blaster' and typically 2-3 workers.

The drawbacks of the jet-blast method are:

- Surfaces that are underwater cannot be cleaned with a water 'jet-blaster'.
- Rapid growth of the algae can occur within days and make the surface slippery whereas the Councils operate a fortnightly-to-monthly cleaning schedule.
- Cleaning can be delayed because:
  - water jet-blasting is required for other general cleaning operations (e.g. graffiti, or high use public areas such as parks and picnic grounds after holiday periods or public events).
  - mechanical breakdown of the water jet-blaster during scheduled cleans.
  - access is prevented or limited due to periods of high public use;
  - high swell conditions prevent safe access.
- The public is inconvenienced with pool closures and emptying. In particular, the most frequent cleaning is required during the high-use periods in Summer.

2. Scope

A preliminary report described the primary and secondary specifications for coatings to be included in the trial (**Attachment 1**). The key coating specifications were:

- Non-toxic
- Effective control of marine fouling for at least 1 month
- Suitable for on-site application to concrete surfaces

3. Results

3.1 Preliminary Trials

The first field trial screened a range of coatings from commercial suppliers and UNSW. The coatings were applied primarily to test blocks made of concrete (10 cm x 10 cm) and placed at field sites at Clovelly Bay, Malabar Pool and Rozelle Bay. A limited number of coatings were directly applied to a variety of concrete surfaces at sites within Randwick and Sutherland Shires, such as boat ramps, pool walls and a promenade. One coating from company C (X1) and two coatings from UNSW (W1, W2) exhibited promising anti-fouling activity during the first trial. Blocks coated with X1, W1 or W2 each showed antifouling activity at two different sites. X1 coating also showed promising anti-fouling activity when directly applied to the wall of Malabar Rock Pool. For further details see Final Report on Field Trial: March-June 2009 (**Attachment 2**). The commercial suppliers and UNSW used the results of the first trial to improve the formulations of the most promising coatings for retesting in the second and third trials.

The second trial was conducted as part of an Honours student thesis (**Attachment 3**). The student tested a range of coatings during Winter (2009) at Rozelle Bay, Clovelly Bay and Malabar Rock Pool. Results for the coatings were consistent with the findings of the first trial, with two X coatings (X4, X6) showing some anti-foul activity. Two additional coatings tested for the first time showed promising anti-fouling activity: Z3 coating (Company A) and Y2 coating (Company B). Interestingly, Y2 is a black non-slip paint which showed anti-foul activity in the second trial yet the grey-tinted non-slip paint (Y1 coating) from the same supplier did not show anti-foul activity in the first trial. All of these coatings were selected for testing in the final trial.

3.2 Community Survey

The Honours student also conducted a social survey of public users of coastal pools and platforms in the Randwick Shire regarding the issue of antifouling and slippery surfaces. Key findings of the survey were: i) that slippery surfaces present the highest perceived danger to the community surveyed, ii) over 20% of participants in the survey had hurt themselves slipping over and iii) over 70% of the community surveyed agreed that council's use of jet-blasting to remove slip hazard is sufficient (Todd Walton 2009, Honours Thesis -Antifouling Technologies for Coastal Pools and Platforms and Community Response).

3.3 Recommended Coatings and Cleaning Methods

The final field trial focussed on the direct application of selected coatings to surfaces typically used as access points to coastal Pools and Bays (i.e. steps, ramps, pool edges and promenade areas). It was conducted over the period mid-Dec 2009 to early March 2010. In addition to direct application a set of test blocks were also coated and tested at Clovelly steps. The blocks could be coated under optimum conditions and provided a more uniform substrate than the surfaces at the field sites.

A total of three main test sites were used (Clovelly, Malabar and Cronulla) with a limited set of coatings applied at Mahon Pool. In addition, cleaning methods were assessed for removing any algae growing on the coatings. The results for the recommended coatings and cleaning methods for each field site are summarised at **Table 1** and **Appendix A**. A more detailed description of the Final Trial Results and Method is at **Appendix B**.

The coatings found to be most effective were a paint (coded White-X8) and a sand-wax mixture over a rubber mat (coded SW-Mat). The paint was applied by brush and allowed to dry for at least a couple of hours before immersion. The mat was coated with a mixture of sand and molten wax (supplied by Centre for Marine Bio-Innovation, UNSW). This mixture was applied in-situ as a hot-melt over a rubber mat bolted to the concrete.

The pattern of fouling and the effectiveness of the coatings were relatively similar across the test sites and the results are also likely to be applicable to other sites with similar fouling characteristics. The algae in the final trial were similar to those observed in previous trials with the green alga *Ulva* being the most prominent on submerged surfaces (steps/ramps) and brown algae (unidentified) growing on more exposed surfaces such as Clovelly Promenade (**App A.2**) and Cronulla Pool Wall (**App A.8**). The green alga on Clovelly steps (**App A.1**) was shorter and more strongly attached than the same alga at Malabar Pool (**App A.5 and A.6**) while the green alga at Cronulla Pool (**App A.7**) was in-between these two extremes. This is likely due to the greater level of wave activity at Clovelly steps however the rate of fouling was similar at all three sites with fouling being observed within the first 2 - 4 weeks on most of the coated surfaces.

White-X8 performed very well on the more exposed sites fouled by the brown algae with no fouling being observed during the course of the trial (12 weeks) (**Table 1**). These sites were only intermittently wet at high tide or when the swell was big enough (Clovelly Promenade; **App A.2**) or were constantly moist but did not have enough water for growth of the green alga (Cronulla Pool wall; **App A.8**). White-X8 also inhibited green algae on the fully submerged site at Malabar Pool steps and ramp for about 4 weeks (**App. A.5**) and the inter-tidal site at Clovelly steps for a similar length of time (**App A.1**).

White-X8 coating on submerged surfaces are likely to need cleaning approximately once every 4 - 6 weeks using a medium pressure water jet. A stiff broom was also tried during the final Trial but failed to remove the algae. The effect of a medium pressure jet for cleaning this coating was observed at the Clovelly steps site (**App. A.1**). Here the coating started to lift from the concrete steps, to some extent before cleaning but mainly during application of the water jet. As the coating remained on the concrete test blocks one option maybe to recoat the steps with new concrete before commercial trial of the coating. The formulation of the coating may also be changed to improve adhesion to the older concrete and aggregate of the steps. Self-cleaning and foul-release properties may keep this coating free of fouling at some sites particularly on the exposed sites that are only intermittently submerged (e.g. Clovelly Promenade and Cronulla Rock Pool wall; **Apps A.2 and A.8**).

The SW-Mats performed well on submerged surfaces at the relatively protected site of Malabar Pool (**App. 1.5**) followed by Cronulla Pool steps (**App A.7**). The relatively robust nature of the sand-wax mixture and the thickness of the coating allowed a plastic scouring pad to be used to remove algae. Following this cleaning step, a solid wax block was rubbed over the surface to refresh the wax on the surface. This 'wax-rub' process also helped to remove algae. The cleaning process was often performed underwater because the pools had not been emptied (see) reducing the need to empty pools and the reliance on the jet-blaster for cleaning.

The trial of the SW-Mat coating was limited by weak adhesion between the wax-sand mixture and the rubber mat. This was most evident at Mahon Pool due to the high wave impact and to a lesser degree at Cronulla Pool. An improvement to the design of the SW-Mat is recommended to overcome this problem before commercial trial.

The site characteristics for more general applications of these two coatings are summarised at **Table 2**. With either coating in place the surface will get fouled at a slower rate substantially reducing; 1) the slip hazard for local users, 2) the need to empty/close the pool for cleaning and 3) the reliance on the water jet-blast truck for cleaning.

A limited trial of coatings was also performed on the wall of the Malabar Rock Pool and Clovelly Pool. For these sites the algae impacts the public amenity because it has such a visual impact and it is also likely to reduce the water quality. A wax from UNSW was tried at Clovelly Pool with encouraging results but required improvements in coating application before it could be considered for more extensive trial (**App A.3 and Attachment 2**). The initial trial at Malabar Pool (**Attachment 2**) was not promising but the second trial (**App. A.6**) demonstrated good anti-fouling effect of at least three coatings Grey-WE, White-X8 and Blue-Z3. Trials at other sites are recommended before these coatings are considered for commercial trial.

Coatings tested but not recommended for more extensive commercial trials are Blue Z3 and Black Y3 (**Appendix B**). Blue Z3 appeared to significantly inhibit algal growth however most of the coating was lost relatively quickly (e.g. Clovelly Steps, Mahon Pool and Malabar Pool steps). Residual activity was most apparent in the exposed sites at Clovelly Promenade and the top of the Cronulla Pool wall. As this coating did not lift from the surface but tended to wear away improvement in coating cohesion is likely to result in a coating worth testing in the future.

The Black Y3 coating inhibited the green algae on Clovelly Steps however when the coating was cleaned with the water jet-blast the algae required the highest pressure for removal. This coating was not recommended for more extensive commercial trial because it is considered that the pitting resulting from the high pressure water jet will lead to more rapid algal fouling over time and not provide any advantage over concrete. Furthermore the inhibition observed during the trial may have been as a result of the black surface becoming hot at low tide when exposed to the sun. The high temperatures of a black surface at an access point for bathers may also be a hazard for bathers.

3.4 Regulatory aspects

The Federal and NSW Governments both have legislation relevant to the application of coating for the control of algae on coastal pools and platforms. For this study suppliers were provided the Preliminary Report (Attachment 1) as the specification. While this Specification included a requirement for a non-toxic coating no tests of the coating supplied were undertaken.

It is recommended that Local Councils or others intending to use the coatings described in this Study ensure the Supplier has received the necessary regulatory approvals for the intended use.

4. Summary

Trials were conducted in 2009-10 at coastal pools and platforms of Randwick City and Sutherland Shire Councils to identify new coatings and cleaning methods to control algal fouling. Two coatings (coded White-X8 and SW-Mat) were found to reduce algal fouling and be easier to clean when compared concrete surfaces. It is expected that the application of these coatings to the steps, ramps and surrounding platforms of coastal pools will reduce the risk of pool users and other pedestrians slipping and reduce the resources required to clean these surfaces of algae.

- **It is recommended that promenades and other similarly exposed areas such as pool edges are coated in White-X8.**

  The results from this study indicate that these surfaces remain free of algal fouling for at least 12 weeks. Cleaning with a medium pressure water jet-blast is recommended when algal fouling is observed on the coating. This approach is an improvement on the current situation where algal fouling of concrete cleaned with a high pressure water jet-blast can occur within 2-4 weeks.

- **It is recommended that submerged and inter-tidal surfaces such as steps and ramps of coastal pools and bays are coated with either White-X8 or SW-Mats.**

  In both cases cleaning is likely to be required every 4-6 weeks. White-X8 is more easily applied over broader areas than SW-Mats but it is recommended that only a medium-pressure water jet be applied for cleaning. This requires that pools are emptied to expose the surfaces for cleaning. As SW-Mats can be cleaned underwater pools would not have to be emptied for cleaning access points.

A number of improvements could be made to the coatings. For White-X8 improved adhesion to older concrete and aggregate maybe required and an alternative colour to white maybe required to reduce the visual impact of painted surfaces. For SW-Mats the main area of improvement is in adhesion of the sand-wax mixture to the underlying rubber mat.

The results and conclusions of this study were obtained from trials that were conducted over relatively short periods of time (up to 3 months). The level of fouling and the performance of the coatings can be affected by many variables so the times recommended for cleaning are only indicative. It is therefore recommended that the next step for the White-X8 and SW-Mat coatings is for a commercial trial over more extensive areas. Local Councils interested in pursuing this course can be put in touch with the Suppliers via Sydney Coastal Councils Group and the University of New South Wales.

Disclosure

Drs Tim Charlton and Peter Steinberg are shareholders and Directors of Ecozean Pty Ltd and co-Inventors of a patent (WO 2008/009067) that covers materials used in the SW-Mat. Ecozean Pty Ltd was recently established to commercialise research into anti-fouling materials conducted at the University of New South Wales.

Table 1 Recommended coatings and cleaning: Field Trials

Test Site	Recommended : Coating	: Cleaning	Cleaning frequency Min. period (wks) [1]	Other options
Clovelly Bay				
- Steps	White-X8 (repair concrete)	1. Empty pool to expose steps 2. Medium pressure water jet	4 – 6	Blue-Z3 after improved adhesion
- Promenade	White-X8	Medium pressure water jet	> 12	-as above-
- Pool	No change	No change		Coatings used on Malabar Pool Wall
Mahon Pool				
- Steps	White-X8 (repair concrete)	1. Empty pool to expose steps 2. Medium pressure water jet	4– 6	Blue-Z3 (as above)
- Pool edge/ rock platform	White-X8	Medium pressure water jet	> 12	Blue-Z3 (as above)
Malabar Pool				
- Steps and Ramp	SW-Mat	1. Plastic scouring pad 2. Refresh surface with wax block	2–4	Blue-Z3 (as above)
	White-X8	1. Empty pool to expose steps 2. Medium pressure water jet	4– 6	
- Pool Wall	Extended trial for all coatings	to be determined		
Cronulla Pool				
- Top of pool wall	White-X8	Medium pressure water jet	> 12	Blue-Z3 (as above)
- Steps	SW-Mat	Plastic scouring pad Refresh surface with wax block	2-4	
	White-X8	Empty pool to expose surfaces Medium pressure water jet	4-6	
- Ramp	White-X8	Medium pressure water jet	> 12	

Note: 1. Conditions of rapid algal growth such as Summer

Table 2 Recommended coatings and cleaning: General Application

Coating	Descrip.	Areas	Cleaning : method	: frequency (wks)	Pros and Cons	Improvements to coating
White-X8	Paint	Steps and Ramps Pool wet edges Promenades	• Empty pool to expose surfaces • Medium pressure water jet 'blast' • Medium pressure water jet 'blast'	2-4 high fouling 4-6 medium fouling > 12 >12	**Pros** ▫ Reduced algal fouling ▫ Works for exposed surfaces ▫ Apply to broad areas **Cons** ▫ Good conditions for *in-situ* app. ▫ Cure time ▫ Cleaning requires – Empty pool – Water jet-blast	Increased adhesion : old concrete : aggregate Tint to reduce visual impact
SW-Mat	Sand-wax mixture over a rubber mat	Steps and Ramps	• Plastic scouring pad • Refresh surface with wax block • (submerged or exposed)	2-4 high fouling 4-6 medium fouling	**Pros** ▫ Reduced algal fouling ▫ Cleaning – while pool in use – by pool users **Cons** ▫ Restricted to o submerged surfaces o low-medium wave impact zones	Increase adhesion of sand-wax mixture to mat

A : Site Performance of the Recommended Coatings and Cleaning Methods

A .1: Clovelly Bay Steps

The coatings were tested on a large concrete step on the south side of Clovelly Bay that provides access to the water from the promenade (**Figure A.1**).

Fouling

- Algal fouling was visible on the step within 2 weeks of cleaning and commencing the Trial. The alga grew as a slippery green 'lawn' and was only removed from the concrete by water 'jet-blast' on the highest pressure setting (after 8 weeks).

Coating

The White-X8 coating is recommended for a more extensive application to the Clovelly Bay steps. The White-X8 coating maintained effective anti-fouling for 4 weeks (Statistical analysis **Tables B.1, B.2, B.3**) and effective foul-release after 8 weeks after cleaning with medium pressure from a water 'jet-blast' (**Table A.1**).

Maintenance

- *Surface preparation*. It is recommended that the concrete steps are refurbished before further coating. Poor adhesion of all coatings applied directly to the concrete steps was observed in the Summer 2009-10 Trial. As the coatings adhered well to the concrete blocks prepared off-site it is recommended that the concrete steps are recoated with new concrete before painting. The effect of concrete additives on adhesion of the coatings should be checked with the coating suppliers beforehand.
- *Cleaning*. It is recommended that the coating be maintained by physical cleaning with a medium-pressure water 'jet-blast' when fouling is observed (3-4 weeks in Summer).

Outcomes

- Coating the concrete steps in White-X8 and cleaning every 4 weeks with a medium pressure water 'jet-blast' is expected to keep the coated areas relatively free of algae and lead to a significantly reduced risk of bathers slipping compared to the current situation.

Options

- *In-situ* application of the coating requires a low tide and favourable weather conditions. An alternative approach would be to apply the coating off-site to a removable slab which could be fixed to the existing step with recessed stainless steel bolts. This would ensure the coating is applied under optimum conditions and allow easy replacement of the slab for recoating.

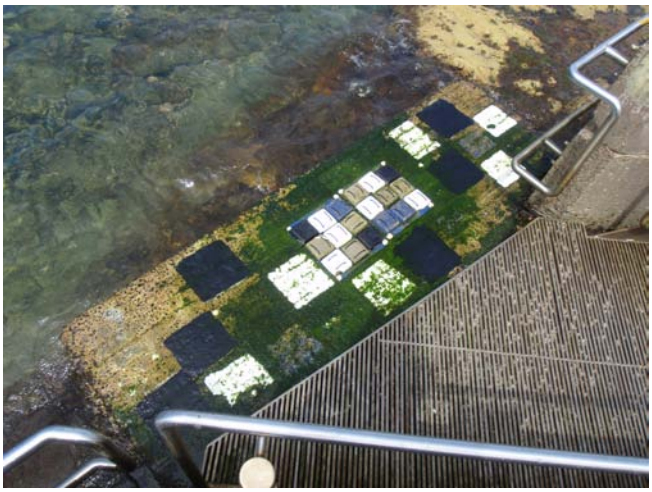
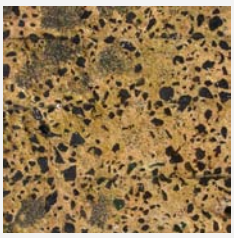
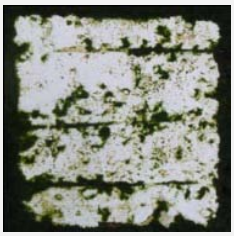
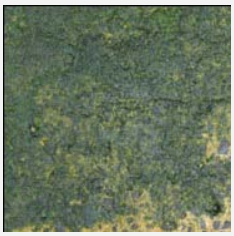
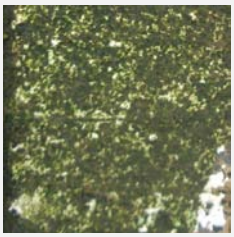
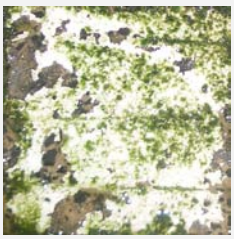


Figure A.1 The step at Clovelly Bay after 4 weeks of the final Trial. The coatings were applied to the concrete step (*in-situ*) and to small concrete blocks (off-site).

Table A.1 The coating recommended for Clovelly steps: anti-foul and foul-release effectiveness. Adhesion of White-X8 to the blocks was better than the concrete step.

EFFECT	COATING :White-X8 (on step)	:White-X8 (on test blocks)	CONTROL Uncoated step
Anti-Fouling			
: Start			
: 4 weeks			
Foul-Release			
: 8 weeks (6 wks for block) - before cleaning			
-after cleaning *water jet*[1]			
			Not to scale

Note: 1. Mid-range pressure setting with a water 'jet-blast

A .2 Clovelly Bay - promenade

Fouling

- The concrete promenade closest to the water experienced algal fouling that led to a black slippery surface. Fouling of the control panels started within 4 weeks and most were completely covered by 12 weeks (**Figure A.2**). The promenade around the test panels was cleaned every 4-5 weeks during the trial period.

Coating

- The White-X8 coating is recommended for the concrete promenade (**Table A.2**).

Maintenance

- As the test panels were not subjected to physical cleaning during the trial only relatively infrequent cleaning is likely to be required. If fouling is observed then the algae should be removed with water from a 'jet-blast' on the mid-range pressure setting. The White-X8 coating on areas of the promenade exposed to surging seawater during big seas may self-clean, reducing further the need for manual cleaning.

Outcomes

- Coated areas are likely to require only minimal cleaning with the water 'jet-blast'. Based upon the trial results the minimum time period between cleaning would be around 12 weeks.
- The coated areas are expected to have a reduced requirement for cleaning and present a lower risk of slipping by pedestrians.

Options

- The White-X8 coating maybe tinted to another colour. This option should be explored with the supplier.
- One of the other coatings (Blue-Z3) showed potential however improvements in coating adhesion and integrity are required before more extensive trials.

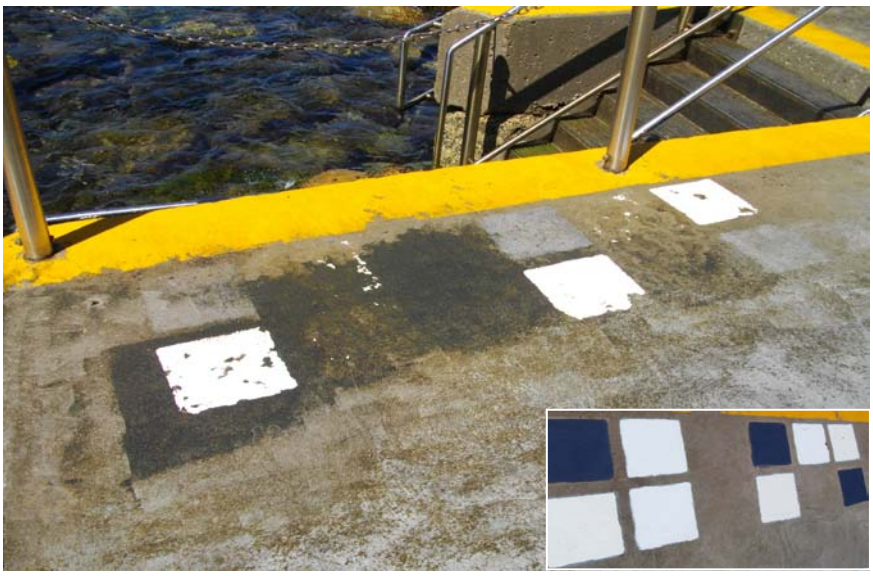


Figure A.2 Test area on the Clovelly promenade after 12 weeks. The surrounding area was cleaned 3 times with a high pressure water jet during the trial period. Inset: Test area at the start of the Trial.

Table A.2 The coating recommended for the Clovelly promenade: anti-foul effectiveness. Adhesion of White-X8 coating may have been compromised due to poor weather conditions on the day of application.

EFFECT	COATING :White-X8	CONTROL :Uncoated concrete
Anti-Fouling		
: Start		
: 12 weeks		

Not to scale

A.3 Clovelly Bay Pool

Clovelly Bay Pool was the only pool in the trial that was coated with pool paint (**Figure A.3**). A limited trial with a wax-based coating was conducted from Dec 08 to Feb 09. Most coatings were not tested due to the need to avoid damage to the existing paint.

Fouling

- The Clovelly Pool is coated with an epoxy paint. Growth of algae was observed below the water-line within 1 week of cleaning by Council staff during the trial period (Dec 08 – Feb 09). There was relatively less growth on the floor of the Pool. Cleaning of the pool is required every 2 weeks in Summer and less frequently at other times.

Coatings

- The coating showed potential for the control of algal fouling however it is not considered to be in a suitable formulation for more extensive application (**Attachment 2**).
- Other coatings were tested on the wall of the Malabar Pool in the 3rd trial (Summer 2009-10). A number of these coatings had both anti-foul and foul-release effects against and are likely to have a similar level of effectiveness at the Clovelly Pool.

Maintenance

- To remove algae from the epoxy paint the water 'jet-blast' is currently required to be applied at its highest pressure. Based upon advice from the Maintenance Supervisor, this level of water pressure leads to micro-pitting of the paint and over time it becomes more difficult to remove the fouling.
- In addition to cleaning algae the Clovelly Pool needs to be emptied after periods of high patronage and when high seas bring sand and seaweed into the pool.

Options

- An option for this type of pool is the application of an anti-foul/foul-release coating over an existing epoxy coating. Where fouling does occur, a foul-release coating would allow removal with a standard 'mains-pressure' hose or lower-mid pressure setting for a 'jet-blast'. This would reduce the maintenance resources required to clean the pool.
- It should be noted that compatibility of these coatings with an existing pool coating would need to be confirmed with the supplier or tested separately before further testing.
- It is recommended that coatings trialled from the Malabar Pool trial (Summer 2009-10) be considered in future trials at this site.

Figure A.3 Cleaning the Clovelly Bay Pool.

Coatings tested at Malabar pool maybe applicable for future trials at this pool.

A.4 Mahon Pool

The SW-Mat was tested on the southern steps (**Figure A.4**) and the Blue-Z3 coating was tested on edge of the pool and nearby sandstone.

Fouling

- The steps of the Pool were fouled with green algae within 2 weeks of Council cleaning and created a significant slip hazard.
- Fouling of the surrounding rock platform and concrete areas was slower on the areas that were above the pool. These areas also became very slippery when algae was present.

Coatings

- Only two coatings were tested at this site: the SW-Mat on the steps and the Blue-Z3 coating on the sandstone and concrete areas surrounding the pool. In both cases poor adhesion of the coatings compromised their effectiveness.
- The White-X8 coating demonstrated effective anti-foul and foul-release activity at the other test sites and application of this coating at Mahon Pool is also likely to be effective. It is recommended that this coating be trialled more extensively at this site.

Maintenance

- *Surface preparation*. As the condition of the concrete steps is poor it recommended that the surface is repaired before coating. This is likely to improve coating adhesion and effectiveness in control of algal fouling.
- *Cleaning*. Any algae on the White-X8 coating should be removed with a medium pressure water 'jet-blast' as required. In Summer this maybe as frequent as once every 4 weeks for the steps and wet edges around the pool.
- Steps: Lower the water level of the pool to allow cleaning with the water 'jet-blast'.

Options

- The area is in a relatively natural state and white paint on the rocky areas surrounding the pool may cause significant community dissent. It is recommended that alternative tints be sought for White-X8 and coating be restricted to areas of high traffic.
- This site is too exposed for the current version of the SW Mat coating. An alternative design with improved adhesion of the sand-wax material to the mat could provide an option for the steps that are underwater. This coating can be cleaned underwater and would reduce the need to empty the pool for cleaning.

Figure A.4 Steps and rock platform at Mahons Pool.

A.5 Malabar Pool - Steps and Ramp

Four coatings were tested on the steps and ramp on the southern side of Malabar Pool from 16 Dec 09 to 13 Mar 10 (**Figure A.5**).

Fouling

- Fouling occurred within 2 weeks of the pool being cleaned, with the steps and ramp becoming very slippery. After 4 weeks into the Trial the algae had formed a thick mat over the concrete (**Figure A.5B,** for Statistical analysis see **Table B.4**).

Coatings

- Two coatings are recommended for this site (**Table A.3**):
  - White-X8. Performance was patchy with some panels showed effective anti-fouling to at least 4 weeks while other panels were fouled within 2 weeks. Foul-release was tested only by the rubbing a hand across the surface however a water jet would be the most practical approach. Adhesion of the algae to White-X8 varied considerably during the Trial and a more extensive trial would be required to determine if the foul-release performance of the coating could be maintained.
  - SW-Mat. Effective anti-fouling was observed for 2-4 weeks. Algae that had grown on the mat was easily removed with a plastic scourer pad. Future application of this coating should ensure a smooth finish because algae was difficult to remove where the coating surface was not level. Algae was also removed when a solid block of wax was rubbed over the surface. This was done primarily to refresh the surface wax on the coating. The plastic scour pad and wax procedure can be performed while the SW-Mats are underwater.

Maintenance

- White-X8. Algae on the White-X8 coating should be removed with a medium pressure water 'jet-blast' as required. In Summer the cleaning is likely to be required once every 4 weeks. This would require that the pool is emptied to expose the coated surfaces.
- SW-Mat. Algae on the SW-Mats could be removed manually with a plastic scouring pad. Algae can also be removed by rubbing the surface with a block of anti-foul wax which also deposits a fresh layer onto the coating. Using the latter method, cleaning frequency is likely to be required every 2 weeks during Summer and less frequently in the other months. This can be done without emptying the pool.
- This pool experienced the greatest level of fouling of all the pools in the Trial. The algae not only completely covered the surfaces but also grew long strands to form a thick layer. This high rate of growth may simply be due to a lack of wave action however high nutrient levels could also be a factor. Note that nutrient levels were not determined and they are simply noted as a possible factor. The coating may need to be cleaned more frequently than at other sites due to the relatively high level of fouling.

Outcomes

- White-X8 and SW-mats will reduce the level of fouling on the steps and ramp for 2-4 weeks resulting in a less slippery surface for this period of time and less risk of slipping.
- Cleaning schedules could be halved from fortnightly to monthly during Summer and less frequently in the cooler months reducing the number of days the pool is closed for cleaning
- SW-mats could be cleaned every 2-4 weeks in Summer without emptying the pool and without the need for water 'jet-blaster' truck.

A

B

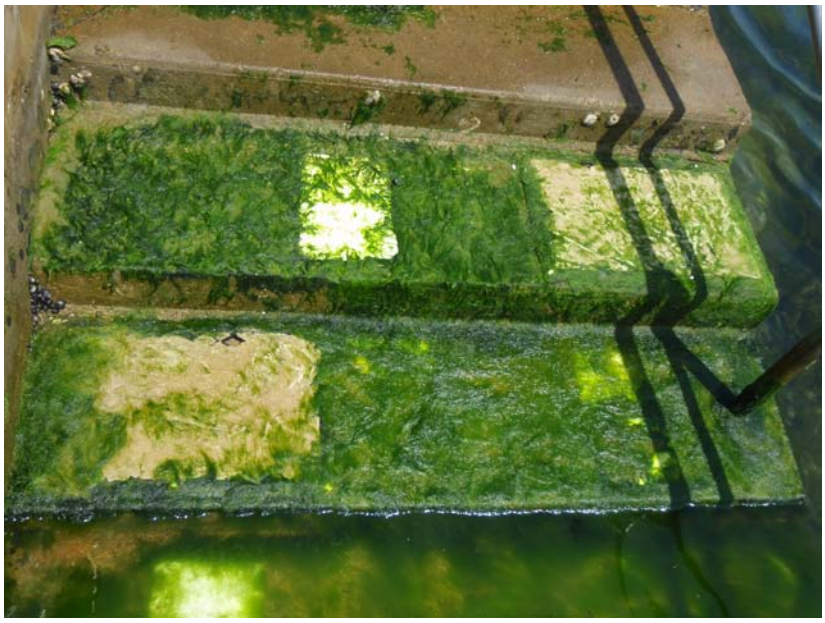
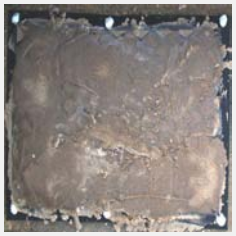
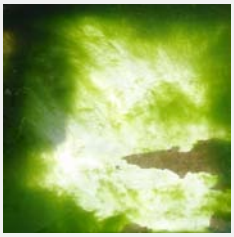
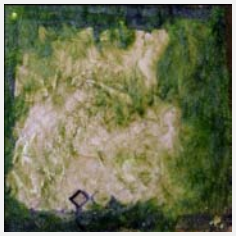
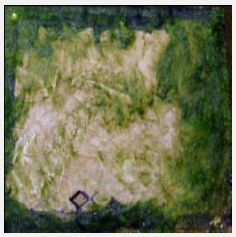
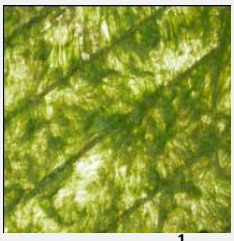
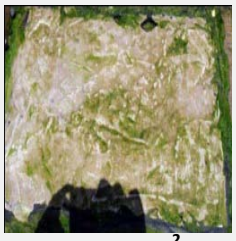
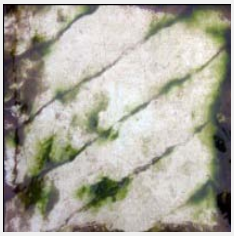
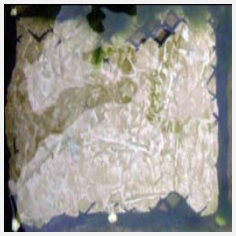


Figure A.5 A. The steps and ramp used for coating trials at Malabar Pool. B. The steps were exposed after 4 weeks of the trial to allow cleaning. Algal growth was rapid and the lack of wave action due to the location of the pool was likely to be a factor contributing to the algae growing relatively long strands.

Table A.3 The two coatings recommended for the steps and ramp at Malabar Rock Pool: anti-foul and foul-release effectiveness

EFFECT	COATINGS :White-X8	COATINGS :SW-Mat	CONTROL : Concrete
Anti-Fouling			
Start			
4 weeks			
Foul-Release			
4 weeks - before cleaning			
- after cleaning	 **HAND-RUB** [1]	 **WAX-RUB** [2]	 **HAND-RUB** [1]
6 weeks - after heavy swell			

Not to scale

Notes: 1. Rubbing by hand.
2. Rubbing by hand with plastic scourer and then block of solid wax.

A.6 Malabar Pool - Wall

Four coatings were tested on the southern wall of the pool over the same period as the steps and ramp. The coatings were: White-X7, White-X8, Blue-Z3 and Grey-WE (**Figure A.6A**).

Fouling

- The wall of the Pool experienced a similar level of fouling as the steps and ramp however the algae was not as strongly attached to the wall. The fouling on the wall peaked after 4 weeks with a thick mat of algae growing on the concrete surfaces (**Figure A.6B**). It then declined with a noticeable loss 2 weeks later, particularly from the upper part of the wall after high seas hit the Pool.

Coatings

- All coatings reduced the level of fouling with only Grey-WE panels had significantly less fouling at 4 weeks than on control panels (**Table A.4**, and **Tables B.5, B.6** for statistical analysis). All coatings are recommended for further testing at this site and for consideration as pool coatings for other sites:
    - White-X8. This coating had the best adhesion and coating integrity. It was overwhelmed at 4 weeks during the period of rapid algal growth however most of this fouling appeared to be removed 2 weeks later by wave action.
    - White-X7. This is the only site where this coating maintained good adhesion and it showed (almost) significant anti-fouling activity at 4 weeks (**Table B.6**).
    - Grey-WE. This coating showed the strongest and most consistent anti-fouling effect particularly during the peak fouling period at week 4 when it was the only coating to significantly prevent growth of the algae (**Table B.6**). As this coating started to peel from the concrete by week 6 it needs to be reformulated to improve adhesion to concrete before it can be taken into an extended trial.
    - Blue-Z3. This is the only site where this coating maintained good adhesion. Fouling on the coating was easily removed with rubbing by hand.

Maintenance

- The only attempt to clean the entire surface of the test panels was at 4 weeks, when the fouling had reached peak coverage. Panels were rubbed by hand to assess strength of the attached algae and although some algae was removed most was found to be firmly attached.
- The time period between cleaning cannot be predicted in any meaningful way from this trial. It is recommended that an extended trial be undertaken where the coatings are applied across a greater number of panels and a wider surface area.

Options

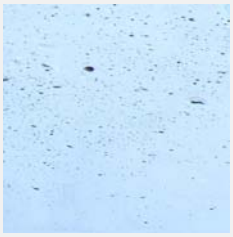
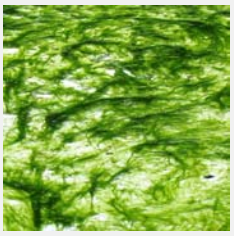
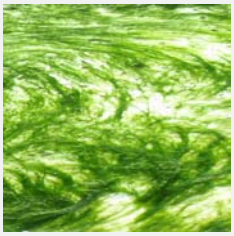
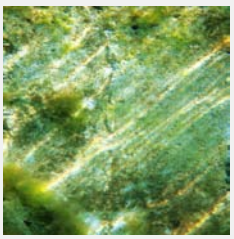
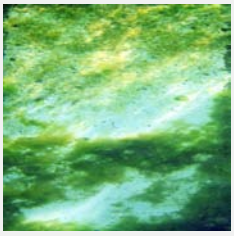
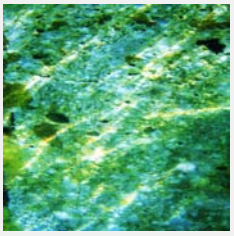
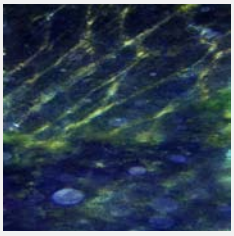
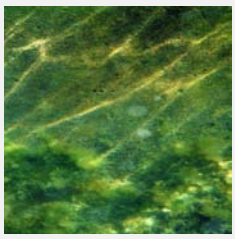
- Extended trial of all coatings.

A

B

Figure A.6 The test panels on the wall of Malabar Rock Pool: A. Directly after application B. After 4 weeks of the coatings trial.

Table A.4 Anti-foul and foul-release effectiveness of the coatings on the wall of Malabar Rock Pool.
All coatings are recommended for further testing

EFFECT	COATINGS : White-X8	: White-X7	: Grey-WE	: Blue-Z3	CONTROL : Concrete
Anti-fouling					
Start					
4 weeks					
11 weeks[1]					

Not to scale

Note 1. Photos taken underwater at this timepoint.

A.7 Cronulla Rock Pool – Steps and Ramp

Ramp

The ramp can become fouled with a slippery brown algae however there was no algal growth during the Trial. The recommended coating for this area is White-X8 based upon the performance of this coating at test sites with similar characteristics i.e. Clovelly Promenade and the top of the Cronulla Pool wall.

Steps

The steps at Cronulla Rock Pool are covered in a rubber mat (**Figure A.7A**). For the trial two SW-Mats were placed on the lowest step where a section of rubber mat had been removed (**Figure A.7B**).

Fouling

- The rubber mats on the steps become fouled with green algae within 1 week of cleaning during Summer (**Figure A.7A**). To clean the steps the Pool is emptied and a high pressure water jet applied.

Coating

- The SW-mats reduced algal fouling compared to the concrete areas for the first 4 weeks. . The mats were then physically cleaned by hand (scourer and wax-rub, underwater) after 4, 6 and 8 weeks (**Table A.5**).

Maintenance

- SW-Mat. Algae on the SW-Mats could be removed manually with a plastic scouring pad. In addition, rubbing the surface with a block of anti-foul wax deposits a fresh layer onto the coating. Using this method, cleaning frequency is likely to be required every 2-4 weeks during Summer and less frequently in the other months. This can be done without emptying the pool.

Outcome

- The steps covered with SW-Mats will reduce fouling for 2-4 weeks and be less slippery during this time. The SW-mats could be cleaned manually (as described above) as needed without emptying the pool and without the need for jet-blaster.

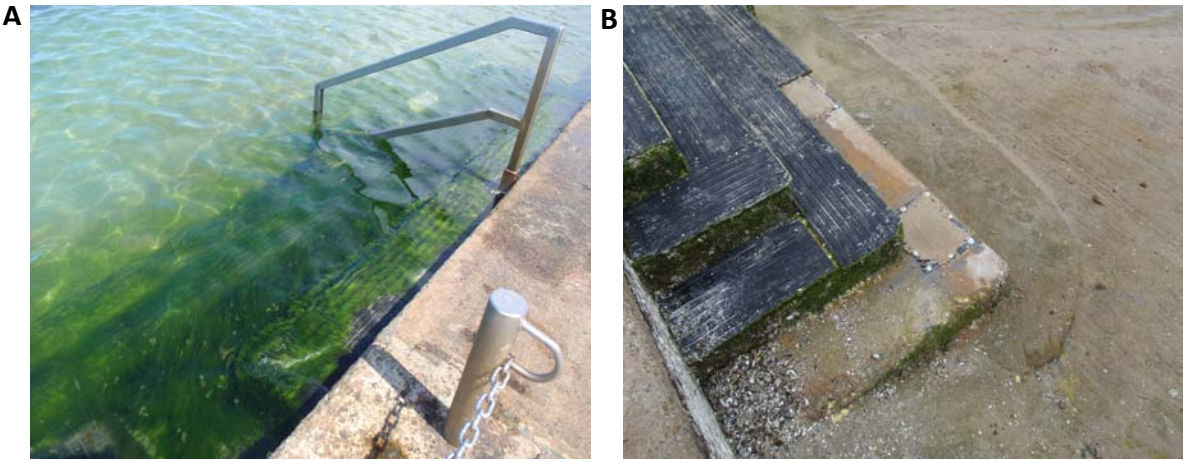
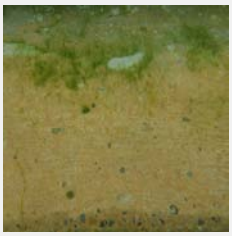
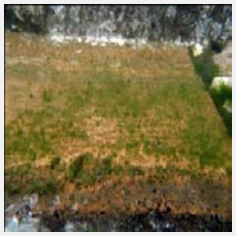
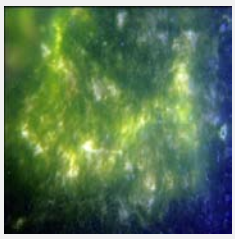
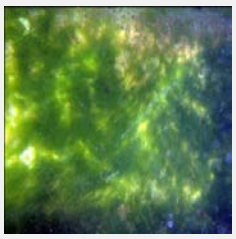
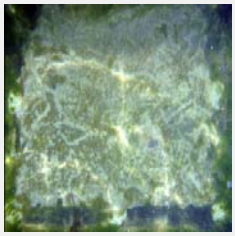


Figure A.7 A. The Cronulla Pool steps fouled with green algae. B. The existing rubber mats and the SW-Mats ready for testing.

Table A.5 The SW-mats tested on steps in Cronulla Rock Pool: anti-foul and foul-release effectiveness

EFFECT	COATING :SW-Mat	CONTROL : Concrete
Anti-Fouling		
2 weeks		
6 weeks		
8 weeks		
Foul-Release		
8 weeks - after cleaning		**not attempted**

Not to scale

Note: There was a relatively low level of algae on the concrete area at 6 weeks (Control) because it was accidentally cleaned by Council staff at around 4 weeks of the Trial.

A.8 Cronulla Rock Pool – North-West Edge

The trial was located on the top of the wall on the north-western side of the Pool (**Figure A.8**). Four coatings were tested: White – X8, White – X7, Blue-Z3 and the SW-Mat.

Fouling

- The top of the pool wall becomes fouled over time with brown algae. The north-western edge fouls more frequently with brown and green algae due to constant overflow from the pool.

Coating

- The White-X8 coating is recommended for the top of the pool wall (**Table A.6**). This coating remained free of fouling over the course of the trial (3 months). The uncoated concrete became fouled within 4 weeks and by 8 weeks was heavily fouled with brown and some green algae in the wettest section (**App. B.5**).
- The test panels were not subject to cleaning.

Maintenance

- White-X8 coating on exposed surfaces does not require frequent cleaning (maybe every 3-6 months). Brown algae did not grow on white-X8 after 3 months however green algae may grow on white-X8 in NW corner (white-X8 not tested in NW corner). If cleaning is required, it is recommended to use only a medium pressure on water jet-blast.

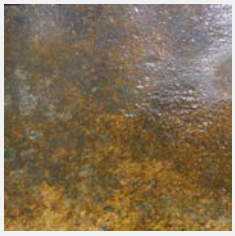
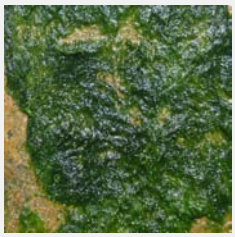
Outcomes

- The top of the pool walls can be painted with white-X8 to dramatically reduce the growth of the very slippery brown algae which grows on the top of all pool walls. The NW edge may need to be cleaned more frequently to completely stop the growth of the green algae.

A  B 

Figure A.8 A. Top of pool wall showing coatings after application B. Application site - NW corner of the Pool

Table A.6 There was no fouling on the White-X8 panels on the top of the wall at Cronulla Rock Pool. The control panels (uncoated concrete) were heavily fouled with brown and green algae within 8 weeks

EFFECT	COATING : White-X8	CONTROL : Concrete
Anti-Fouling		
Start		
8 weeks		
-"-		

B : Final Trial Results (Dec 2009 - Feb 2010)

B.1 Clovelly Bay Step

Anti-fouling activity

Four coatings were applied directly onto the concrete step (Photo 1). Two coatings, black-Y3 and white-X8, showed significant anti-fouling activity after 4 weeks (Photo 2; Table B.1,B.2). However, the antifouling effect of black-Y3 and white-X8 coatings was no longer significant at 6 weeks (Table B.3) and 8 weeks (Photo 3,).

Photo 1 – Clovelly Step at 0 weeks. The direct application of 4 coatings (white-X8, black-Y3 and blue-Z3, white-X7 squares [flaked off in first week]) onto concrete step. The control squares are untreated concrete.

Photo 2 – Clovelly Step after 4 weeks. Black-Y3 squares showed 5–25% fouling cover while white-X8 (remaining white) squares showed 10–60% fouling cover. Most control squares (four of six) showed 100% fouling cover (now green) but two control squares had less than 10% fouling cover (Table B.1, B.2 for statistical analysis) Note: the tile experiment was added to the centre of this step after 1 week as white-X7 and blue-Z3 coatings painted here had peeled off by this time.

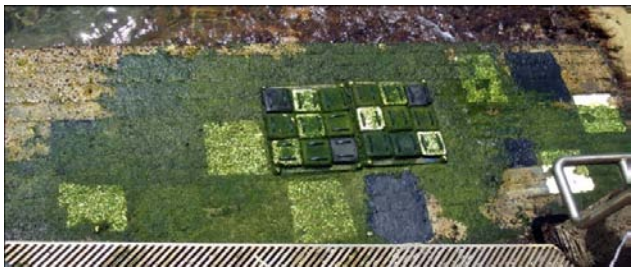


Photo 3 – Clovelly Step after 8 weeks. Most black-Y3 squares are heavily fouled (>75% cover) however two squares show less than 5% fouling cover. Most white-X8 squares are completely fouled but fouling cover is less dense than fouling cover on control (green/concrete) squares. Control squares are the same as at 5 weeks.

Foul- release properties

After 8 weeks, Clovelly step was cleaned using a jet-blaster to see the effect of high-pressure hosing on attached fouling and the integrity of the coatings. Two levels of high-pressure were tested, mid-strength (nozzle held ~1 m above surface; Photo 4, 5A,B,C) and full-strength (nozzle held ~20 cm above surface, Photo 6A,B,C).

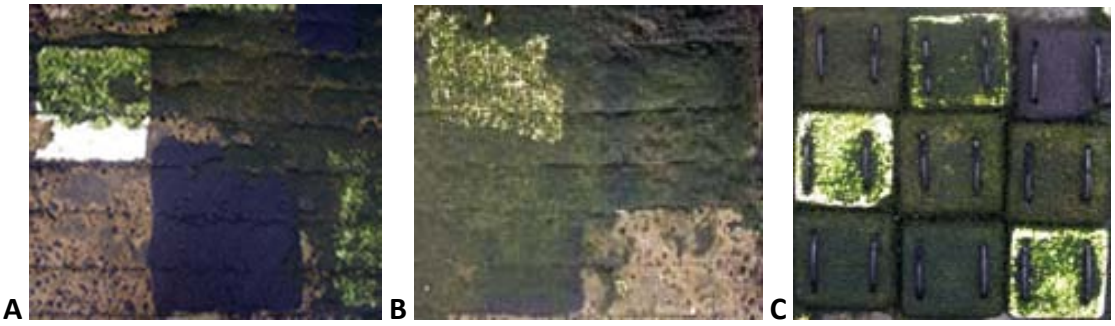


Photo 4 - Before hosing. A) and **B)** are two sections of direct application experiment on step, **C)** is half of the block experiment on step.

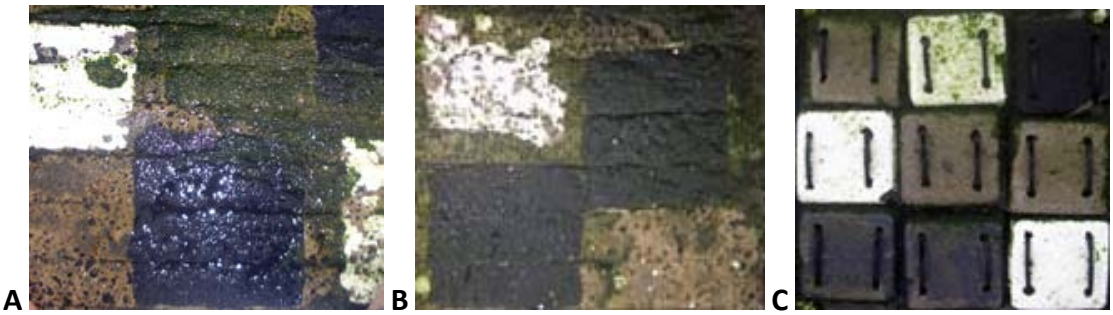


Photo 5 – Same sections after mid-strength high-pressure hosing. (A, B) All fouling was removed from white-X8 squares and tiles (**C**, white 2nd and 3rd row) but not from black-Y3 squares (**B**) and tiles (**C**), or control squares (**A**, green). Some white-X8 coating flaked off with mid pressure hosing **(B)** however this did not occur on white-X8 blocks on which coating was applied off-site **(C)**

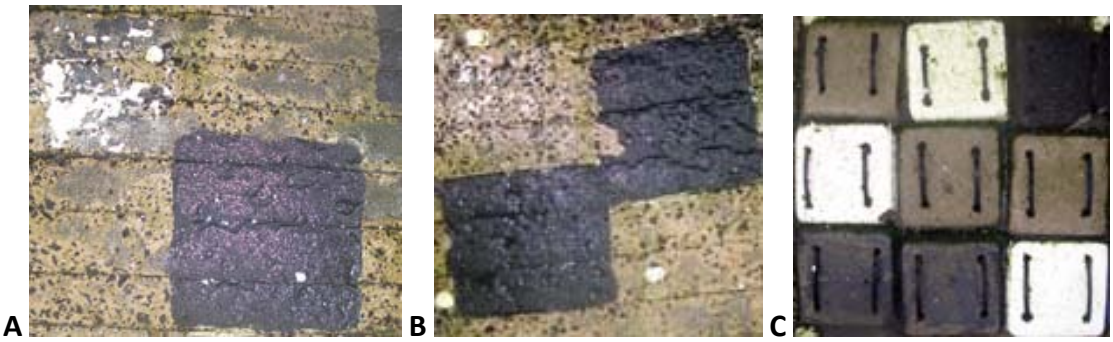


Photo 6 - After full-strength high-pressure hosing. (A, B) White-X8 squares on the step flaked off completely at high pressure but white-X8 coating did not flake off the tiles under high-pressure hosing **(C)**. Fouling was removed from black-Y3 squares **(B)** and tiles **(C)** with high-pressure hosing. Full-strength high-pressure hosing did result in 'pitting' of black-Y3 coating and a small amount of coating peeled off step **(B)**.

B.2 Clovelly Promenade

Three coatings were applied directly onto the concrete promenade (Photo 7A). Two coatings showed strong anti-fouling effects after 12 weeks, white-X8 and blue-Z3 (Photo 7B).

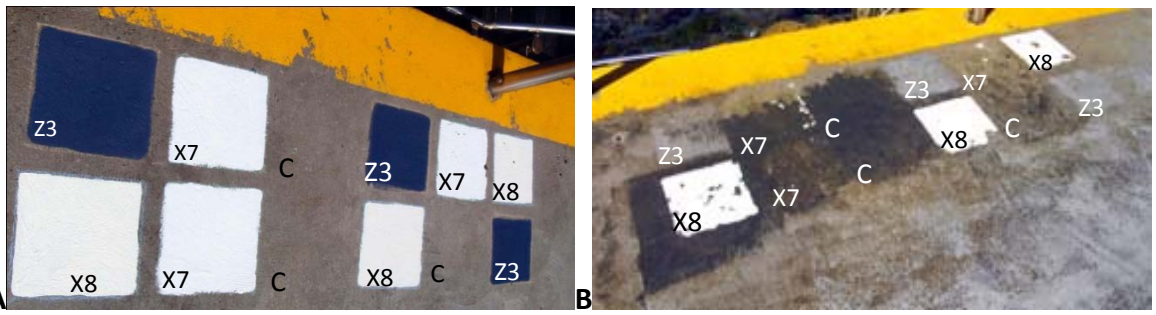


Photo 7 – Promenade at 0 weeks (A) and 12 weeks (B). (A) Three coatings were applied to promenade (white-X7, white-X8 and blue-Z3). **(B)** White-X7 peeled off within a week. White-X8 (remaining white squares) and blue-Z3 (very pale blue) squares have less than 5% fouling cover after 12 weeks while all control (concrete) squares are heavily fouled with brown algae. Note that blue-Z3 paint started to flake off 1 week after application which continued gradually over the course of the experiment.

B.3 Malabar Rock Pool- Steps

Anti-fouling activity

Three coatings were applied directly onto the concrete steps in the pool. SW mats, made with anti-fouling wax/sand, were also fixed to steps. One coating, white-X8, and the SW mats, showed antifouling activity after 4 weeks (Photo 8B) however the effect was not statistically significant (Table B.4).

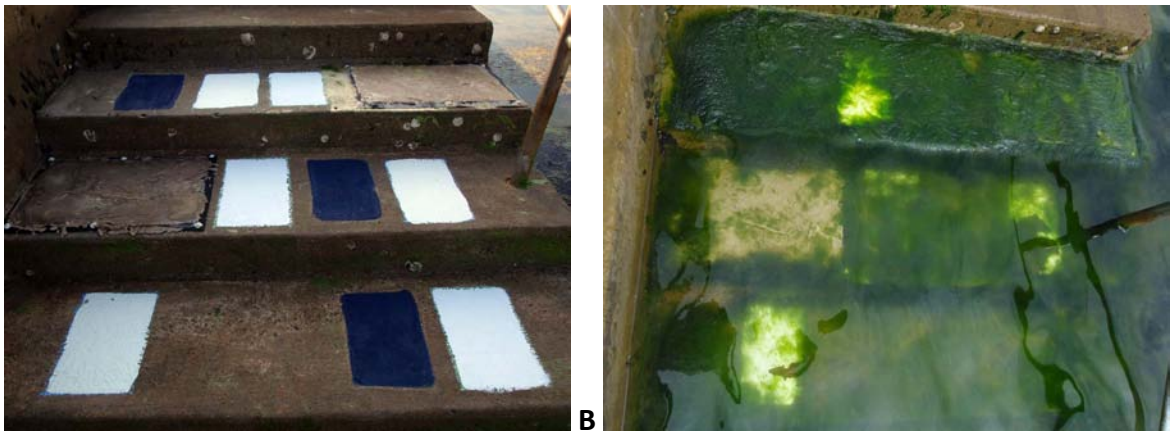


Photo 8 – Malabar Steps at 0 weeks (A) and 4 weeks (B). (A) The direct application of 3 coatings (white-X7, white-X8 and blue-Z3) and SW mats onto concrete step. **(B)** white-X8 (remaining white rectangles) and one SW mat (step 2) have less fouling cover than adjacent control areas (green).

Foul-release properties

After 4 weeks, the foul-release properties of SW mats and white-X8 coating were assessed by physical agitation, i.e., by sweeping hand movements across the surface, including control areas. A small amount of algae was removed from all surfaces (compare green and white areas on step 1 [upper] in Photos 8B and 9A). However,

the majority of fouling was only removed from SW mats by rubbing small areas with a hard block of anti-fouling wax (compare SW mats in 8B and Photo 9A, B). This process (wax-rub) also replenished the surface of the SW-Mat with anti-foul wax. SW mats were cleaned with a plastic scouring pad and maintained with a wax-rub fortnightly from 4 weeks onwards.

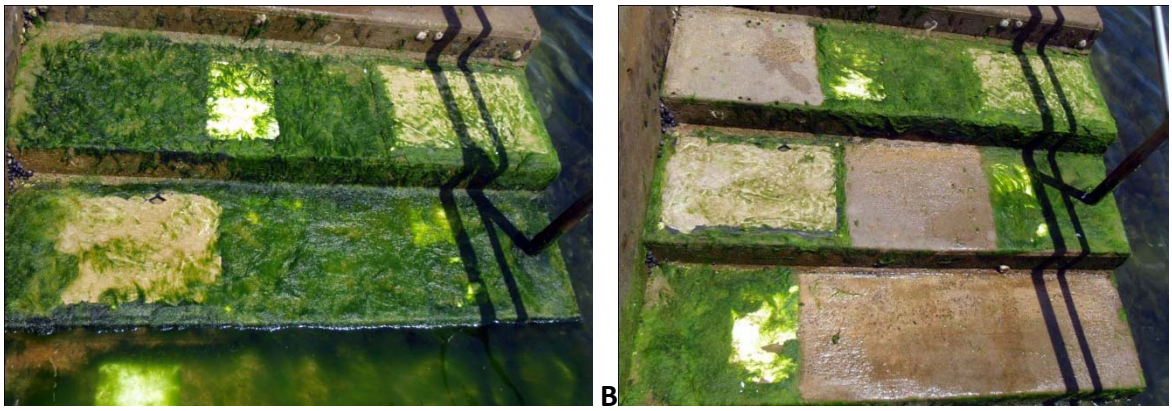


Photo 9 – Malabar Steps, foul-release properties of coatings. (A) Step 1 (upper) after physical agitation of surface and wax-rub of SW mat. Step 2 had not yet been subjected to physical agitation in photo 9A. **(B)** Step 2 and 3 were cleaned by physical agitation with the SW mat also cleaned by wax-rub. A section of each step was also cleaned by jet-blaster at 4 weeks to allow safe access to rock pool (control areas [green] remain alongside each coating/mat).

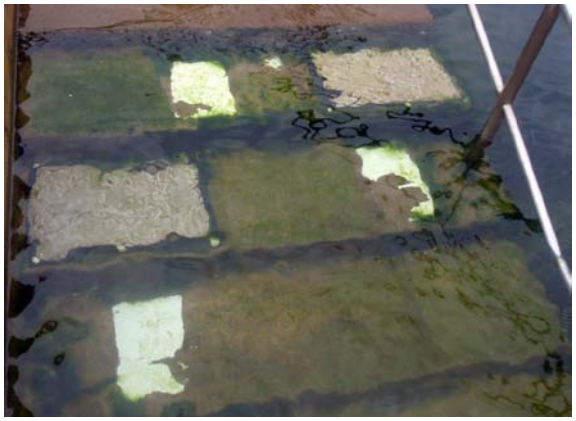


Photo 10 – Steps at 6 weeks. Algae have grown back on concrete areas cleaned 2 weeks earlier by jet-blaster and there is less algal growth on SW mats and white-X8 coating than at 4 weeks (see Photo 9). Recent 'big seas' appear to have 'self-cleaned' SW mats and white- X8 coating on steps (compare with Photo 9B).

6 weeks onwards - SW mat on step 1 was removed by big seas in week 7 of trial. Steps cleaned by jet blast after 6 weeks. X8 rectangles on step 2 and 3 were accidentally removed by jet-blast clean. Step experiment terminated due to lack of replication however remaining SW mat (step 2) and white-X8 rectangle were observed, cleaned and maintained (wax-rub) up to 11 weeks.

Results from the experiment on the wheelchair ramp were very similar to those from the pool steps.

B.4 Malabar Rock Pool- Wall

Anti-fouling activity and foul-release properties

Four coatings were applied directly onto concrete vertical wall (Photo 11). The grey-WE coating performed the best here under immense fouling pressure exhibiting significant anti-fouling activity (Appendix 2-Table 5, 6) and foul-release properties (Photo 12, 13) at 4 weeks. White-X7 and blue-Z3 coatings also showed some degree of anti-fouling activity at this time but the effect was not quite significant (Appendix 2-Table 6). This trend continued for 11 weeks (Photo 13, 14).

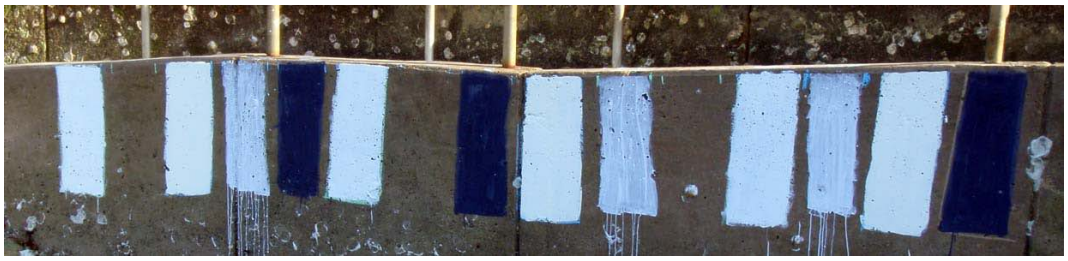


Photo 11 – Malabar Rock Pool Wall at 0 weeks. The direct application of 4 coatings (White-X7, White-X8, Blue-Z3 and Grey-WE) onto concrete wall, with untreated concrete as control panels.

A  **B** 

Photo 12 – A section of pool wall after 4 weeks before (A) and after physical agitation (B). (A) Malabar rock pool experienced intense fouling pressure during the first 4 weeks of the trial. Thick layers of algae grew on the upper section of the wall. Grey-WE panels exhibited antifouling activity at this time with considerably less algae growing on grey-WE. **(B)** The same section of the wall after physical agitation of the surface (panels L to R: grey-WE, white-X8, blue-Z3, green-control).

4 weeks - Foul-release properties of the coatings were assessed at this time by physical agitation, i.e., sweeping hand movements across the surface of the pool wall. A lot of algae were released from the upper wall probably because of loose attachment of algae in the first place. However, foul release properties of the coatings may have also played a part given that less algae was removed from control panels (Photo 12B)

6 – 11 weeks Big seas had removed the majority of fouling from the upper half of all panels on the pool wall by 6 weeks (Photo 13, 14). Thick algal growth remained in the lower sections of most panels at 6 weeks but less algae grew on WE and Z3 panels (Photo 13, 14). This pattern of algal growth continued until 11 weeks with new growth primarily appearing as flat fuzzy growth in upper regions of panels (Photo 14B, C).

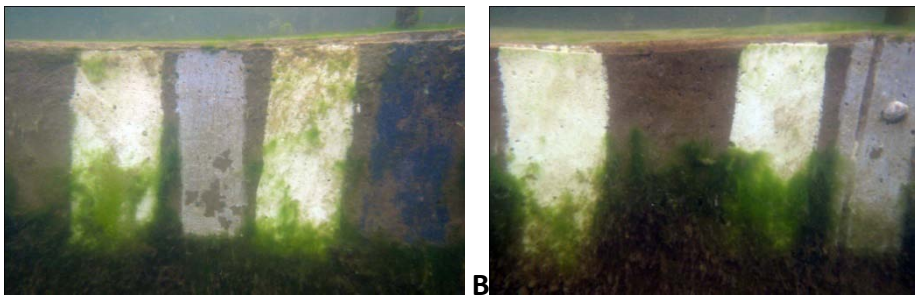


Photo 13 – Two sections of pool wall at 6 weeks. **(A, B)** Big seas removed a lot of algae that had grown on the upper section of the wall by 4 weeks (see Photo 12). Less algae were seen on grey-WE and blue-Z3 panels than on white-X7/8 coatings and concrete-control panels at 6 weeks.

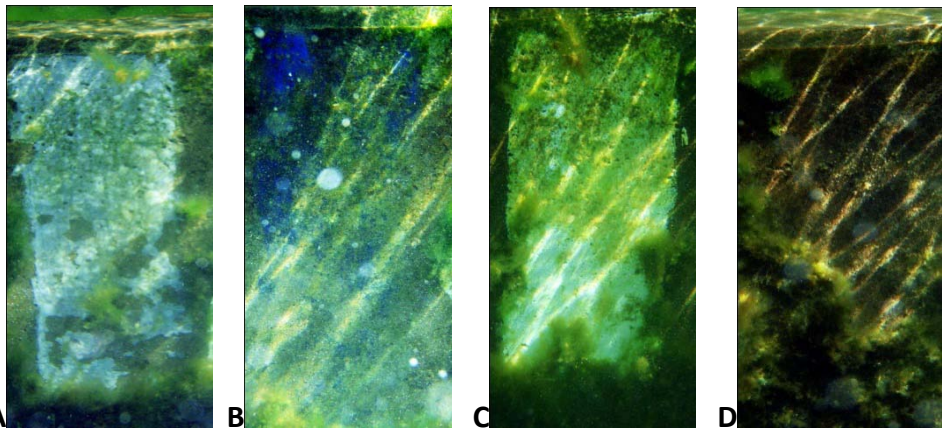


Photo 14 – Representative panels at 11 weeks. (A) Very little algae grew on grey-WE panels throughout trial. Algal growth in latter part of trial was short and fuzzy in appearance and primarily in upper section of panels. This growth form was most obvious in blue-Z3 **(B)** and white-X 7/8 panels **(C)** but difficult to see in photographs of control panels **(D)**.

B.5 Cronulla Rock Pool - NW Pool Edge

Three coatings were tested on the north-western pool edge (Photo 15) and one coating at the access point (ladder). The test area for white-X7 and white-X8 coatings was half the size (20 x 40 cm^2) of the blue-Z3 and concrete-control squares (40 x 40 cm^2) due to limited availability of these coatings.

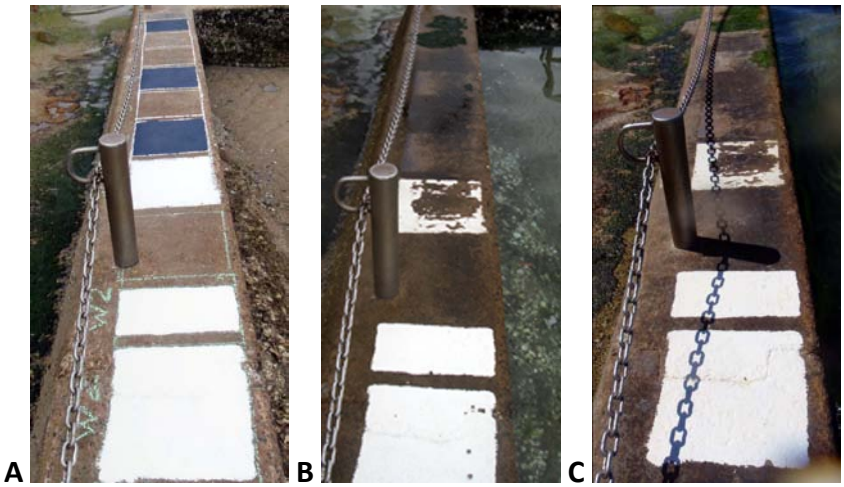


Photo 15 – The north-west edge of Cronulla Rock Pool at 0 weeks (A), 6 weeks (B) and 8 weeks (C). (A) The application of three coatings on pool edge; blue-Z3, white-X7 and white-X8 coatings with untreated concrete as controls. **(B,C)** White-X8 panels (foreground) were completely free of fouling at 6 and 8 weeks despite the heavy growth of brown algae around them (dark brown coloured concrete in **B, C**). Blue-Z3 squares (2 pale/concrete areas above bollard, B & C) show anti-fouling activity in the left side of the square even though the majority of it had flaked off by week 2. The surfaces of white-X8 and blue-Z3 squares (pale, unfouled area) were not slippery even when wet.

Note: Results at Cronulla rock pool could not be statistically analysed due to different sized test areas and low replication.

One SW mat was attached at the NW corner access point using the adjacent concrete area as the control (Photo 16A, D). This area only experienced moderate fouling pressure.

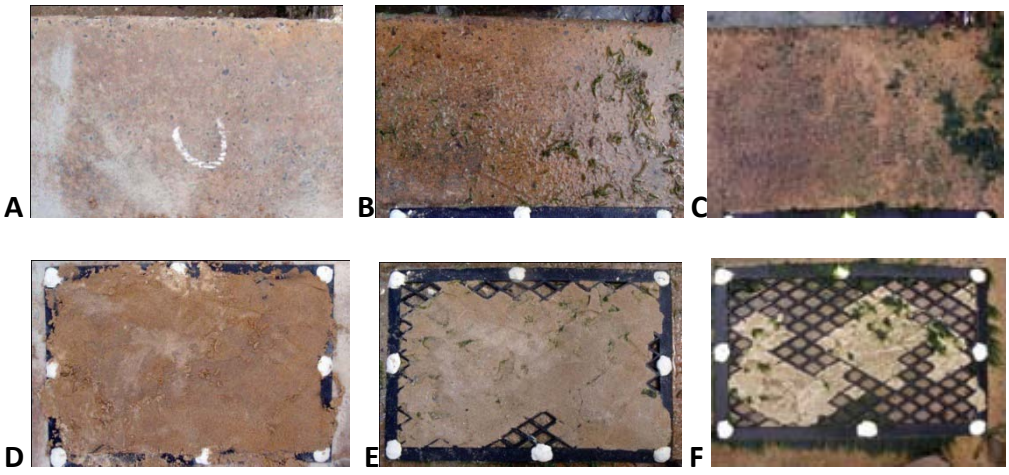


Photo 16 - NW corner SW mat (D, E, F) and control (A, B, C) at 0, 4 and 6 weeks . Control area at NW corner at 0 weeks **(A)**, 4 weeks **(B)** and 6 weeks **(C)**. SW mat at 0 weeks **(D)**, 4 weeks **(E)** and 6 weeks **(F)**. There was minimal growth of green algae in NW corner, however, brown algal growth was quite prominent after 6 weeks on the concrete (**C**, darker areas).

B.6 Cronulla Rock Pool - Ramp

Three coatings were tested on the pool ramp on the western side of the pool (Photo 17). The test area for white-X7 and white-X8 coatings was half the size (20 x 40 cm^2) of the blue-Z3 and concrete-control squares (40 x 40 cm^2) due to limited availability of these coatings.

A  B 

Photo 17 – The concrete ramp at Cronulla Rock Pool at 0 weeks (A) and 14 weeks (B). (A) The direct application of 3 test coatings; blue-Z3, white-X7 and white-X8, and control areas (untreated concrete). Blue-Z3 coating had started to flake off at 2 weeks and was almost completely flaked off at 8 weeks. **(B)** There was no fouling on any control or coating squares at 14 weeks.

B.7 Cronulla Rock Pool - Steps

Two SW mats (half size) were attached to the lower step in the pool and the concrete between the mats was used as the control area (Photo 18A, B).

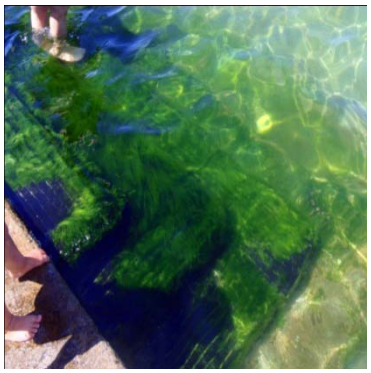
A  B  

Photo 18 – SW mats on steps in Cronulla rock pool at week 0 (A), week 2 (B) and week 8 (C). (A) SW mats on pool steps at week 0. **(B)** Growth of algae on control area of pool steps at 2 weeks with no growth visible on mats. **(C)** Steps and SW mats were heavily fouled at 8 weeks

4 weeks - The control area was accidentally cleaned by council workers somewhere between 2 and 4 weeks, so that the algal growth observed at 6 weeks (Photo 19A) is less than it should be. A cleaning procedure for SW mats was commenced at 4 weeks, and repeated fortnightly, which involved i) rubbing surface of SW mat with a scourer which removes some algae through abrasion, and ii) rubbing surface with a block of anti-foul wax which also removes algae and replenishes wax coating (Photo 19C, F). At the time of SW mat cleaning, control areas were physically agitated by rubbing hand over the surface which only removed loosely attached fouling.

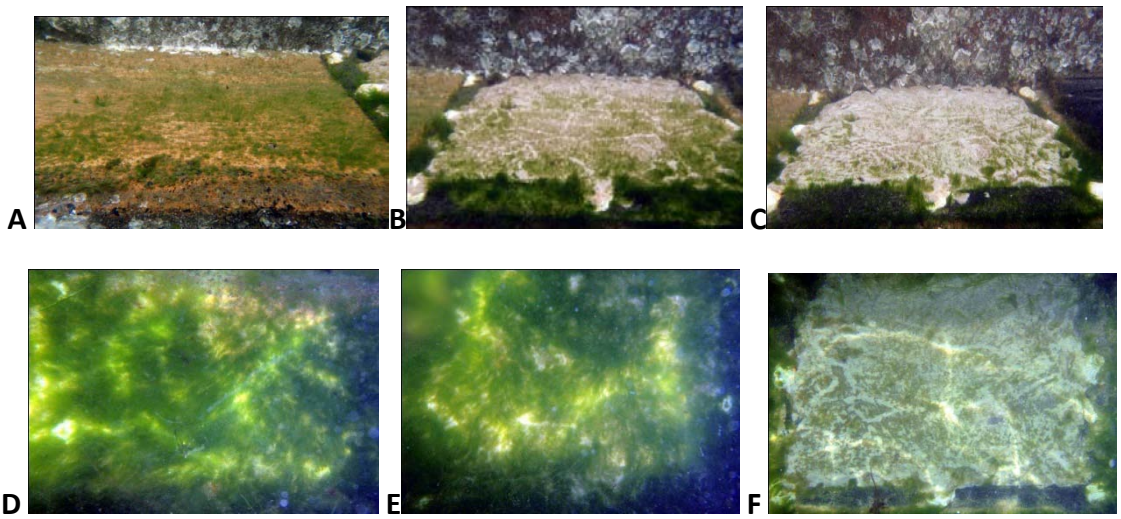


Photo 19 – A section of the lower pool step at 6 weeks (A,B,C) and 8 weeks (D,E,F). Control area at 6 weeks **(A)** and 8 weeks **(D)**. SW mat at 6 weeks **(B)** and 8 weeks **(E)** showing considerable algal growth by 8 weeks. The same SW mats after cleaning at 6 weeks **(C)** and 8 weeks **(F)**.

B.8 Statistical analysis

Experiments were analysed using analysis of variance (ANOVA) when the experimental design fit the criteria for the analysis, and the results met the assumptions of the test. When a significant effect of antifouling treatment was reported, Tukey's post-hoc multiple comparisons were used to determine which treatments differed from one another.

Clovelly Bay Steps

Table B.1 - **Single factor ANOVA Table of Percent Algal Cover at 4 weeks**. Remaining anti-foul coatings (white-X8, black-Y3) on the Clovelly Step. Blue-Z3 was excluded from the analysis as the coating had peeled off most squares at this time.

Source	Sum of Squares	df	Mean- Square	F-ratio	P
Treatment	10285.8	2	5142.9	6.146	0.011
Error	12552.0	15	836.8		

P=0.011 indicates that their was a significant difference in percent algal cover on the test squares at 4 weeks (but it does not tell us which coatings were sig. dif. to control. See Table B.2).

Table B.2- **Tukey's post-hoc test of percent cover at 4 weeks**. Matrix of pair-wise comparison probabilities (1=control, 2=black-Y3, 3=white-X8).

	1	2	3
1	1.000		
2	0.011	1.000	
3	0.058	0.674	1.000

Black-Y3 significantly different percent cover than control (p = 0.011) while percent cover on white-X8 coating is almost significantly different to algal cover on control (p=0.058).

Table B.3- **Single factor ANOVA table of Percent Algal Cover at 6 weeks.**

Source	Sum of Squares	df	Mean- Square	F-ratio	P
Treatment	680.4	2	340.2	0.244	0.787
Error	20935.8	15	1395.7		

P= 0.787 indicates that the percent algal cover observed across treatments was no longer significantly different to one another at 6 weeks

Malabar Rock Pool- Steps

Table B.4 - Single factor ANOVA of Percent Algal Cover at 4 weeks. Remaining anti-foul coatings (white-X8, SW mat) on Malabar Step.

Source	Sum of Squares	df	Mean- Square	F-ratio	P
Treatment	1800.0	2	900.0	1.714	0.258
Error	3150.0	6	525.0		

P= 0.258 indicates that the percent algal cover observed across treatments was not significantly different to one another at4 weeks

Malabar Rock Pool - Wall

Table B.5 - Single factor ANOVA table of percent algal cover observed on anti-foul coatings (white-X8, white-X7, blue-Z3, grey-WE) on Malabar Pool Wall at 4 weeks (after physical agitation of surface)

Source	Sum of Squares	df	Mean- Square	F-ratio	P
Treatment	13976.7	4	3494.2	35.5	0.000
Error	983.3	10	98.3		

P=0.000 indicates that there were very significant differences in percent algal cover between test panels but does not tell us which ones were different (see Table B.6)

Table B.6 - Tukey's post-hoc test of Percent Cover at 4weeks. Malabar Rock Pool wall at 4 weeks; matrix of pair-wise comparison probabilities (1=blue-Z3, 2=white-X8, 3=grey-WE, 4=white-X7, 5 =control)

	1	2	3	4	5
1	1.000				
2	0.128	1.000			
3	0.000	0.000	1.000		
4	1.000	0.128	0.000	1.000	
5	0.069	0.993	0.000	0.069	1.000

Grey-WE panels (wax-based emulsion) had much less algal cover than control panels and therefore highly significant (p=0.000). White-X7 and Blue-Z3 had less algal cover than controls but these differences were not (quite) statistically significant (p=0.069).

B.9 Methods for the Final Field Trial 2009-10

Direct application of novel anti-foul coatings

Coatings that progressed to the final round of testing were:

- White-X7 and white-X8 coatings (company C)
- Black-Y3 coating (company B)
- Blue-Z3 coating (company A)
- Anti-foul wax from UNSW
    - SW Mat: selected wax formulation melted with sand and applied over a rubber mat fixed the concrete with bolts.
    - Grey-WE. Wax-based coating.

Coatings were applied directly to surfaces at all sites (summarised in Table B.7) by the manufacturer or by UNSW personnel as per manufacturer's instructions. SW mats could only be tested at sites where excessive heat was not a factor. #

Table B.7– Coastal sites, experimental design and test coatings for the Final Trial Summer 2009-10#

Site	Experimental Design	Coatings
Clovelly Bay		
Step	Direct application (& Tiles)	2 x White Black Blue
Promenade	Direct application	2 x White Blue
Malabar Rock Pool		
Step/Ramp	Direct application	2 x White Blue
	SW Mat	Wax-sand mix
Wall	Direct application	2 x White Blue Wax emulsion
Cronulla Rock Pool		
Pool edge & Access ramp	Direct application	2 x White Blue
Pool Steps & NW corner	SW Mat	Wax-sand mix

Please refer to *Antifouling Technologies for Coastal Pools and Platforms- Project outline and specifications, February 2009* for:

- a detailed description of environmental factors at each site
- application and performance specifications for coatings at each site.

1. Clovelly Bay

There was a strong nor-easterly wind blowing during the application (16.12.09) which may have resulted in coatings drying too quickly. This could explain why the application of white-X7and blue-Z3 coatings was unsuccessful.

i) Step

- Four coatings (white-X8, black-Y3, white-X7and blue-Z3) were applied directly onto the concrete step in the bay. The step was cleaned by jet-blast the day before the application.
- Very low tides were predicted for the day of application (16/12/09) allowing ~1 hour for the step to dry off at low tide before applying test coatings. Coatings also had 1 hr to cure before the tide came back in.
- The step was divided into 30 squares (25cm x 25cm) with a 5 cm border around each. Treatments were randomly assigned to each square on the step with six replicates per treatment (Photo 1)

ii) Promenade

- Three coatings (white-X8, white-X7and blue-Z3) were applied directly onto the eastern end of the concrete promenade. The area had been cleaned by jet-blast recently. This area was chosen as it had been heavily fouled earlier in the year.
- The area was divided into 12 squares (25cm x 25cm) with a 5 cm border around each. Treatments were randomly assigned to each square on the promenade with three replicates per treatment (Photo 7A).

2. Mahon Pool

- One coating, blue-Z3, was applied to 4 locations at Mahon Pool on both concrete and sandstone surfaces. At each location, three rectangles (10cm x 20cm) were painted alongside three control rectangles (concrete or sandstone)
- Two SW mats (60cm x 40cm) were anchored to steps at the southern end of pool. Once the rubber mat was in place hot wax –sand mixture was poured in and smoothed over with a trowel. Nine dynabolts (10mm x 60 mm, stainless steel, flat top) were used to anchor each mat at this site given the exposure to big seas. The top of the bolts were covered with aqua-putty so that bathers would not stub their toes.

3. Malabar Rock Pool

There was a strong nor-easterly wind blowing during the application (16.12.09) which may have resulted in coatings drying too quickly. This could explain why the application of white-X7and blue-Z3 coatings was unsuccessful.

i) Step

- Three coatings (white-X8, white-X7and blue-Z3) were applied directly onto the concrete steps in the pool. The pool was emptied and cleaned by jet-blast on the day of application. Two SW mats were fixed to Step 1 and Step 2 using 6 mm standard dyna-bolts (stainless steel). The top of the bolts were covered with aqua-putty so that bathers would not stub their toes.
- The steps were divided into 6 rectangles each (approximately 20cm x 30 cm) with a 5-10 cm border. Treatments were randomly assigned to each square on the step with three replicates per treatment (Photo 8A) with one SW mat equal to two replicates (for SW mat treatment) due to the dimensions of the mat. Only one-half of the SW mat on step 1 was included as a replicate for analysis with two replicates coming from the SW mat on step 2.

ii) Ramp

- One large test area of white-X7and white-X8 were painted on the ramp as well as two smaller test areas of blue-Z3 coat. Three SW mats were anchored to the ramp using 6 mm standard (60mm) dyna-bolts (stainless steel). Once the rubber mats were in place hot wax –sand mixture was poured in and smoothed over with a trowel. The top of the bolts were covered with aqua-putty so that bathers would not stub their toes.

iii) Wall

- Four coatings were applied directly onto concrete vertical wall (white-X7, white-X8, blue-Z3 and grey-WE) with untreated concrete as control panels. (Photo 11).
- The wall was divided into 15 panels (25 cm x 50 cm) with a 5 cm border around each. Treatments were randomly assigned to each panel on the wall with three replicates per treatment (Photo 11)

4. Cronulla Rock Pool

The pool was emptied and cleaned by jet-blast on the morning of the application (15/12/09).

i) ***Pool edge and access ramp***

- Three coatings (white-X8, white-X7and blue-Z3) were applied directly onto the edge of the pool (western side) and along one side of the access ramp.
- Initially, it was thought that blue-Z3 was the only coating being tested here but it was later discovered that a small amount of white-X7 and white-X8 coatings were available hence the cluster of white-X7/X8 at each end of pool edge (Photo 15A) and access ramp (Photo 16A). The test area for white-X7 and white-X8 coatings was half the size (20 x 40 c^{m2}) of the blue-Z3 and concrete-control squares (40 x 40 c^{m2}) due to low availability of these coatings. White-X7 coating ran out before the final rectangle was painted on the pool edge so that only two rectangles of white-X7 were painted (merged as a square near bollard, Photo 15A)

ii) NW corner

- One SW mat was fixed to the pool edge at the NW corner. This is the lowest point of the pool and is constantly wet. The adjacent concrete area was used as the control. The SW mat was anchored by eight dynabolts (10mm x 60 mm, stainless steel, flat top) and a large (30mm) washer at this site given the exposure to big seas. Once the rubber mat was in place hot wax –sand mixture was poured in and smoothed over with a trowel. The top of the bolts were covered with aqua-putty so that bathers would not stub their toes.

iii) Pool steps

- Two half size mats were (30cm x 40cm) anchored to the lowest pool step using seven dynabolts (10mm x 60 mm, stainless steel, flat top) and a large (30mm) washer. Once the rubber mat was in place hot wax –sand mixture was poured in and smoothed over with a trowel. The top of the bolts were covered with aqua-putty so that bathers would not stub their toes. The concrete section between the two mats was used as the control.

Tile (Block) Experiment – Clovelly Step

- All coatings were tested on concrete tiles (blocks) in one experiment on Clovelly Bay Step, in addition to the direct application experiment, in case the on-site application of coatings was unsuccessful.

- Concrete tiles (10 x 10 x 2 cm) were prepared by the Centre for Marine Bio-Innovation (UNSW) and coated by personnel from participating companies. A coating by a fourth company not yet tested in this project was included in the tile experiment only.
- Tiles were made using a standard commercial sand/cement mix (no aggregate), which was reinforced with aluminium chicken wire. A piece of fly-screen was imprinted on the upper surface of the tiles to provide a rough finish which is amore favoured as a settlement substrate than a smooth surface. The tiles have rounded edges to minimise the risk of stubbing toes.
- Concrete tiles were attached to polycarbonate backing plates using 2 cable ties through the centre of each tile. These test plates were dyna-bolted (10 x 60 mm) to the centre of a concrete step in Clovelly Bay (Photo 2).

Analysis of fouling

Photographic analysis

- Photographs of each experiment were taken every fortnight with a digital camera.
- Photographs of each test square/panel were assessed using Adobe Photoshop and percent algal cover recorded for all time points

Statistical analysis

- Where possible, the results were analysed using analysis of variance (ANOVA) and Tukey's post-hoc pair-wise comparisons (SYSTAT).