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Performance of the Tin-Free Antifouling Coating International *Ecoloflex* in DSTO/RAN Trials

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ABSTRACT

A national and global ban on the application of antifouling paints containing tributyltin (TBT) is being introduced because of the detrimental effects of TBT on non-target marine species. DSTO, supported by the Royal Australian Navy (RAN), undertook a comprehensive program in an attempt to find alternative products that would match or approach the antifouling performance and effective life of TBT-based systems. The evaluation program included static immersion trials, dynamic flow testing, and trials on Navy ship hulls. Within this program, the Akzo Nobel coating *Ecoloflex* demonstrated antifouling efficacy, consistent ablation characteristics, and long term effectiveness on vessels operating in temperate and tropical Australian waters. This was the best performance seen from a copper-based antifouling coating to date and offered the RAN an alternative to TBT-based systems.

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Executive Summary

The antifouling biocide tributyltin (TBT) has provided the most effective means of preventing fouling growth on ship hulls. Self-polishing copolymer (SPC) coatings based on TBT provided the Royal Australian Navy (RAN) with hulls free of fouling for periods up to and exceeding five years without the need for repainting. This performance conferred significant economic and operational savings through increased operational readiness, reduced fuel consumption, extended docking intervals, and reduced docking costs.

However, the impact of TBT on non-target marine species throughout the world has led to widespread regulations and restrictions on the use of antifouling coatings containing TBT. Moves are now underway to implement a global ban on the application of TBT paints. The International Maritime Organisation (IMO), through its Marine Environment Protection Committee (MEPC), developed an instrument to totally ban the application of TBT-containing paints from 1 January 2003. Australian Government policy supported and promoted this IMO action, and further stated that unilateral action would be taken to ban TBT paints from 2006 should there have been a delay in implementation of the IMO instrument.

Available alternatives to TBT paints did not provide the reliable antifouling performance and long term effectiveness afforded by TBT SPC coatings and, when these were used, Navy experienced failures within 18 months under Australian conditions. DSTO, with support from the RAN, undertook a comprehensive program to seek and evaluate products to find the best tin-free alternatives for RAN use. The program utilised DSTO marine immersion facilities in Melbourne and Cairns, a rotor apparatus for simulating ship movement, and patch and hull trials of selected products on Navy vessels. More than 120 products were assessed in this program up to the year 2000.

DSTO/RAN trials on the copper-based antifouling coating *International Ecoloflex*[1], manufactured by *Akzo Nobel Pty Ltd*, demonstrated its efficacy in both panel trials and patch trials on operational vessels. The results for this system were the most promising of any of the candidate products, and indicated it may provide antifouling effectiveness and long term performance comparable with TBT SPC coatings on large vessels. Subject to registration by the National Registration Authority (NRA), the *Ecoloflex* system offered the RAN an effective alternative to TBT systems for surface ships. To fully validate performance, full hull trials of this system were initiated on the ANZAC-Class Frigate *Warramunga* and the Fremantle-Class Patrol Boat *HMAS Geraldton*.

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[1] At the time of this work, *Akzo Nobel Pty Ltd* were affiliated with the *Nippon Paint Co. Ltd*, Japan, who developed and own the name "*Ecoloflex*". The companies have since separated and the equivalent antifouling product marketed by *Akzo Nobel* in Australia is now known as *International Intersmooth 360 SPC.*

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After completing BSc (Hons) and MSc degrees in marine biology at the University of Melbourne in 1977, John Lewis embarked on a career as a scientist in the Defence Science & Technology Organisation, with primary interests in marine biofouling and its prevention, and the effects of RAN activities on the marine environment. John became the head of the Environmental Compliance and Biotechnology Group, within the DSTO Maritime Platforms Division, and led a team investigating new, environmentally acceptable methods of biofouling control, biofouling and marine pest management, environmental compliance of naval vessels, and other aspects of naval operations.

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1. Introduction

Antifouling paints containing tributyltin (TBT) as the primary biocide were proven in the latter decades of the twentieth century to be the most effective means of preventing fouling growth on the underwater hulls of vessels (Lewis, 1998). Self-polishing copolymer (SPC) systems based on TBT provided the Royal Australian Navy (RAN) with fouling-free hulls for periods up to and exceeding five years without the need for recoating. This performance maximised operational readiness, reduced fuel consumption through reduced hull friction, minimised acoustic signatures, extended docking intervals, and reduced docking costs including the need for removal and disposal of spent antifouling coatings.

However, TBT was found to cause malformations in shellfish at ultratrace concentrations and to accumulate in the tissues of marine biota. The use of tin-containing paints is therefore becoming increasingly regulated (Lewis, 2003). Initial controls were directed at prohibiting or limiting their use on recreational craft but moves proceeded toward total national and global bans on the use of paints containing TBT. The International Maritime Organisation, through its Marine Environment Protection Committee (MEPC), developed an instrument to totally ban the application of TBT-containing paints from 1 January 2003 (IMO, 2001). Australian Government policy was to support and promote this IMO action, and further stated that unilateral action would be taken to ban TBT paints from 2006 should there be a delay in implementation of the IMO instrument (Anon., 1998a, 1998b).

The main concern for shipowners and operators about the prospective TBT ban was the lack of alternative products that could be expected to provide reliable antifouling performance and long-term effectiveness comparable to that of TBT SPC coatings. The costs to the operators of even a small amount of fouling growth include increased fuel costs, reduced speed and inability to meet schedules, and more regular dockings and maintenance. Ineffective antifouling coatings also increase the risk of transport of exotic marine pests, of which 80% of those currently known are now considered to have been transported as hull fouling. The RAN directly experienced the shortcomings of the alternatives to TBT paints in the early 1990s when a number of vessels were painted with tin-free antifouling coatings (Lewis, 2002). Severe fouling occurred on these within 18 months of launch.

The primary alternatives to TBT paints are coatings containing copper as the primary biocide (Lewis, 1998). Copper-based paints were first introduced in the mid 19th century but, at the time TBT paints were first introduced in the 1970s, their effective life still rarely exceeded 18-24 months. More recent developments extended their expected life to close to 36 months, but without the reliability provided by TBT coatings. The problems encountered in their performance included:

- the high cuprous oxide loading required to give long life, which often compromised film integrity and led to cracking and other physical failures
- the lack of a suitable paint matrix to generate long-term controlled and consistent polishing and biocide release

- the copper resistance of some major fouling organisms which necessitated inclusion of secondary or booster biocides in the paint formulations to provide broad spectrum performance
- chemical reactions at the paint surface which formed insoluble copper precipitates which blocked further biocide release and led to premature paint failure

In 1989, soon after concerns were first raised about the environmental impact of TBT, DSTO initiated a comprehensive program to seek effective, more environmentally acceptable methods of fouling control for the RAN fleet. Through until 2000 more than 130 systems were included in this program. Initial screening of these materials was undertaken in static immersion and dynamic flow panel trials, which indicates the antifouling efficacy, ablative characteristics and physical resilience of the coating systems. With the cooperation of the Navy, more promising products were then evaluated in patch trials on RAN vessels.

This report presents the results of our studies from 1993 through until 2000 on the *Akzo Nobel* product *International Ecoloflex*[1], which showed promise as one of the first alternatives to the TBT-containing self-polishing antifouling systems to provide similar efficacy, effective longevity and performance.

2. Experimental Trials

2.1 Panel Trials

2.1.1 Raft Trials

Antifouling efficacy of the *Ecoloflex* system was assessed by static immersion using DSTO's two test rafts: at the temperate waters site at Williamstown in northern Port Phillip Bay, Victoria, and at the tropical site in Trinity Inlet, Cairns, Queensland. For each of these sites, coatings were applied to 300 mm x 150 mm mild steel panels. These test panels were then attached to frames and suspended vertically between 0.5 and 1.5 m below the water surface at each site. Two panels were immersed at each site. Panels were inspected regularly for biofouling presence and coating integrity and non-toxic controls routinely immersed to assess the abundance and diversity of fouling settlement. These test procedures accord with *Australian Standard Test Method AS 1580.481.5--1993: Coatings--Durability and Resistance to Fouling--Marine Underwater Paint Systems* (Standards Australia, 1993).

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[1] At the time of this work, *Akzo Nobel Pty Ltd* were affiliated with the *Nippon Paint Co. Ltd*, Japan, who developed and own the name "*Ecoloflex*". The companies have since separated and the equivalent antifouling product marketed by *Akzo Nobel* in Australia is now known as *International Intersmooth 360 SPC.*

2.1.2 Rotor Trials

The performance of coatings under dynamic flow conditions was evaluated using the DSTO Rotary Simulator located on Breakwater Pier, Williamstown. This facility consists of a baffled tank in which a drum is rotated with a peripheral speed of 20 knots. Seawater is continually pumped through the tank. The *Ecoloflex* system, along with other experimental systems for evaluation, was applied to the surface of slightly curved, 150 mm x 150 mm mild steel panels and two panels of each system attached to the periphery of the drum. Panels were then inspected at regular intervals for physical integrity, and coating thicknesses measured to enable calculation of ablation, or polishing rates.

2.2 Patch Trials

2.2.1 HMAS Townsville (Trial 1126)

The first of the series of patch trials of tin-free antifouling systems was initiated on the Cairns-based Fremantle-Class Patrol Boat (FCPB) *HMAS Townsville* in March 1993. This trial was initiated following the premature failure of a tin-free system on Cairns-based vessels painted during a period when the ship-repair facilities in Cairns were not registered to apply TBT-containing antifoulings. For example, significant weed and tubeworm fouling were present on the underwater hull of *HMAS Townsville* within 12 months of initial paint application and, by 18 months, fouling growth was adversely affecting ship performance. The patch trial was implemented to enable the performance of tin-free coatings from the major marine coatings manufacturers to be compared under equivalent conditions. *International Ecoloflex* was not available at the time this trial was initiated.

The patch trial on *HMAS Townsville* was terminated at the vessel's subsequent scheduled refit in October 1995.

2.2.2 HMAS Bendigo (Trial 1178b)

As the scheduled refit interval for major RAN surface ships is a minimum of 4 years, a more comprehensive series of patch trials was planned to assess the suitability of available tin-free products over a four year period and on vessels home-ported in different regions of Australia. Three vessels were selected for these trials: the FCPB *HMAS Bendigo* based in Cairns, the destroyer *HMAS Brisbane*, and the FCPB *HMAS Bunbury* based in Western Australia.

Strips of six different antifouling systems were applied to the underwater hull of *HMAS Bendigo* in Cairns in November 1993. 700 mm wide strips were applied to the bow section on both port and starboard sides and extended from 150 mm below the water line to the keel with a gap of 350 mm between strips. The sequence of test coatings varied on the two sides of the hull. Strips were applied on top of the old tin free antifouling after this was high pressure washed at 3000 psi.

Two coatings from *Akzo Nobel* were included in the patch trial: *International Duplex* (*Intersmooth Tin-Free SPC BGA535/537*) and *Ecoloflex* (*SP600*). The marine paint companies *Jotun*, *Hempels*, *Wattyl* and *Resene* also provided materials for this trial.

The trial continued through until April 1998 when *HMAS Bendigo* next docked for refit. Detailed inspections by DSTO staff were undertaken at an emergency docking in February 1995 at the completion of the trial. Underwater inspections and photography of the strips were also undertaken in January 1995 and October 1997. The vessel also underwent an emergency docking in January 1998 but no detailed inspection could be arranged at this time. The entire underwater hull, including the strips, was high pressure washed at this docking.

2.2.3 HMAS Brisbane (Trial 1178a)

The same six paint systems applied to *HMAS Bendigo* were also applied to *HMAS Brisbane* during refit in Sydney in November 1993. Strips of the same width and separation were applied approximately midships on both port and starboard sides from 150 mm below the waterline to 750 mm below the bilge keel. The patches were applied over one coat of *International SPC HISOL BFA 900 Series*.

The trial continued through until March 1999. A detailed inspection was also undertaken during an emergency docking in May 1996.

2.2.4 HMAS Bunbury (Trial 1178c)

Strips were applied to the forward port and starboard hulls of *HMAS Bunbury* in Western Australia in March 1994. The positioning of the strips was the same as on *HMAS Bendigo*.

Unlike the previous two vessels, *HMAS Bunbury* underwent a major docking two years after patch application. At this docking, in February 1996, the test strips were hydroblasted and coatings "refreshed" with additional coat(s) of paint to facilitate the trial running for a further 4 years. Unfortunately, by May 1998, the underwater paint system had suffered premature failure attributed to excessive electrolytic action and full refurbishment of the underwater paint system was necessary. The trial was terminated at this time.

2.2.5 CSL Boronia (Trial 1179)

To assess the performance of tin-free products for harbour and support craft, strips of 5 coatings, including *Ecoloflex*, were applied to the hull of the Crane Stores Lighter *Boronia* in July 1996. *Boronia* is a twin-hulled vessel that operated within Sydney harbour. Strips 700 mm wide were applied to the port underwater hull area from waterline to waterline. This vessel has not been taken out of the water when results for this report were collated in 2000 and no results from this trial are included.

Restructuring of the RAN has led to the ownership and operation of support craft, including this vessel, transferring from the Navy to the privately run company *Defence Maritime Services Pty Ltd*.

2.3 Full Hull Trials

2.3.1 HTS Currawong (Trial T97/012)

The underwater hull of the Sydney tug *Currawong* was fully painted with *International Intersmooth 360 Ecoloflex* in September 1997 to assess the long term performance of this product as an alternative to existing systems on harbour craft. As with *CSL Boronia,* the tug had not been docked prior to the collation of results for this report, so no results are included. As with *CSL Boronia*, this vessel is no longer owned and operated by the RAN.

2.3.2 NUSHIP Warramunga

Tenix Defence Systems undertook a full hull application of *Ecoloflex 360* on the third of the ANZAC frigates under construction for the RAN, *NUSHIP Warramunga*, at their Williamstown facility in July 1999. On 5 May 2000, a small boat was used to examine and photograph the system from alongside. At this time the ship was at the stage of advanced outfit in preparation for sea trials, was still to leave dockside, and had not been drydocked after the hull was painted.

2.3.3 HMAS Geraldton

The first full trial of *Ecoloflex* on an operational naval vessel commenced in January 2000 with a full underwater hull application of *International Intersmooth 360 Ecoloflex* on the FCPB *HMAS Geraldton* in Western Australia. In April 2000 photographs were taken of the visible hull from the wharf alongside.

3. Results and Observations

3.1 Panel Trials

3.1.1 Raft Trials

The first test panels of *International Ecoloflex* were immersed on the Williamstown raft in April 1994. This trial ended prematurely when the raft broke free from its moorings in June 1996. At the inspection prior to this incident, *Ecoloflex* panels were free of macrofouling growth.

Trials recommenced in December 1996 with fresh panels of the *Ecoloflex* system immersed at this time. At the inspection on 3 May 2000, these panels were free of macrofouling growth after 40 months immersion. Figure 1 illustrates the appearance of the panels at the inspection on 23 March 2000. Only slime and mud tubes built by free-living amphipods were present on the *Ecoloflex* panels, whereas the control panels, after less than 2 months, were heavily fouled by tubeworms, macroalgae, barnacles, bryozoans and ascidians. Fouling and physico-chemical data for the raft site over this period are included in the Appendix.

Test panels of *Intersmooth 360 Ecoloflex* and *Intersmooth 460 Ecoloflex* were added to the trial program in October 1998 and were also free of macrofouling on inspection in May 2000.

Ecoloflex panels were immersed on the raft at *HMAS Cairns*, Trinity Inlet, Cairns, in August 1997. When inspected in May 2000, the panels were predominantly covered by a thick slime, unlike the control which was heavily fouled by barnacles and other fouling species (Figure 2). Several barnacles and bryozoan colonies were present on the surface of the *Ecoloflex* panels, but these were loosely adherent and easily dislodged.

3.1.2 Rotor Trials

The first rotor trial which included *Ecoloflex* commenced in March 1994 and continued through until October 1995, the effective rotor exposure time totalling more than 8500 hours. Two panels of each system were included in the trial. Graphs showing the performance in this trial of three *International* systems, a TBT-containing self-polishing copolymer coating (*Intersmooth BFA956/959*), an ablative tin-free coating (*BGA535/536*) and *Ecoloflex* (*XRS071/071*), are illustrated in Figures 3-5. The TBT system is the same system used at that time by the RAN on large surface vessels. The ablative tin-free is the system that gave unacceptable performance when used by the RAN as an alternative to TBT in the early 1990s. The graphs show that, unlike the ablative tin-free product, the *Ecoloflex* ablated consistently through the duration of the trial. Ablation rates for the three systems, calculated by linear regression of the measured data, are summarised in Table 1.

Table 1. Ablation rates of the three International systems in the 1994/1995 rotor trial (XRS 071/072 = Ecoloflex).

Coating System	Ablation Rate (micron/day)	
	Panel 1	Panel 2
BFA 956/959	0.23	0.14
BGA 535/537	-0.02	0.03
XRS 071/072	0.09	0.08

Midway through this trial, in February 1994, one panel of each system was suspended below Breakwater Pier for a period of approximately 6 weeks to test for antifouling efficacy. No macrofouling established on the *Ecoloflex* system during this period. The system also showed no physical defects during the trial.

A second rotor trial which included *Ecoloflex* (*SP600*) panels commenced in October 1996 and continued through until September 1997, a total exposure of 6221 rotor hours. *Intersmooth BFA956/959* was again used as the control. Similar results were obtained as in the earlier trial, with the *Ecoloflex* again showing consistent ablation through the trial period (Figures 6, 7). Ablation rates are presented in Table 2.

Table 2. Ablation rates of TBT SPC (BFA956/959) and Ecoloflex (SP600) in the 1996/1997 rotor trial.

Coating System	Ablation Rate (micron/day)	
	Panel 1	Panel 2
BFA 956/959	0.24	0.41
SP600	0.31	0.29

In this trial, one panel of each pair was also suspended under Breakwater Pier for 10 weeks from September until December 1997. At the end of this period the *Ecoloflex* panel remained completely free of macrofouling, whereas the non-toxic control panel was heavily fouled by a diversity of fouling organisms (Figure 8).

3.2 Patch Trials

3.2.1 HMAS Townsville

Although *Ecoloflex* was not one of the coating systems tested in this trial, the results are of value as a base for assessing antifouling performance on vessels based in Cairns. At the completion of this trial, after 31 months, all five coatings tested had fouled (Figure 9); all were fouled by green macroalgae near the water surface, and all but one were also fouled by macrofouling animals deeper down.

3.2.2 HMAS Bendigo

The first inspection of the test strips after the trial commenced on *HMAS Bendigo* in November 1993 was by divers in January 1995, and this showed the *Ecoloflex* coating to be in pristine condition (Figure 10). The more detailed inspection shortly after this, at the docking in Darwin in February 1995, confirmed the superior performance of the *Ecoloflex* system over the other five systems (Table 3, Figure 11). A second diver inspection in October 1997 found only slime on the *Ecoloflex* surface (Figure 10).

Table 3. Fouling abundance on the port side strips on HMAS Bendigo 15 months after immersion. Values represent percentage surface cover; left of slash = between wind and water line and lower load line, right of slash = below lower load line; + = <5% cover

	System1	Duplex	*Ecoloflex*	System 4	System 5	System 6
Weed	40/-	40/-	10/-	40/-	40/-	75/75
Barnacles	+/-	+/-	-/-	+/-	+/-	5/-
Tubeworm	10/-	10/-	-/-	10/-	+/-	20/5
Bryozoans	5/80	5/-	-/-	+/-	-/-	10/+

Unfortunately the timing and nature of the emergency docking of *HMAS Bendigo* in January 1998 did not allow for a detailed inspection of the test strips. However, a photograph taken shortly after the docking clearly shows continued good performance of the *Ecoloflex* system (Figure 12). At this docking the underwater hull, including the test strips, were high pressure washed. Continued good performance of the *Ecoloflex* was evident at the final inspection in April 1998 (Figure13).

3.2.3 HMAS Bunbury

At the docking of *HMAS Bunbury* for refit in January 1996, the *Ecoloflex* was clearly the best performing coating in terms of both antifouling efficacy and coating integrity (Table 4, Figure 14).

DSTO staff were unable to inspect *HMAS Bunbury* at the docking in Darwin in May 1998, which preceded the premature removal of the test strips. However, the hull surveyors, G.A. Glanville & Co (Naval Architects) Pty Ltd, provided a brief report and photographs of the trial areas. The photographs (Figures 15, 16) show the *Ecoloflex* system to be performing effectively, and the report includes the comment:

> "At the waterline green weed/slime coated all the strips with the exception of the 1st Strip on Stbd and 5th Strip on Port."

These strips were the *Ecoloflex* strips.

Table 4. Ranking of strips on HMAS Bendigo for antifouling performance and coating integrity at the docking in January 1996 (1 = best performance).

	System 1	Duplex	*Ecoloflex*	System 4	System 5	System 6
Antifouling						
- Port	2	6	1	3	5	4
- Stbd	5	6	1	2	4	3
Integrity						
- Port	2	6	1	5	3	4
- Stbd	3	6	1	5	2	4

3.2.4 HMAS Brisbane

When the trial areas on *HMAS Brisbane* were inspected at a docking in May 1996, after 30 months, the *Ecoloflex* system was showing superior performance in both fouling control and coating integrity (Table 5, Figure 17). This effective performance was maintained through to the end of the trial in March 1999, a total period of 64 months (Figure 18).

Table 5. Ranking of strips on HMAS Brisbane for antifouling performance and coating integrity at the docking in May 1996 (1 = best performance).

	System 1	Duplex	*Ecoloflex*	System 4	System 5	System 6
Antifouling						
- Port	6	3	1	3	5	4
- Stbd	6	5	1	4	3	2
Integrity						
- Port	6	2	1	3	4	5
- Stbd	6	3	1	2	4	5

3.3 Full Hull Trials

3.3.1 NUSHIP Warramunga

When inspected from a small boat alongside in May 2000, aided by clear water conditions, *NUSHIP Warramunga* only slime was visible on the submerged surfaces (Figures 19, 20). The integrity of the coating at and above the water line was also sound with no signs of physical degradation.

3.3.2 HMAS Geraldton

Photographs taken of the hull of *HMAS Geraldton* from alongside in April 2000 showed no signs of fouling growth (Figures 21, 22).

4. Discussion

Self-polishing copolymer antifouling paints, based on tributyltin methacrylate as both binder and primary biocide, proved to be superior to other available antifoulings because of their capacity to provide reliable antifouling effectiveness for 5 or more years on large vessels. This performance resulted from their broad-spectrum biocidal efficacy, their consistent polishing rate that generated controlled biocide release, and their physical integrity. Alternative systems could not match this performance because of difficulties in formulating an effective polishing matrix compatible with available tin-free biocides. The best performing alternative systems, containing cuprous oxide as the primary biocide, could provide protection for up to 36 months, although under some conditions failures occurred much earlier.

Panel trials of the *Akzo Nobel* coating *Ecoloflex* demonstrated antifouling efficacy and consistent polishing performance. Under static immersion conditions the coating resisted fouling for more than 3 years, including 3 summer fouling seasons in temperate waters. In tropical waters, panels remained almost macrofouling free after 30 months. Our experience is that Trinity Inlet, Cairns, is the most severe site for testing antifoulings in Australia. The only macrofouling present was easily dislodged and possibly attached to the heavy slime build up from static exposure in these conditions.

In rotor trials, consistent ablation of the coating was observed in two separate trials, and the rate of ablation in the second trial was similar to that observed for the TBT SPC (BFA 956/959) system. This indicated that the formulation could provide long term performance through consistent ablation and therefore controlled biocide release. The basis of this formulation is a copper acrylate polymer that reacts in seawater in a manner analogous to tributyltin methacrylate. However, the copper released from the polymer is insufficient to control fouling in its own right, and cuprous oxide and a booster biocide, zinc pyrithione (ZPT) are also dispersed through the resin. These biocides are released in a controlled manner as the coating ablates.

The results achieved in patch trials verified the performance expected from the panel trials. On the three operational vessels, *HMAS Bendigo*, *HMAS Bunbury*, and *HMAS Brisbane*, the *Ecoloflex* system out-performed the other five test systems and continued to provide effective performance for more than five years. This performance was comparable to that of TBT SPC under the same conditions. The use of three vessels in the patch trial program was planned to enable testing of the coatings in three major operational regions for the RAN: east coast, west coast and north coast. *Ecoloflex* proved to be effective in each of these geographic environments. In addition to the antifouling effectiveness, the coating remained physically sound through all the trials.

The proposed IMO ban on the application of TBT antifouling coatings from 1 January 2003 created an urgent need for shipping to have alternative systems available that have antifouling performance comparable to existing systems. The consequences of not having these systems would be increased operating costs through the increased fuel consumption, speed penalties and docking and repainting costs. The risks of transport of marine pests would also increase. Significant in the dates set by the IMO was their acceptance that effective alternative systems would be available. Initial proposals within IMO to ban TBT were subject to the proviso that the ban would be subject to the availability of effective alternatives. The development of such alternatives in Japan, with *Ecoloflex* a prime example, and evidence of their efficacy were considered sufficient to support a full global ban.

The copper acrylate *Ecoloflex* system met the requirements of efficacy and performance in all trials initiated within the DSTO/RAN evaluation program, confirming the good results reported from overseas. However, full verification that the system is as effective as TBT SPC coatings would only be possible when a large number of vessels, operating under different conditions and in different environments, are fully painted with the system and achieve their intended docking cycles. However, results from this study suggest performance close to that of the TBT-based systems is possible[2].

5. Conclusions

DSTO/RAN trials demonstrated the efficacy of the *Akzo Nobel* copper acrylate system in both panel trials and patch trials on operational vessels. Effective life in excess of five years was achieved. Integral to this performance was the consistent ablation of the coating when exposed to water flow, combined with an effective biocide package.

The proposed global ban on the application of TBT antifouling paints from 1 January 2003 required alternative products offering similar performance to be available. *Ecoloflex* was the first system fully evaluated within the DSTO/RAN antifouling research program to demonstrate such potential.

[2] Subsequent to the trials reported herein, the *International Paints* antifouling formulation *Intersmooth 360 SPC,* equivalent to *Ecoloflex,* was registered by the Australian National Registration Authority (now the Australian Pesticides and Veterinary Medicines Authority) and, from April 2002, the system was phased in across the RAN fleet as a replacement for TBT SPC coatings.

6. References

1. Anon. (1998a) *Australia's Oceans Policy. I.* Commonwealth of Australia, Canberra.

2. Anon. (1998b). *Australia's Oceans Policy. II. Specific Sectoral Measures.* Commonwealth of Australia, Canberra.

3. IMO (2001) International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001. International Maritime Organization, London, UK.

4. Lewis, J.A. (1998) Marine biofouling and its prevention on underwater surfaces. *Materials Forum* **22**, 41-61

5. Lewis, J.A. (2002) Alternatives to TBT antifouling paints: The performance of "new technology" products in Australian trials. *Proceedings. 11th Inter-Naval Corrosion Conference, Auckland, NZ, April 2002.* Defence Technology Agency, Auckalnd, NZ.

6. Lewis, J.A. (2003) TBT antifouling paints are now banned! What are the alternatives and what of the future? *Surface Coatings Australia*, **40** (1), 12-15.

7. Standards Australia (1993) Paints and related materials – Methods of test. Method 481.5: Coatings – Durability and resistance to fouling – Marine underwater paint systems. *Australian Standard AS 1580.481.5 – 1993.* Standards Australia, Sydney

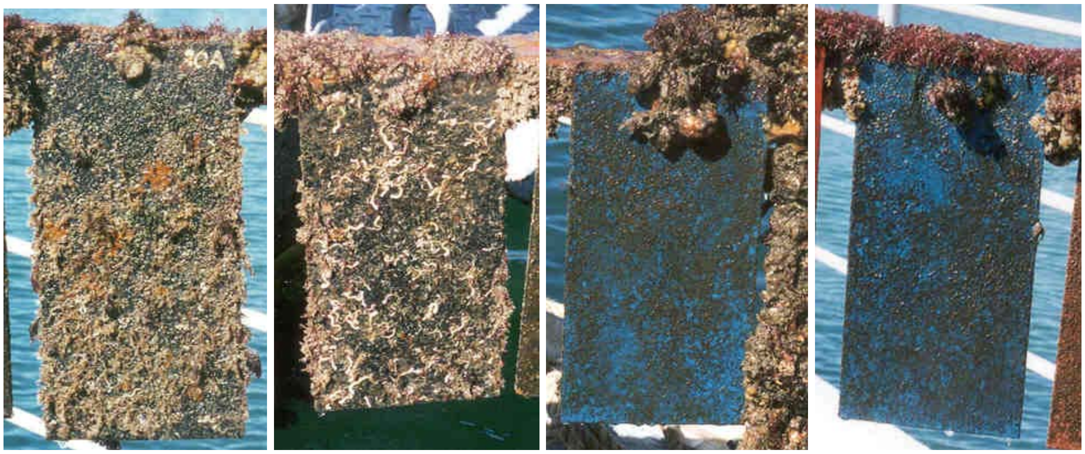

Figure 1: Test panels on Williamstown raft, 23 March 2000: left, control panels after 43 days immersion; right, Ecoloflex panels after 39 months (first immersed 23 Dec 1996)

Figure 2: Test panels on Cairns raft, 12 May 2000: left, control panel after approximately 3 months immersion; right, Ecoloflex panel after 33 months (first immersed 14 August 1997)

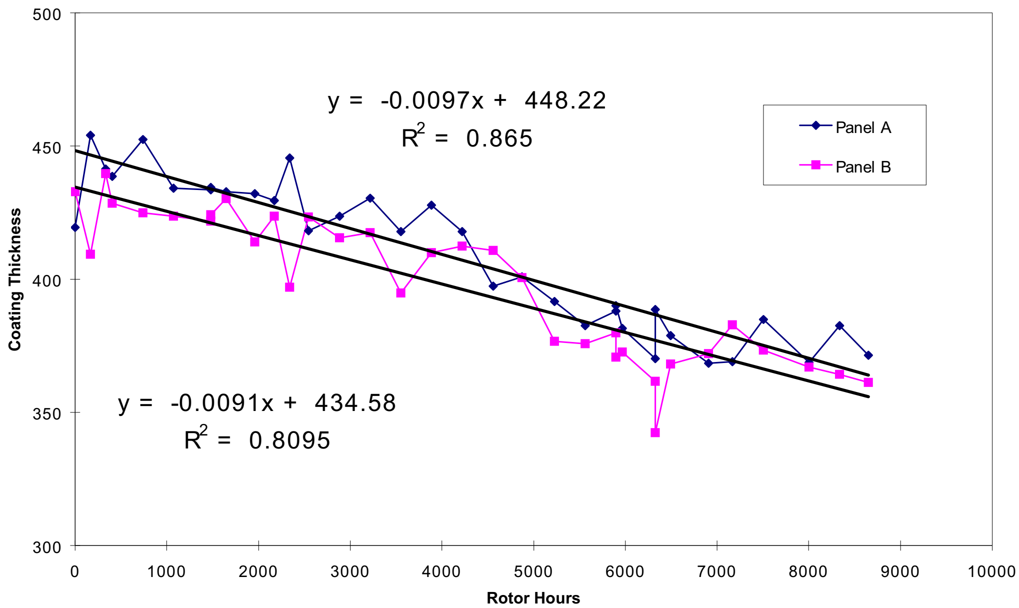

Figure 3: Ablation of the TBT SPC system BFA956/959 in the 1994/1995 rotor trial [In this and subsequent figures, the equations and r values are calculated by linear regression of thickness data for each panel]

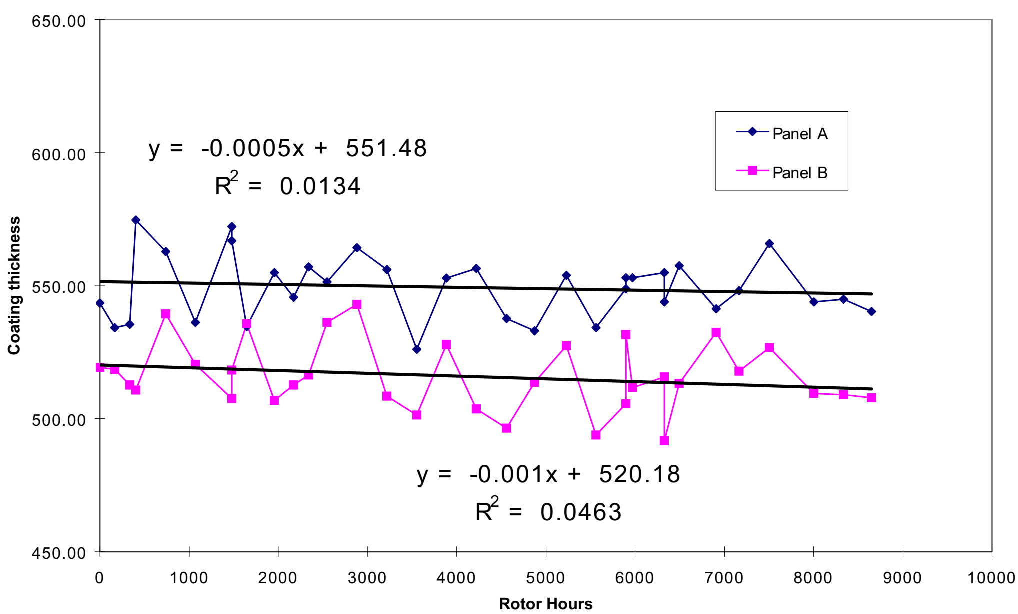

Figure 4: Ablation of the Tin-Free system BGA535/537 in the 1994/1995 rotor trial

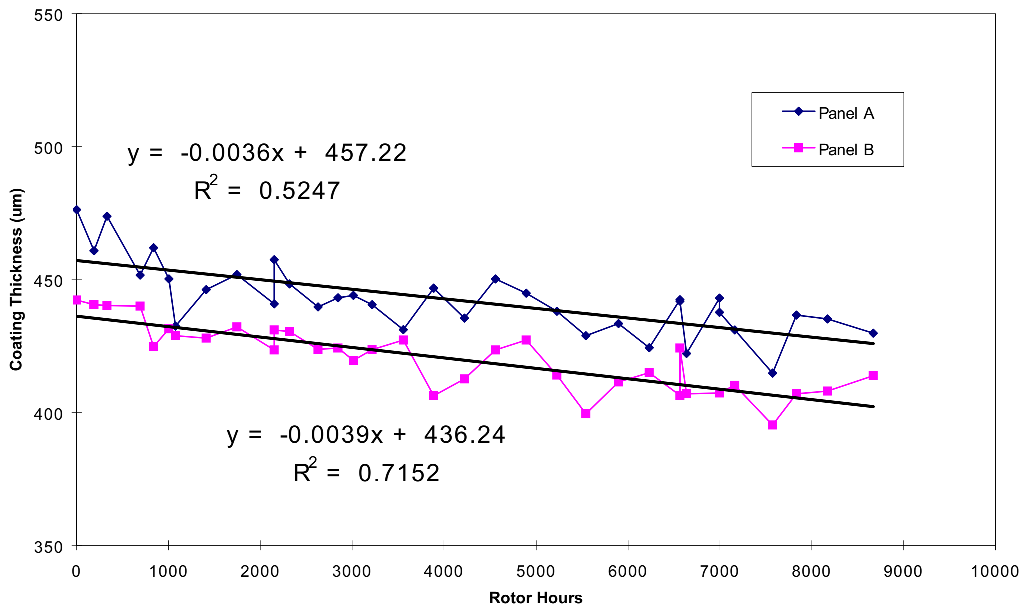

Figure 5: Ablation of the Ecoloflex system XRS 071/072 in the 1994/1995 rotor trial

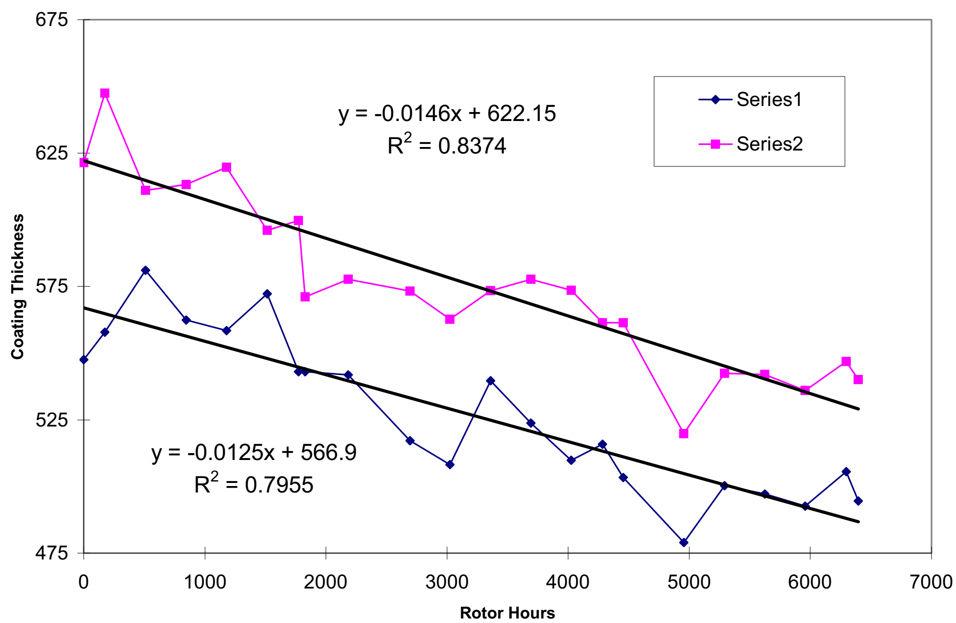

Figure 6: Ablation of the TBT SPC system BFA956/959 in the 1996/1997 rotor trial

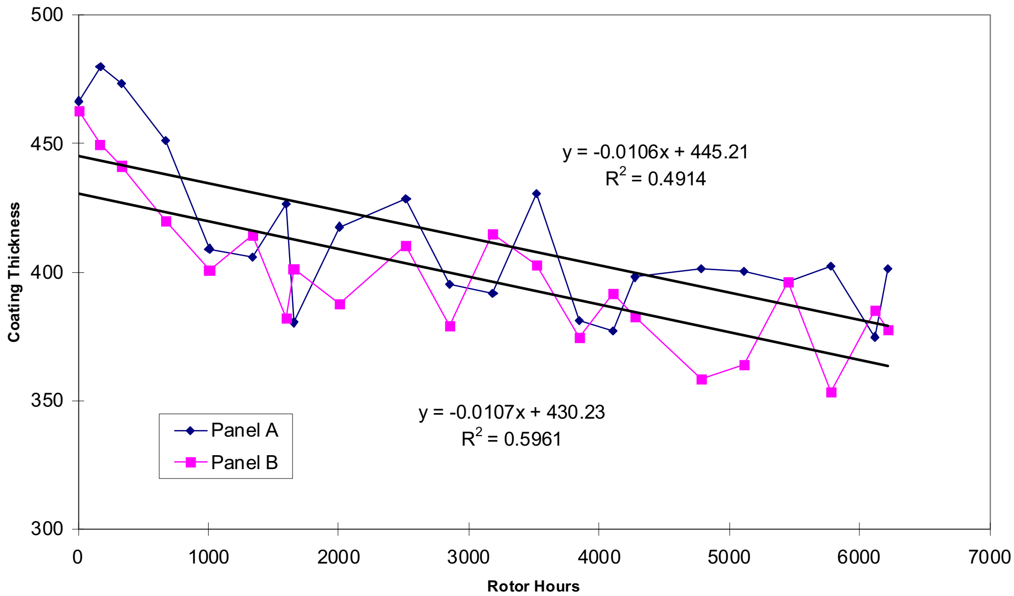

Figure 7: Ablation of the International SP600 (=Ecoloflex) system in the 1996/1997 rotor trial

Figure 8: Ecoloflex panel (right) and non-toxic control (left) after static immersion during 1996/1997 rotor trial

Figure 9: Port side midships test strips on HMAS TOWNSVILLE at completion of trial after 31 months

Figure 10: Underwater photographs of Ecoloflex strip on HMAS BENDIGO in January 1995 (left) and October 1997 (right) showing only slime

Figure 11: Starboard side strips on HMAS BENDIGO, February 1995. Ecoloflex strip is second from right.

Figure 12: Starboard side strips on HMAS BENDIGO, January 1998

Figure 13: Starboard side strips on HMAS BENDIGO, April 1998

Figure 14: Port side strips on HMAS BUNBURY, February 1996. Blue strip is Ecoloflex

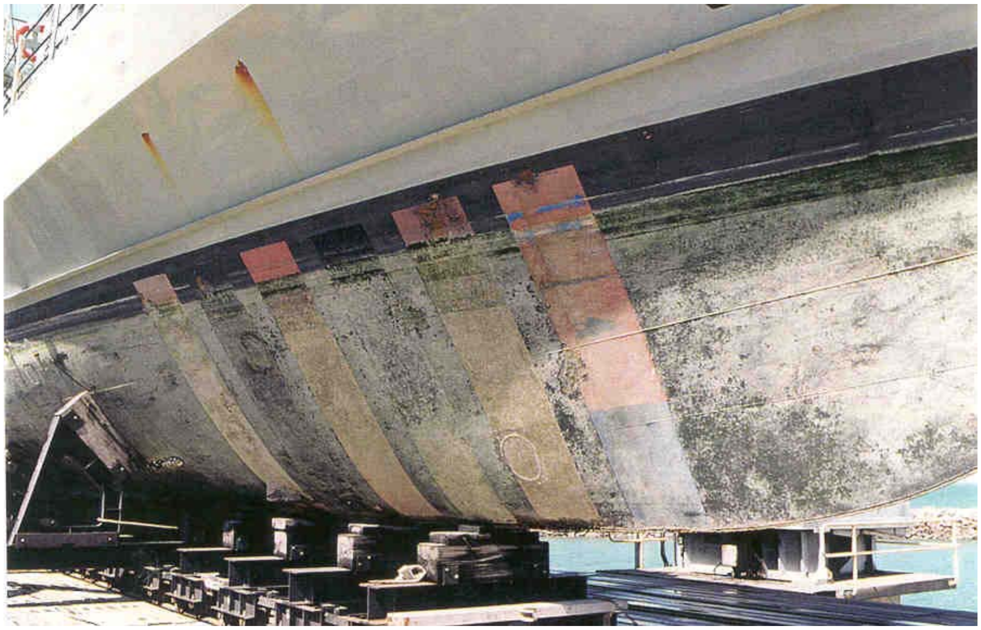

Figure 15: Starboard side strips on HMAS BUNBURY, May 1998. Ecoloflex strip is first from right.

Figure 16: Port side strips on HMAS BUNBURY, May 1998

Figure 17: Port side strips on HMAS BRISBANE, May 1996. Ecoloflex strip is third from right.

Figure 18: Starboard side strips on HMAS BRISBANE, March 1999. Ecoloflex strip is second from right.

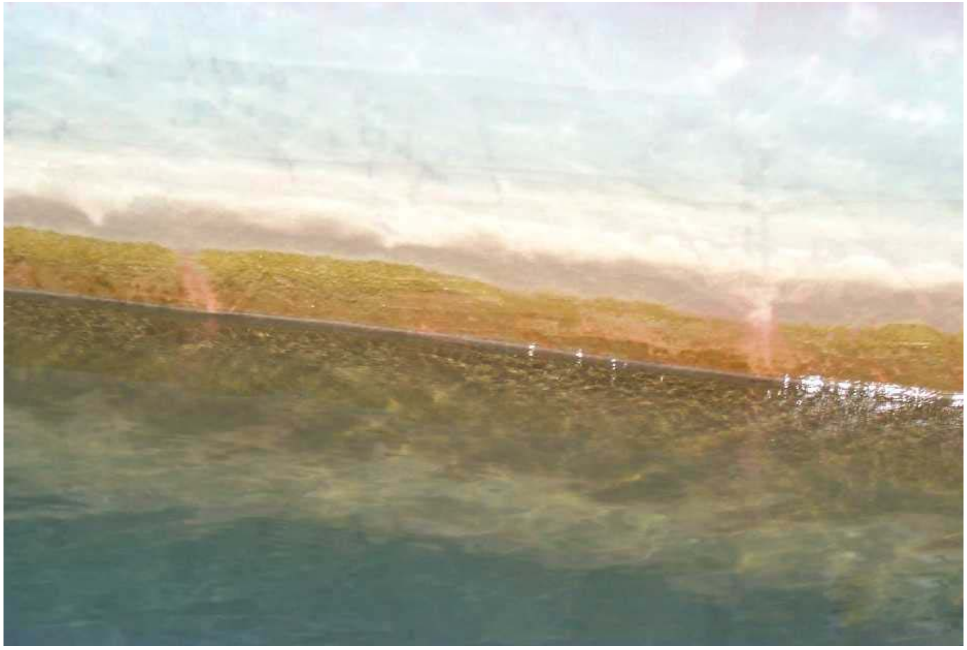

Figure 19: Transom of NUSHIP WARRAMUNGA at Williamstown May 2000

Figure 20: Starboard side of NUSHIP WARRAMUNGA at Williamstown, May 2000

Figure 21: Forward port side of HMAS GERALDTON, Garden Island WA, April 2000

Figure 22: Transom of HMAS GERALDTON, Garden Island WA, April 2000

Appendix A: Williamstown Raft Data

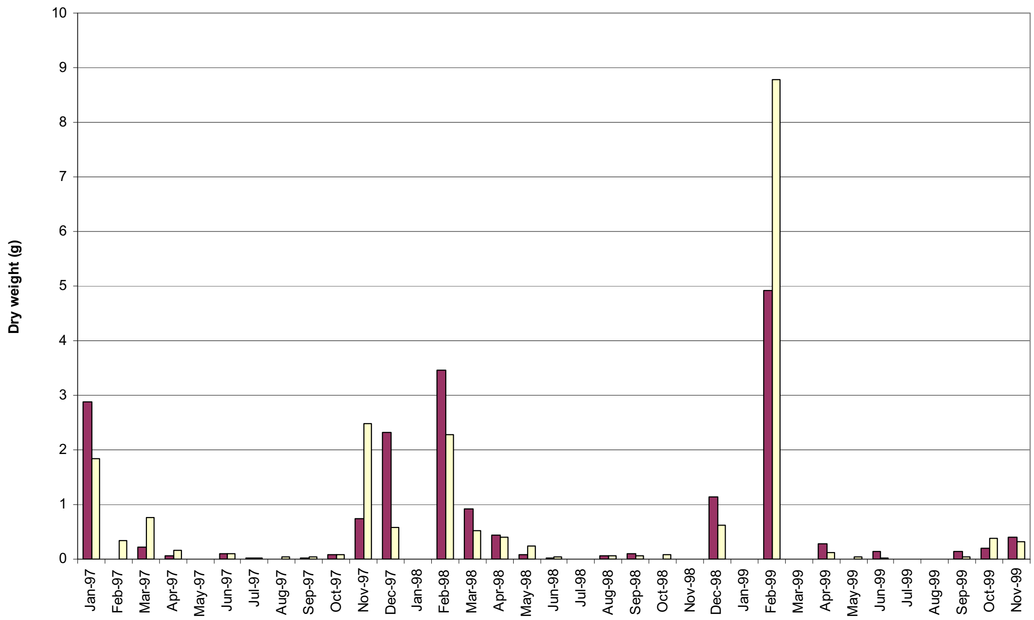

Figure A.1 Seasonal variation in fouling abundance measured as dry weight (g.dm^{-2}) of fouling on monthly control panels (December 1996 – January 2000)

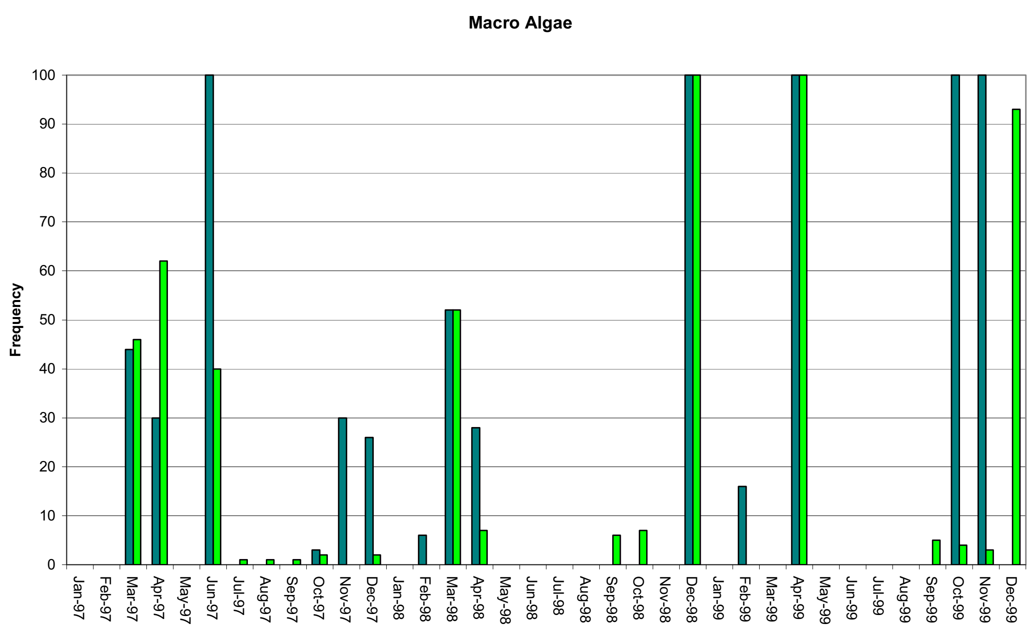

Figure A.2 Seasonal variation in abundance of macroscopic algal fouling on the control panels (December 1996 – January 2000)

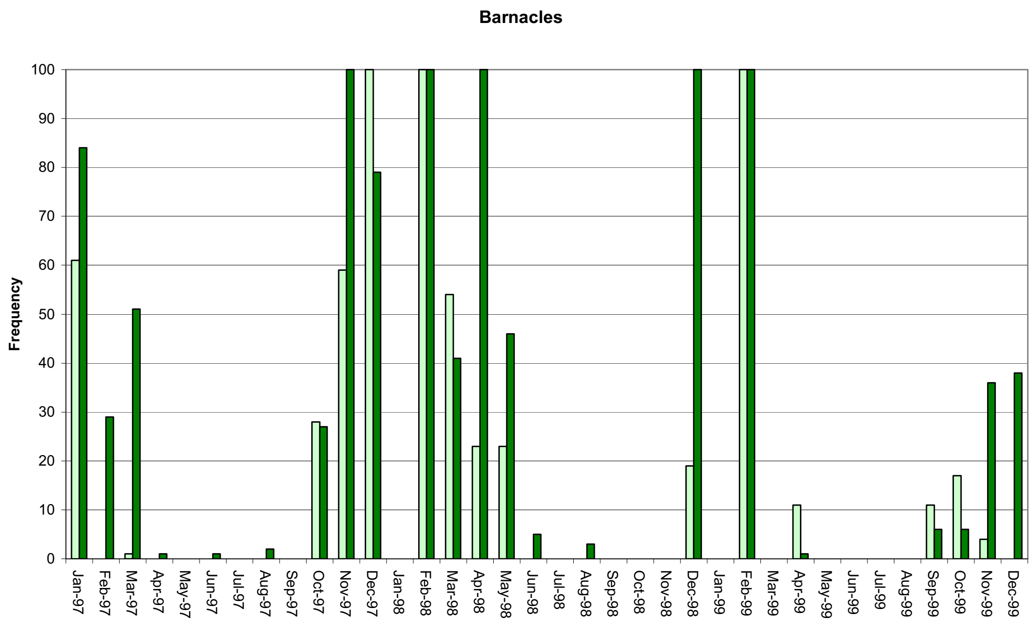

Figure A.3 Seasonal variation in abundance of barnacles on the control panels (December 1996 – January 2000)

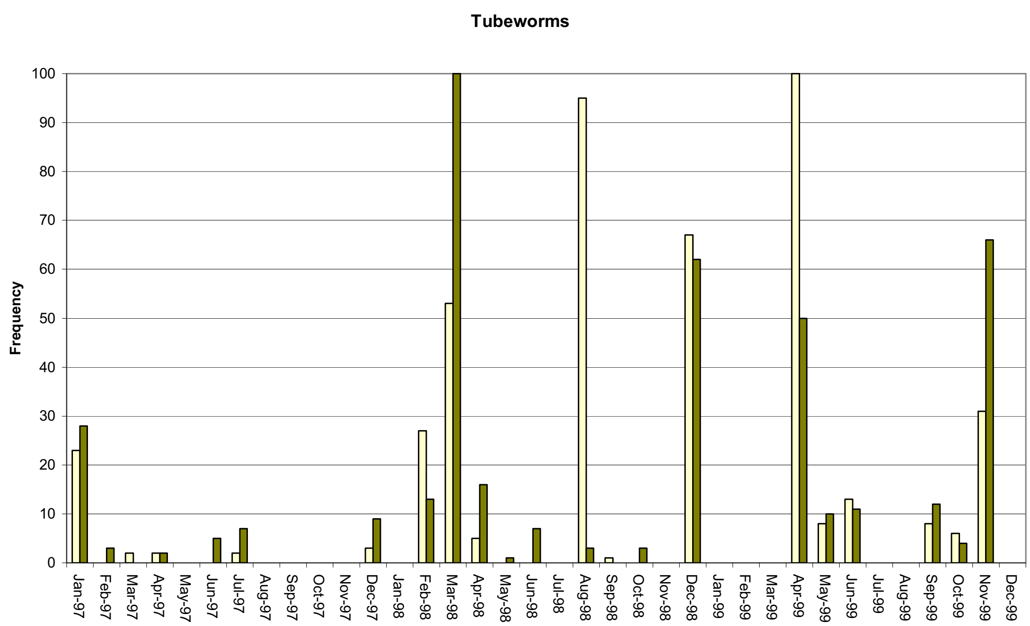

Figure A.4 Seasonal variation in abundance of tubeworms on the control panels (December 1996 – January 2000)

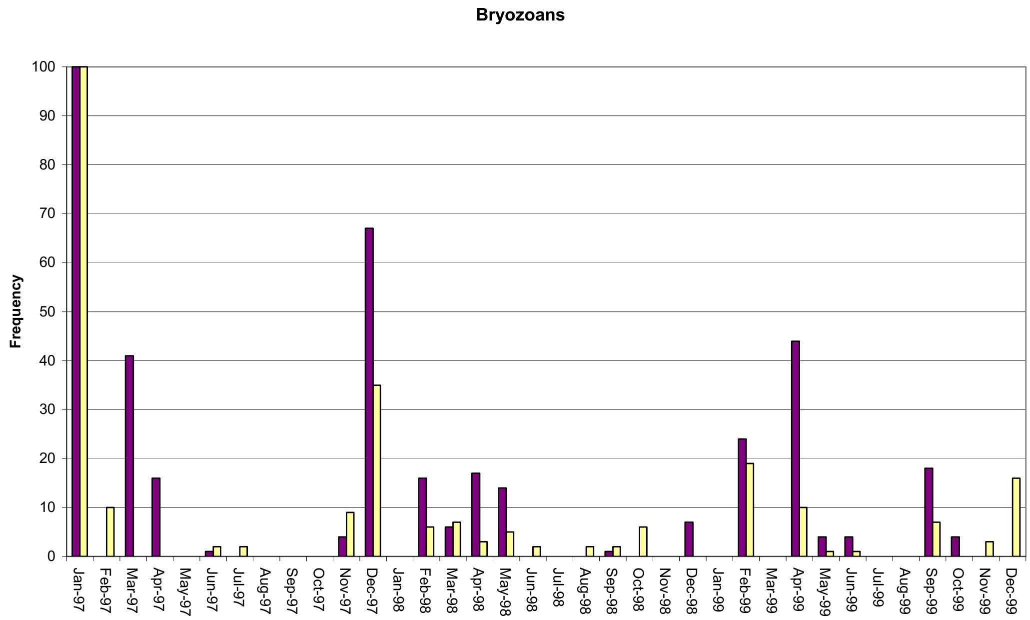

Figure A.5 Seasonal variation in abundance of bryozoans on the control panels (December 1996 – January 2000)

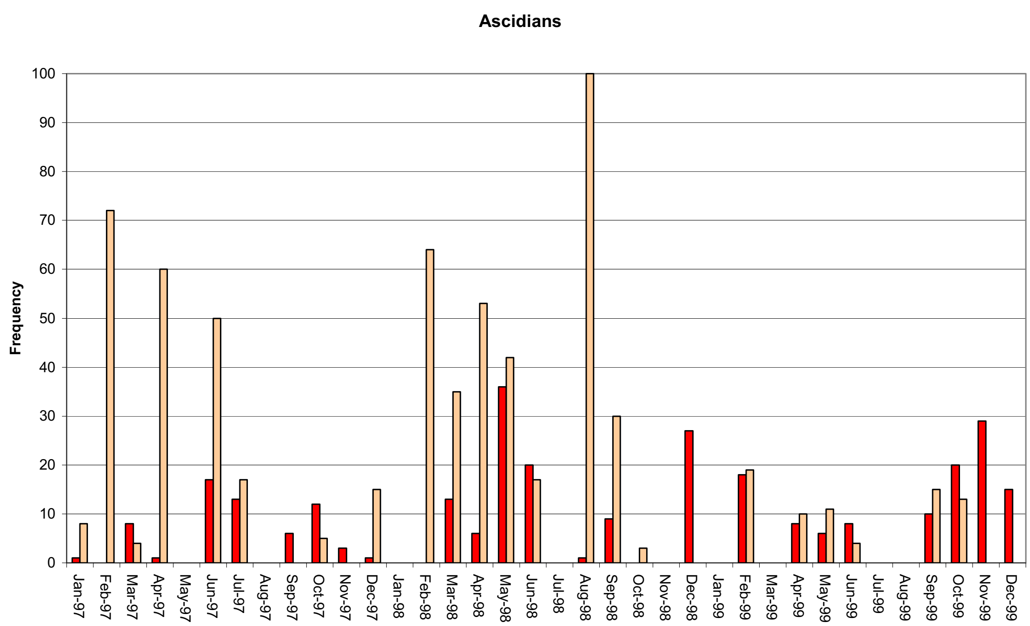

Figure A.6 Seasonal variation in abundance of ascidians on the control panels (December 1996 – January 2000)

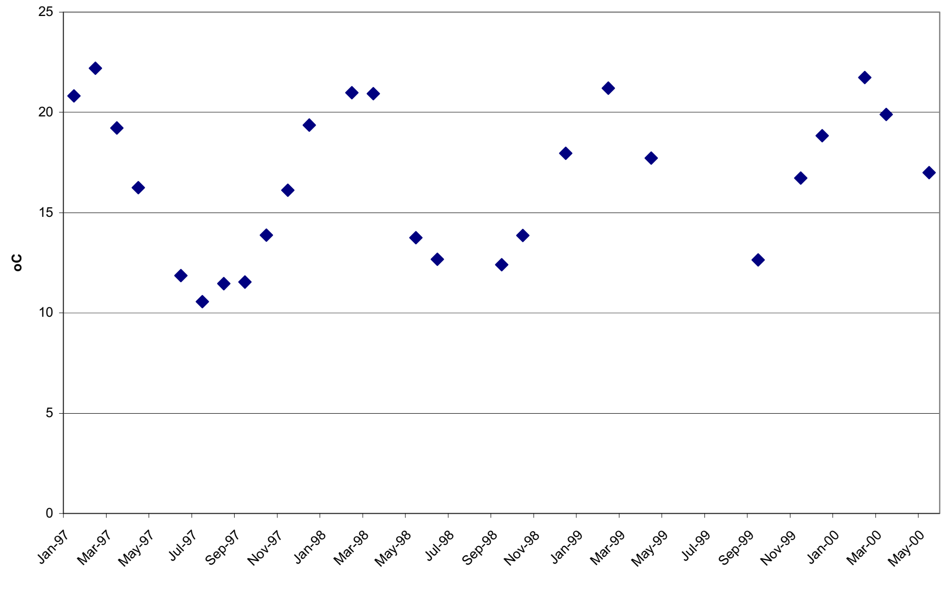

Figure A.7 Seasonal variation in water temperature measured 1 m below the water surface at the raft site (January 1997 – May 2000)

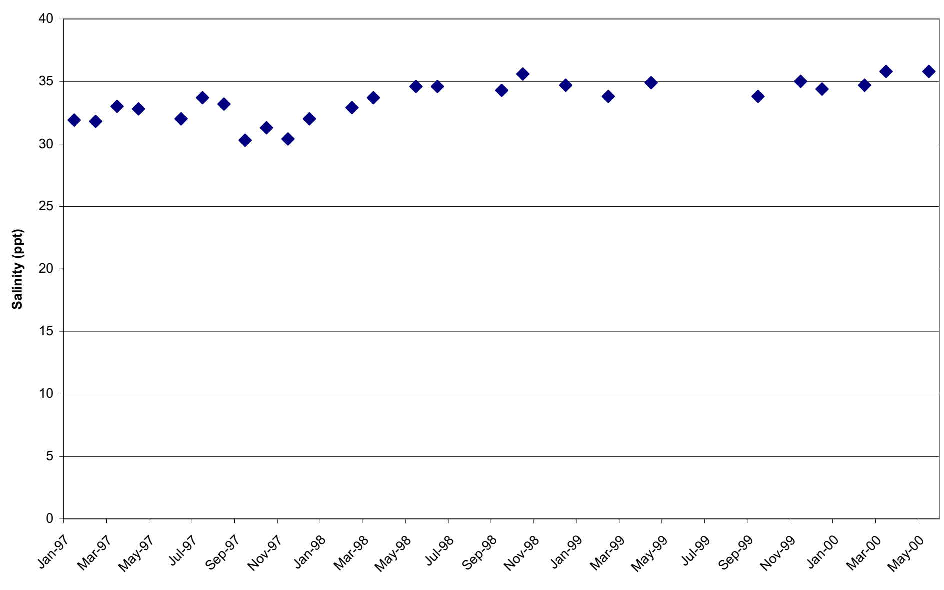

Figure A.8 Variation in salinity (ppt) as measured 1 m below the water surface at the raft site (December 1996 – January 2000)

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antifouling paint, protective coatings, biofouling, paints

19. ABSTRACT
A national and global ban on the application of antifouling paints containing tributyltin (TBT) is being introduced because of the detrimental effects of TBT on non-target marine species. DSTO, supported by the Royal Australian Navy (RAN), undertook a comprehensive program in an attempt to find alternative products that would match or approach the antifouling performance and effective life of TBT-based systems. The evaluation program included static immersion trials, dynamic flow testing, and trials on Navy ship hulls. Within this program, the Akzo Nobel coating *Ecoloflex* demonstrated antifouling efficacy, consistent ablation characteristics, and long term effectiveness on vessels operating in temperate and tropical Australian waters. This was the best performance seen from a copper-based antifouling coating to date and offered the RAN an alternative to TBT-based systems.