Staying Afloat with Nontoxic Antifouling Strategies for Boats

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New Solutions to an Old Problem

More boaters are considering switching to nontoxic antifouling strategies as they learn about the harmful effects of copper-based antifouling paints. Boat repair yards and hull cleaners are gaining experience with nontoxic coatings and their performance capabilities. Different vessels require different antifouling strategies, depending on their type and on where and how they are used and stored. The University of California Cooperative Extension – Sea Grant Extension Program has produced this report to provide boaters, boating and coating businesses, government, environmental organizations and others with the best available information on nontoxic antifouling strategies.

Why Control Fouling Growth?

Every sailor knows that algae, barnacles and other fouling growth love to hitch a ride on boat bottoms. These fellow travelers create enough friction, or "drag," to slow sailboats and increase fuel consumption by power boats, in some cases by 30% (Younqlood et al. 2003). Reducing drag is so important that, during the Age of Exploration, mariners careened their ships on distant shores to expose the hull. This dangerous process enabled them to scrape away fouling growth and perform other maintenance.

(Reprinted with permission from Les & Diane @SailNet.com)

Careening a sailboat
Caution: Don't try this yourself!
Go to a boat repair yard, instead.

(Jamie Anne Gonzalez)

Fouling Growth on Boat Bottom

What's the Problem with Recent Fouling Control Methods?

In modern times antifouling paints with heavy metals, such as tin and copper, have been used widely. Although they slow fouling growth, they do not prevent it. These metals leach out of antifouling paints and accumulate in the water of crowded and poorly flushed boat basins to levels that scientific research has shown to harm marine life. As a result, the International Maritime Organization has begun a phased ban on tributyl tin-based, antifouling paints that will be completed by 2008. Now, regulatory agencies are investigating copper levels in the water of southern California boat basins. Restrictions on copper-based, antifouling paints have been proposed for the Shelter Island Yacht Basin of northern San Diego Bay.

How Else Can You Control Fouling Growth?

Recreational boaters will still need to control fouling growth if copper-based antifouling paints are restricted or banned. With the goal of educating boat owners and boating businesses on cost effective options for controlling fouling growth and protecting marine life, the University of California Cooperative Extension – Sea Grant Extension Program (UCSGEP) has been investigating nontoxic antifouling strategies and sharing their findings since 1999.

This booklet, ***Staying Afloat with Nontoxic Antifouling Strategies for Boats,*** is the third in our series. It includes:

- How fouling growth colonizes a boat's hull;
- How copper from antifouling paints affects marine life;
- Antifouling policy developments in the United States and Europe;
- Introduction to nontoxic antifouling strategies;
- Highlights of our 2002 economic study;
- Results of our field demonstration of three, nontoxic boat bottom coatings;
- Outreach and impacts report;
- A view to the future; and
- More resources that you can find at: http://seagrant.ucdavis.edu;
- Nontoxic Antifouling Strategies Sampler updated for 2004.

How Does Fouling Grow?

Many factors influence where fouling growth chooses to settle. These include the availability of nutrients, the texture of the surface, the chemical reactions taking place on it, and the movement of surrounding currents (Crisp 1974; Hudon et al. 1983; Rittschof et al. 1984; Clare et al. 1992; Rittschof 1993). The fouling on a boat bottom sometimes proceeds by stages beginning with the attachment of bacteria (Clare et al. 1992). Immediately following this stage, a slimy "biofilm" of bacteria, protozoans, and microscopic algae attaches to the hull (Characklis & Cooksey 1983). Various scientists have found that this slime layer has varying effects on the next generation of fouling organisms (Mimh et al. 1981; Maki et al. 1988)! In fact, some scientists have found that "whatever gets there first is what attaches first" (Rittschof 2004, pers. comm.).

In addition to microscopic organisms, such as bacteria, diatoms, and algae, fouling growth includes larger organisms such as mollusks, sea squirts, sponges, sea anemones, tube worms, polychaetes and barnacles. Other factors influencing fouling growth include salinity, temperature range, sunlight, and water movement. Although species vary widely in their settlement seasons, most fouling organisms spawn in spring and summer when sea water temperature rises. (Parliament of Victoria 1996; Keough 1983)

If left unattended, fouling growth can increase the roughness of the hull, thereby decreasing the vessel's maneuverability and increasing drag. Eventually, fouling growth leads to damage of the hull and to the vessel's deterioration (Rolland & DeSimone 2003). Because of this, San Diego area hull cleaners recommend that boat hulls be cleaned regularly to prevent damage to the coating and potential damage to the hull by fouling organisms. Thus, besides hampering the efficiency of a vessel's performance, accumulated fouling can eventually penetrate the coating itself, causing paint loss and requiring more aggressive cleaning. Best Management Practices (BMPs) recommended by professional hull cleaners include cleaning frequently and using the least abrasive cleaning methods. (CPDA 2003)

What Are Antifouling Paints?

Antifouling paints contain materials that slow the development of fouling growth. Tributyl tin is a very toxic antifoulant that has been banned for pleasure craft for many years. The International Maritime Organization has begun a phased ban of this chemical for all vessels making international voyages; the ban will be completed in 2008. (IMO 2004; CDPR 2004)

Today, bottom paints with cuprous oxide are the most popular antifouling agents for recreational boats. Although they retard fouling growth, they do not prevent it altogether. They are designed to continuously leach small amounts of copper into the water. These paints typically contain 67% – 76% cuprous oxide. Paints with 20% – 45% cuprous oxide are available, but more coats are needed or they must be reapplied more often to deter fouling growth (pers. comms.: Hall 2002; Soeterik 2002; Nicely 2002; Storfer 2002). Thus, copper tends to accumulate in the water of crowded and poorly flushed boat basins.

Why Are High Dissolved Copper Levels a Problem?

Reflecting the latest scientific knowledge, the California Toxics Rule (CTR) (USEPA 2000) defines levels of pollution that are low enough to protect marine life. These standards are based on many scientific studies and they are designed to protect marine life.

The CTR concentration levels for dissolved copper are the same as those in the U.S. Environmental Protection Agency (USEPA) National Recommended Water Quality Criteria (USEPA 1999). The federal and state standard for total dissolved copper in marine waters is 3.1 parts per billion (ppb); the USEPA is considering changing the standard to 1.9 ppb (USEPA 2004).

When the level of dissolved copper in the water exceeds this standard, it is harmful to marine life such as mussels, oysters, scallops, sea urchins and crustaceans. It also changes the types of phytoplankton that are able to thrive in boat basins. (Calabrese et al.1984; Coglianese & Martin 1981; Gould et al. 1988; Katz 1998; Krett Lane 1980; Krishnakumar et al. 1990; Lee & Xu 1984; Lussier et al.1985; MacDonald et al. 1988; Martin et al. 1981; Redpath 1985; Redpath & Davenport 1988; Stromgren & Nielsen 1991; VanderWeele 1996)

There is much debate about the extent to which organic matter in the water can bind copper and protect marine life. That debate is beyond the scope of this booklet.

What's in the Policy Pipeline?

Copper-based boat bottom paints are legally registered pesticides (CDPR 2004) that are likely to face new restrictions. For example Total Maximum Daily Load (TMDL) regulatory studies have been completed in Shelter Island Yacht Basin of San Diego Bay and in Newport Bay (CRWQCB, SDR 2003; USEPA 2002). A TMDL study is underway in Marina Del Rey. Oceanside Harbor and various parts of San Diego Bay have elevated levels of dissolved copper (CSWRCB 2003). Dry-dock discharges in Santa Barbara Harbor are under scrutiny (Kronman 2004, pers. comm.).

(Jamie Anne Gonzalez)

Crowded Boat Basin

The TMDL studies found copper levels as high as 8.0 ppb in San Diego Bay and as high as 29.0 ppb in Newport Bay (CRWQCB, SDR 2003; USEPA 2002). Another study found that as much as 90% of the copper in the boat basins comes from bottom paints (Schiff et al. 2003). As a result of these studies, restrictions on copper-based bottom paints have already been proposed for Shelter Island Yacht Basin in north San Diego Bay.

(Suzanne Paisley, UC ANR Communication Services)

Marine Life Protected By California Toxics Rule

Dissolved copper exceeds levels allowed by state laws in marinas and harbors of the Chesapeake Bay in Maryland, of Port Canaveral and Indian River Lagoon in Florida, and in areas of Washington (Hall et al. 1988; Sheffield Engineering 1998; Trocine and Trefry 1996; Washington State Department of Ecology 1999).

Under the Biocidal Products Directive (98/8/EC) implemented in March 2000, the European Commission is reviewing all biocides used in antifouling paints sold in the European Union (EU). Products containing "unacceptable" biocides will be removed from the EU

(Jamie Anne Gonzalez)

Hydro-Washing at Boat Repair Yard

market. Several European countries are monitoring dissolved copper in boat basins. Antifouling coatings applied in the United Kingdom, Sweden, Netherlands, Belgium, Finland, and Austria must be registered under current pesticide laws. (International Coatings Ltd UK and International Paint Inc 2004; EC 1998).

Copper-based bottom paints have been banned for pleasure craft on the east coast of Sweden and are restricted on the west coast of Sweden and in Denmark depending on cuprous oxide leach rates and vessel size. Copper-based antifouling paints have been banned in the Netherlands for recreational boats since 1999. (Swedish Chemicals Inspectorate 2004; Ministry of the Environment Danish Environmental Protection Agency 2003; The Netherlands Ministry of Housing, Spatial Planning and the Environment 2004; College Toelating Bestrijdingsmiddelen 2004)

What Are Your Options If Copper Paints Are Banned or Restricted?

Recreational boaters will still need to control fouling growth, if copper-based antifouling paints are banned or restricted. Replacing copper with another, toxic agent that harmed marine life would not solve the problem. Thus, the University of California Cooperative Extension – Sea Grant Extension Program has been studying nontoxic antifouling strategies since 1999.

Nontoxic antifouling strategies combine a nontoxic boat bottom coating with a companion strategy. Examples of companion strategies include:

- Frequently cleaning the coating,
- Storing the boat out of water; and
- Surrounding the boat with a slip liner and adding freshwater to discourage marine fouling growth.

Although epoxy coatings should be scrubbed often, most of the larger fouling growth may be removed from silicone coatings by a water spray or light brush (Meyer et al. 1994; Callow et al. 1988; Swain and Schultz 1996)

What Costs and Other Factors Should You Consider in Deciding Whether to Try a Nontoxic Coating?

New coatings and companion strategies have different cost profiles than copper-based paints. The following is a general comparison of copper-based and nontoxic coatings resulting from research that we conducted in San Diego Bay with the University of California, San Diego Department of Economics (Carson et al. 2002).

Copper-based bottom paints	Nontoxic epoxy bottom paints	Nontoxic silicone bottom paints
Initially less expensive to apply	Initially more expensive to apply	Initially more expensive to apply
Do not need to be cleaned as often	Need to be cleaned more often	Most fouling can be removed by vessel use (at 20 knots)
Need to be reapplied more often	Do not need to be reapplied very often	Need to be re-applied more often for best performance

When deciding whether to switch to a nontoxic coating, boat owners should consider:

- Whether a nontoxic coating is required where the boat is kept;
- Whether the copper-based coating needs to be stripped before the nontoxic coating is applied;
- Cost to buy and apply the nontoxic coating;
- The most cost-effective timing for making the switch (when the boat is new and unpainted or when the copper-based paint needs to be stripped);
- The cost of maintaining the nontoxic coating;
- The boat's remaining useful life and where it will be stored;
- Where, how and how often the boat will be operated;
- Whether a ban on copper-based paints is likely to be imposed in the area where the boat is kept; and
- The environmental benefits of reducing copper pollution.

For more information and a worksheet for calculating costs of using nontoxic versus copper-based boat bottom paints, see our publication ***Making Dollars and Sense of Nontoxic Antifouling Strategies for Boats*** that is described at the end of this report.

Before choosing a product, boat owners should consider how they use their boat, carefully evaluate manufacturers' statements and ask for referrals to boat owners, boat repair yards and hull cleaning companies that have experience with each product in the local area or one with similar water temperatures, species of fouling growth, tidal flushing in the marina, and other conditions.

Nontoxic Boat Bottom Paint Demonstration Project

(Jamie Anne Gonzalez)

Coatings used in Demonstration

Demonstration Project Methods

To help boat owners make decisions about nontoxic antifouling strategies, the University of California Cooperative Extension – Sea Grant Extension Program (UCSGEP) conducted a field demonstration of nontoxic boat bottom coatings in 2002-2003. The demonstration was funded in part by the USEPA and the California State Water Resources Control Board 319(h) Program.

We tracked the performance of three types of nontoxic bottom coatings:

- Epoxy;
- Ceramic-epoxy; and
- Silicone-rubber

on six recreational boats in San Diego Bay for over a year. Each coating was placed on one sailboat and one powerboat:

Boat	Coating
28-foot Powerboat	AquaPly M®
35-foot Sailboat	AquaPly M®
30-foot Powerboat	CeRam-Kote 54®
21-foot Sailboat	CeRam-Kote 54® CeRam-Kote Marine®
42-foot Powerboat	Miracle Cover® Miracle Cover Marine®
46-foot Sailboat	Miracle Cover® Miracle Cover Marine®

The two-part epoxy coating, Aquaply M,® was placed on a powerboat for the demonstration and it was monitored on a sailboat that had received it in January of 1999. We received hull cleaning data on the sailboat for July, 1999 through September, 2003. This provided an opportunity to assess longer-term performance of Aquaply M.®

The ceramic-epoxy coating, CeRam-Kote 54,® was placed on a sailboat and a diesel-electric launch. A newer formulation, CeRam-Kote Marine,® was placed on the sailboat partway through the project.

The silicone-rubber coating, Miracle Cover,® was replaced by an updated formulation, Miracle Cover Marine,® partway through the demonstration period.

Professional, underwater hull-cleaning divers reported on the following factors twice a month for epoxy coatings and more often for silicone coatings each time the vessels were cleaned:

- Fouling growth level;
- Coating condition;
- Cleaning tool aggressiveness
- Diver effort;
- Cleaning time;
- Days since last cleaning;
- Hand or powered tool used.

The first four factors were rated on a five-point scale developed in cooperation with members of the California Professional Divers Association. The scale is explained in Table 1.

Daily water temperatures from near the Navy and Broadway Piers in San Diego Bay were obtained from the NOAA/NOS Center for Operational Oceanographic Products and Services. They provided a record of relative temperatures experienced by fouling growth on the boats in the demonstration project.

(Leigh Taylor Johnson)

Evaluating Ceramic-Epoxy Coating

Visual Evaluation of Coatings

The six boats were hauled in early October 2003 and their coating conditions were visually evaluated in consultation with Bill Roberts of Shelter Island Boat Yard and Marlan Hoffman of California Marine Services.

All of the coatings were still in good condition or better, including the nearly five-year old epoxy coating on one of the sailboats. Boat owners' comments on the performance of the coatings are discussed later in this report.

Detailed results are presented in Table 2. The ceramic-epoxy coating shown in the photograph, "Evaluating Ceramic-Epoxy Coating," is five months old. The coating's condition is 1.5 – a little past New, Slick and Shiny. The level of fouling growth is 1.5 – a little more than Light Silting – and it reflects two weeks of growth since the most recent cleaning.

Hull Cleaner Data

Please note that the results reported here cover only our findings for the three products in our demonstration on six boats in northern San Diego Bay. The relationship between fouling growth and cleaning interval for all months for which we received data is summarized in Table 3. (Table 3 is based on data collected during the

TABLE 1. FIVE-POINT SCALE FOR DIVER REPORTS

*	Coating Condition	Fouling Growth	Cleaning Tool***, ****	Diver Effort
1	New, slick finish, still shiny if appropriate to type of coating	Light silting (looks like dust) that can be brushed off with a piece of carpet. Some plumes of discoloration.	Use for Level 1 Fouling Growth: a. Carpet, soft, medium to long shag b. White pad, soft c. Soft nylon bristle brush, bristle thickness .028-.032 d. Soft polypropylene brush, bristle thickness .022-.032	Light pressure: very easy to remove growth with one wipe
2	Shine is gone or surface is lightly etched on all of coating, no physical blemishes or defects	Moderate silting (a solid, discernible, physical layer) that must be removed with a soft brush or green 3M® pad.	Use for Level 2 Fouling Growth: a. Green pad, medium b. Nylon bristle brush, medium, bristle thickness .040	Light to medium pressure: still easy to remove growth but may require two or more passes in some areas to remove growth
3	Some blemishes or defects in coating on up to 20% of boat bottom	Dark algae impregnation. Algae must be scrubbed off; can't just wipe it off.	Use for Level 3 Fouling Growth: a. Purple pad, medium b. Nylon bristle brush, medium, bristle thickness .050	Light scrub, firm effort: firm wipe and/or multiple wipes or passes with brush to remove growth
4	Some blemishes or defects in coating on 20%-50% of boat bottom	Hard growth. Need heavier tools, such as steel wool, plastic and metal scrapers.	Use for Level 4 Fouling Growth: a. Brown pad, coarse b. Black pad, coarse c. Stainless steel row bristle brush	Firm scrub, hard effort: firm scrub and continuous passes required to remove fouling growth
5	Blemishes or defects on over 50% of boat bottom	Lengthy, soft algae and hard, tube worms and possibly barnacles impregnating the coatings. Coral** growth can be seen to extend out from the hull. Clean with metal scrapers and stainless steel brushes.	Use for Level 5 Fouling Growth: a. Steel pad, abrasive b. Flat wire bristle brush, very coarse c. Whirlaway® tool, very abrasive	Hard scrub, very hard effort: even with hard physical effort, growth presented a challenge to remove with pad or brush

* 1 is best condition; 5 is worst condition
** Coral is the local name for limestone tubes of worms that grow on the coating's surface.
*** Carpet and pads are hand operated tools; brushes and Whirlaway® are powered tools.
**** In practice, choice of tool did not always correspond to fouling growth level.

project for all six boats plus three more years of historical data on the sailboat with the epoxy coating.) Data means (averages) for the 13-month period during which we collected data on all six boats are presented in Table 4. All four years of data for the sailboat with the epoxy coating are graphed in Figure 1.

Table 3 shows the means (averages) for fouling growth levels for each boat and coating as reported by the underwater hull cleaners each time a boat was cleaned. Note that 1 is the best rating and 5 is worst on our scale. The table also shows the mean and the range of intervals between cleanings.

Comparing results for the four boats with epoxy coatings to results for the two boats with silicone-rubber coating shows that more frequent cleaning of the silicone-rubber coating prevented fouling growth from reaching a higher level. [Table 3 is based on all of the data available for each boat.]

(Jamie Anne Gonzalez)

Evaluating Epoxy Coating

TABLE 2. VISUAL EVALUATION OF COATINGS AT FINAL HAULOUT (OCTOBER 2003)

Boat No.	Coating Application Method Boat Type (Length)	Visual Evaluation and Future Plans for Coating
1	AquaPly M® (two-part epoxy) Coating rolled on. Power (28 feet)	After a little over 15 months the coating surface was lightly etched and worn on edges of the chines due to cleaning. Coating appeared new with little wear. Owner will continue with coating.
2	AquaPly M® (two-part epoxy) Coating rolled on. Sail (35 feet)	After almost 5 years old the coating was in good condition. Some coral scarring and blistering were present. Edges on the hull and through-hull fittings were worn due to cleaning. Overall, coating was smoother due to wear from cleaning. Boatyard and hull cleaner estimated the coating will last another two years. Owner will continue with coating.
3	CeRam-Kote® (ceramic epoxy) Coating rolled on Power (30 feet)	After almost 14 months the coating appeared in new condition with little wear. Coating had a sheen but no shine. Coral scarring and algae impregnation were present. Owner will continue with coating
4	CeRam-Kote® and CeRam-Kote Marine® (ceramic epoxy) Coating sprayed on Sail (21 feet)	After about 9 months the new, improved formula of CeRam-Kote® (CeRam-Kote Marine®) was applied at the owners' request. Overall coating condition improved with the new formula, but fouling growth increased, likely due to seasonal changes. Light, but normal, etching was present at end of project. Owner will continue with coating (new formula); may cover with copper paint.
5	Miracle Cover® and Miracle Cover Marine® (silicone-rubber) Coating sprayed on Power (42 feet)	After a little more than 13 months the new formula of Miracle Cover® (Miracle Cover Marine®) was applied. Older layers of Miracle Cover were sanded down and the boatyard applied one coat of the new formula, Miracle Cover Marine.® After three days the coating was still tacky, so three layers of the original Miracle Cover were applied over the one coat of Miracle Cover Marine.® According to the manufacturer, the silicone-rubber coating should last for five years before a new coating is required. After the project, the owner changed to E Paint, a zinc-based coating, recommended by the boatyard.
6	Miracle Cover® and Miracle Cover Marine® (silicone-rubber) Coating sprayed on Sail (46 feet)	After a little over 12 months the owner decided to try the new formula of Miracle Cover® (Miracle Cover Marine®). The performance of the coating improved with the new formula. According to the manufacturer, the silicone-rubber coating should last for five years before a new coating is required. Owner has replaced boat.

TABLE 3. FOULING GROWTH VERSUS CLEANING INTERVAL

Vessel/Coating	Dates on Which Means Are Based	Mean Fouling Growth	** Cleaning Interval (days)
Powerboat AquaPly M (epoxy)	July 2, 2002 – October 6, 2003 (15.2 months)	3.25	Mean = 16 Range: 11-23
Sailboat AquaPly M (epoxy)	July 7, 1999 – Sept 30, 2003 (50.5 months)	3	Mean = 15 Range: 7-28
Powerboat CeRam-Kote 54 (ceramic epoxy)	August 9, 2002 – October 6, 2003 (13.9 months)	3.5	Mean = 15 Range: 8-24
Sailboat CeRam-Kote 54 (ceramic epoxy)	July 3, 2002 – April 15, 2003 (9.4 months)	3.5	Mean = 15 Range: 8-21
CeRam-Kote Marine (ceramic-epoxy)	April 24, 2003 – September 30, 2003 (5.2 months)	4*	Mean = 18 Range: 14-21
Powerboat Miracle Cover (silicone-rubber)	May 16, 2002 – June 27, 2003 (13.4 months)	2.8	Mean = 12 Range: 5-30
Miracle Cover Marine (silicone-rubber)	July 9, 2003 – September 26, 2003 (2.6 months)	2	Mean = 8 Range: 7-15
Sailboat Miracle Cover (silicone)	May 23, 2002 – May 30, 2003 (12.2 months)	2.5	Mean = 8 Range: 7-14
Miracle Cover Marine (silicone)	July 11, 2003 – September 26, 2003 (2.5 months)	2	Mean = 7 Range: 7-9

* High fouling growth mean is due in part to additional time between cleanings and warmer water temperature in summer months when it was measured. This new formula was only evaluated in summer months.

** Disregards first cleaning interval because it is typical to refrain from cleaning for some time after coating is applied.

Table 4 shows the means (averages) of the coating conditions, fouling growth levels, cleaning tools, and diver effort levels as rated by the underwater hull cleaners each time a boat was cleaned. Note that a level of 1 is best while a level of 5 is worst for each scale. See Table 1 for rating scale details. Three boats received new formulas of the same paints during the project.

[Table 4 is based on the 13-month period when data were collected on all of the boats and it is the same period on which the statistical analysis was based. Restricting the time period used in the statistical analysis allowed us to take seasonal changes into account. We will discuss the results of the statistical analysis later in this report. Note that means differ somewhat from Table 3 which is based on all of the data collected for each boat.]

The average coating conditions for all demonstration project boats were good (scale level of less than 3) throughout the project. This was to be expected because five of the six boats had new or almost new coatings. However, the 5-year old epoxy coating on the sailboat was also in good condition during the project.

The fouling growth means were the highest for the boats with the ceramic-epoxy coating and the lowest for boats with the silicone-rubber coating. Fouling growth means for the ceramic epoxy coating were in the range of levels 3 to 4 while those for the epoxy coating were in the lower level 3 range. In other words, on average the ceramic-epoxy coating had a little more fouling growth than the epoxy coating. (The new formula of ceramic-epoxy was applied just before summer, so its means are higher than for the other coatings because most of its reports were made when the water temperature was warm.) The fouling growth means for the silicone coatings were in the level 2 range, reflecting the fact that they were cleaned more often than the epoxy coatings.

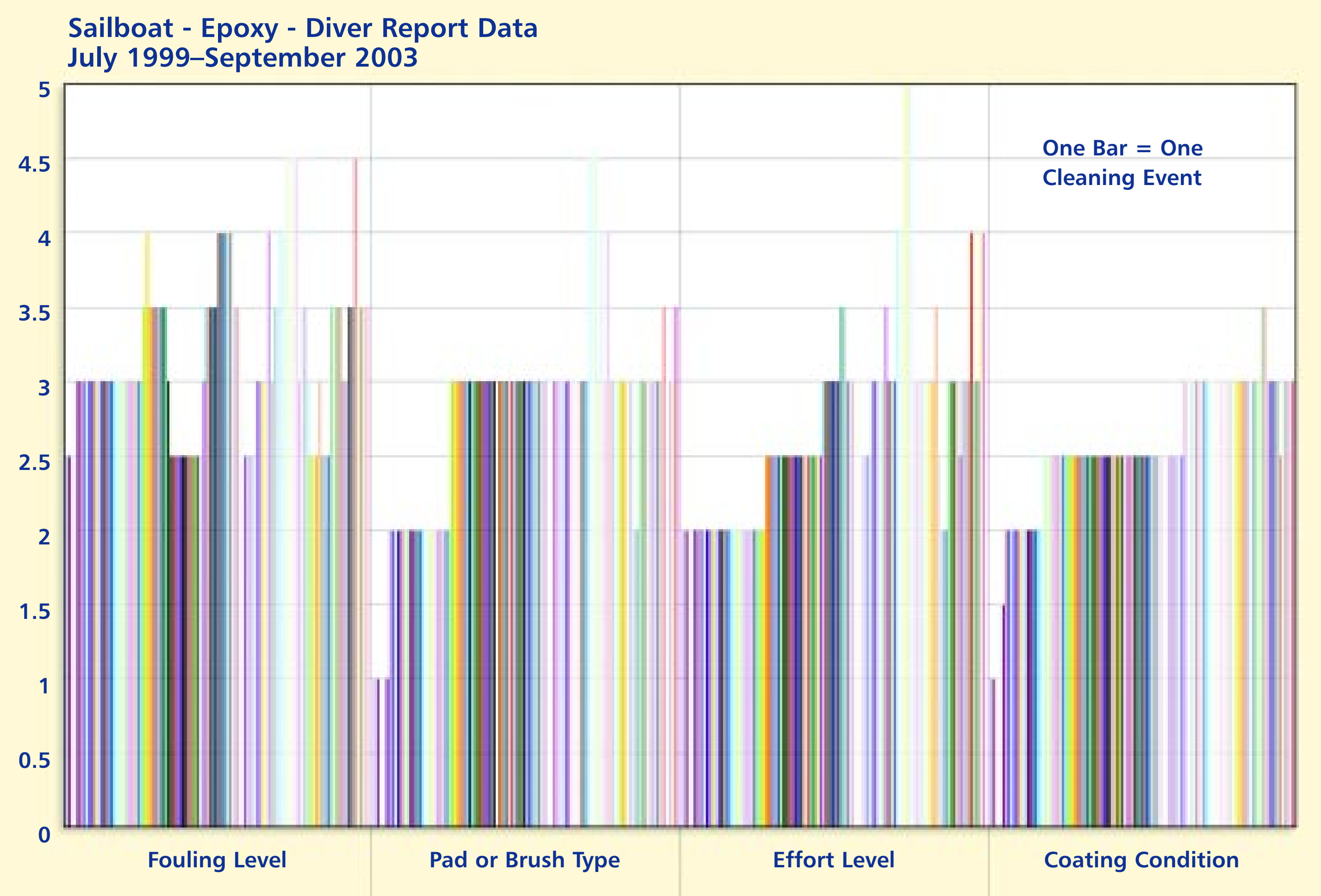
The means for the cleaning tool type and diver effort level generally reflect the fouling growth means for each coating. That is, on average more fouling growth meant a more aggressive cleaning tool and more effort were needed. Diver effort level increased when new epoxy and ceramic-epoxy coatings were applied; perhaps divers tried to keep them pristine.

TABLE 4. DIVER REPORT DATA SUMMARY STATISTICS FOR AUGUST 2002-SEPTEMBER 2003

Coating/Vessel	Coating Condition	Fouling Growth	Cleaning Tool Type	Diver Effort	Coating Age (months)
Epoxy					
Powerboat	Mean = 1.7	Mean = 3.3	Mean = 3.3	Mean = 2.8	15.2
Sailboat	Mean = 2.6	Mean = 3.0	Mean = 3.1	Mean = 3.2	56.5
Ceramic-Epoxy					
Powerboat	Mean = 2.0	Mean = 3.5	Mean = 3.7	Mean = 3.8	13.9
Sailboat	Mean = 2.9	Mean = 3.5	Mean = 3.8	Mean = 3.6	9.4
Sailboat New Formula*	Mean = 2.0	Mean = 4.0	Mean = 4.0	Mean = 4.0	5.2
Silicone-Rubber					
Powerboat	Mean = 2.4	Mean = 2.8	Mean = 2.2	Mean = 3.0	13.4
Powerboat New Formula	Mean = 1.6	Mean = 2.0	Mean = 2.2	Mean = 2.6	2.6
Sailboat	Mean = 2.0	Mean = 2.5	Mean = 2.2	Mean = 2.7	12.2
Sailboat New Formula	Mean = 1.5	Mean = 2.0	Mean = 2.0	Mean = 2.3	2.5

* High fouling growth, cleaning tool type and diver effort means are due in part to additional time between cleanings and warmer water temperature in summer months when they were measured. This new formula was only evaluated in summer months.

FIGURE 1. FOUR-YEAR, DATA SUMMARY FOR SAILBOAT WITH EPOXY COATING



Data on Fouling Level, Pad or Brush Type, Effort Level, and Coating Condition during July 1999 through September 2003 were obtained for the sailboat with the epoxy bottom coating. Each bar on the graph in Figure 1 represents the data for one cleaning event. Fouling Level shows the influence of seasonal temperature changes. Pad or Brush Type and Effort Level show a general increase in aggressiveness over time. In other words, over the first few years the divers had to use increasingly aggressive tools and work increasingly harder to clean the hull. Coating Condition slowly deteriorated over the years (higher level is worse on the five-point scale). Pad or Brush Type, Effort Level and Coating Condition leveled off at about mid-range on the scale.

Introduction to Data Analysis

The objective of nontoxic antifouling strategies is to control fouling growth while protecting the environment and the boat's bottom coating. To be sustainable, the strategies also need to be cost effective. Extending coating life and controlling the cost of each cleaning may enable a boat owner to offset the generally higher costs of buying, applying and frequently cleaning a nontoxic coating. Therefore, we were particularly interested in the effect of BMPs on coating life and cleaning effort and time.

Based on ecological principles and our discussions with boat owners, hull cleaners, and boat repair yard operators, we made the following assumptions:

- Warmth, sunlight and a longer interval between cleanings promote fouling growth;
- Divers work longer and harder to clean heavier fouling growth and if they use hand tools;
- BMPs, such as cleaning frequently and using the gentlest possible tool, can extend the life of a coating.

Data collected by the professional hull cleaners in our demonstration project provided an opportunity to test these assumptions.

(Jamie Anne Gonzalez)

Sailboat-Ceramic Epoxy (5 months): Cleaning with Soft Rag

We worked with Dr. Neil Willits of the UC Davis Statistical Laboratory to examine the relationship of:

- fouling growth;
- nontoxic coatings;
- hull cleaning by experienced divers using BMPs; and
- environmental factors, such as seasonal changes in water temperature and light.

This report is intended for a diverse audience, so we will report only general findings and conclusions. However, a lengthy statistical analysis using multiple and logistical regressions was conducted to reach these conclusions.

We eliminated extreme data that were due to special circumstances, for example when divers spent extensive time cleaning boats before they were hauled for display at our field day. Because 23 divers representing three companies reported data, the influence of individual perceptions on our findings was minimized.

Although we used a 5-point scale to rate fouling growth, aggressiveness of the cleaning tool, how much effort the diver used to clean the boat and the condition of the coating, the hull cleaners never reported a level of 5 on any of the scales. We asked four, experienced, professional hull cleaners the reason. They explained that BMPs, such as frequent cleaning, prevent fouling growth from reaching an extreme level. This way, the most aggressive type of cleaning tool and level of effort are unnecessary. BMPs also include using gentler tools and less pressure. Hand and powered tools were used, both of which can vary in aggressiveness.

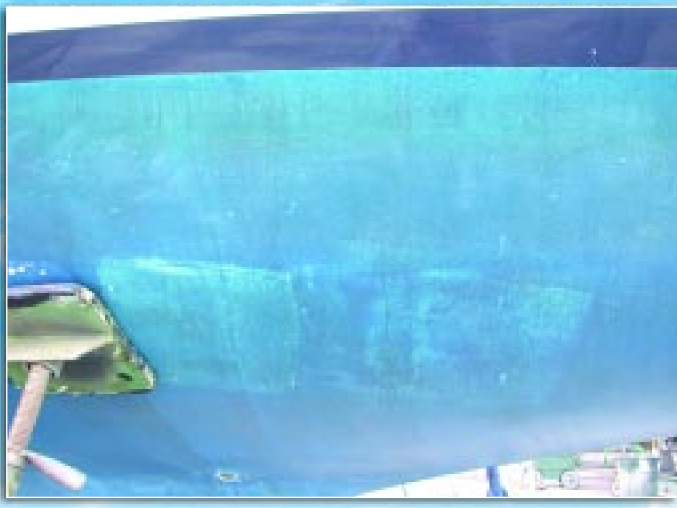
The hull cleaners we surveyed reported that epoxy coatings should be replaced when the condition exceeds a level of 3 and that silicone coatings should be replaced when the condition exceeds a level of 2. The reason is that the coating condition affects time and effort needed to clean the hull. (pers. comm. Rocco 2004; Presley 2004; Orlich 2004; Hoffman 2004) None of the coatings in our study exceeded those conditions.

Boats are cleaned according to a schedule set by their owners in consultation with their hull cleaning companies. In our study, the boats with epoxy or ceramic-epoxy coatings were cleaned on average every 15–18 days; the boats with the silicone-rubber coating were cleaned on average every 7–12 days.

Longer cleaning intervals allowed more fouling growth to develop, so we were able to study the effect of different intervals between cleanings when the statistical program considered all of the boats together. On the other hand, more frequent cleanings can mask the effects of some factors, so we also had the statistical program consider the effects for each type of coating.

We received over four years of data for one of the sailboats that had had an epoxy coating for almost five years by the end of the demonstration. This allowed us to study the effects of coating age and of BMPs in extending the life of a durable coating.

(Jamie Anne Gonzalez)



Sailboat-Epoxy (after first 5 years)

Hull Cleaner Data Analysis

Fouling growth was heavier when:

- Water was warmer;
- Interval between cleanings was longer.

The two most important influences on coating condition were:

- Age of the coating;
- Aggressiveness of cleaning tools.

Using a gentler cleaning tool is the most important factor in extending the life of a coating.

- A more aggressive cleaning tool was used when:
- Fouling growth was heavier;
- Cleaning interval was longer;
- Coating condition was worse;
- Hand cleaning tool was used.

Coating life can be extended by frequent cleaning, especially when water is warmer. This is because frequent cleaning prevents fouling growth from reaching higher levels that require more aggressive tools to remove.

(Leigh Taylor Johnson)

Powerboat-Ceramic-Epoxy (14 months): With Tubeworm Remnants

Further, a more aggressive level of tool was needed if the diver used a hand tool. Thus, using powered, rotary tools may allow divers to use a less aggressive tool and help to extend the life of the coating.

Divers took longer to clean when:

- Fouling growth was heavier;
- Cleaning interval was longer;
- Water was warmer.

Frequent cleaning may reduce cleaning time and related cleaning cost, especially when the water is warmer.

Divers worked harder to clean when:

- Fouling growth was heavier;
- Water was warmer;
- Coating was older;
- Coating was in worse condition.

Divers exerted less effort when using a powered, rotary brush than when cleaning with a hand tool. Repetitive stress injuries are an occupational hazard for hull cleaners.

(Jamie Anne Gonzalez)

Powered Cleaning Tools for Nontoxic Coatings

Thus, powered, cleaning tools may be an important, ergonomic consideration for maintaining a nontoxic hull coating.

Figure 1 shows changes over 4 years in fouling growth, coating condition, cleaning tool aggressiveness and cleaning time for the sailboat with the 5-year old, epoxy coating. It confirms the statistical finding that fouling growth levels reflected seasonal changes in water temperature and that the coating condition deteriorated over time.

In contrast to the smoothness noted in the visual assessment, Figure 1 shows that more aggressive cleaning tools and longer cleaning times were needed as the coating aged and its condition became worse. All reached a level of 3 on the 5-point scale by the end of the demonstration.

Conclusions from Data Analysis

The cost of maintaining a boat bottom coating is affected by how often it must be replaced and how often it must be cleaned. Because nontoxic coatings do not slow fouling growth, an important part of the project was to examine how fouling growth and best management practices affected coating life.

Hull cleaners and boat owners expect more fouling to occur when the water is warmer and the interval between cleanings is longer; our findings confirmed their expectations. When fouling is heavy, divers need to use a more aggressive cleaning tool and they must work harder and longer to clean the hull. They also use a more aggressive level of tool when using hand, instead of power, tools.

Using a gentler tool is the most important factor in extending the life of a coating, so BMPs that allow divers to use less aggressive tools are important.

Although we cannot change the water temperature or prevent a coating from aging, we can control the interval between cleanings. Cleaning more frequently prevents fouling growth from accumulating to high levels. This is especially important when water is warmer.

In turn, this allows divers to use less aggressive cleaning tools, spend less time cleaning, and exert less effort. Frequent cleaning may thus be expected to extend the life of the coating, reduce the cost of each cleaning and reduce wear and tear on hull cleaners.

Frequent cleaning with gentle tools can be expected to extend the life of a coating.

Using a power cleaning tool also allows divers to use a less aggressive tool and exert less effort. Visual inspection found that a 5-year old, epoxy coating which had been cleaned with powered tools had become smoother.

The epoxy and ceramic-epoxy coatings have the potential to last many more years than copper-based coatings and the silicone-rubber coating that was used in our demonstration. Our survey of 200 San Diego Bay boaters (Carson et al. 2002) found that copper-based paints are replaced, on average, every 2 ½ years. The silicone-rubber coating in our demonstration had to be replaced annually. Yet, the epoxy coating that was 5 years old by the end of the demonstration project was expected to last at least 2 more years. The ceramic-epoxy coating appeared likely to have similar durability. These products may perform differently in other areas.

The silicone-rubber coating was preferred by boat owners who liked to race and were willing to invest in very frequent cleaning and annual replacement. The epoxy and ceramic-epoxy coatings appear to be a good choice for boat owners who want a nontoxic coating that may last long enough to compensate for costs incurred in more frequent cleaning and converting from a copper-based coating.


(Jamie Anne Gonzalez)

Powerboat-Silicone-Rubber Prepped to Receive New Formula

Epoxy and ceramic-epoxy coatings appear to last enough to compensate for costs of frequent cleaning and converting from a copper-based coating.

Nontoxic antifouling strategies are a viable alternative to copper-based boat bottom paints. Boat owners should consider how they intend to use the boat and their budget in selecting a coating. They will need to ensure that the hull cleaner uses BMPs that may extend the life of the coating, such as cleaning frequently and using the gentlest tool that is appropriate. Hull cleaning companies will need to learn and use BMPs that are suitable for the coating, the geographic area, and how the boat is used and stored.


(Leigh Taylor Johnson)

Powerboat-Epoxy (15 months) with Wearing on Edges of Chines

How Did Demonstration Project Boat Owners React to the Nontoxic Coatings?

A year after the demonstration ended, we asked project boat owners about their experiences with the nontoxic coatings. All who had used epoxy and ceramic-epoxy coatings reported that they were good, durable, barrier (to water) coats.

The boat owner who has now had an epoxy coating on his sailboat for six years reported that by the end of the fifth year, he had begun to realize cost savings compared to using a copper-based paint. His boat had become faster in races than when the coating was new. Our visual evaluation in 2003 noted that the hull's surface had become smoother over time, possibly due to frequent cleaning with powered, rotary brushes.

The other three boat owners with epoxy or ceramic-epoxy coatings now have a little more than two years of experience with them. One has an out-drive style engine that requires annual maintenance in the boat repair yard. Thus, he would not be able to make up for frequent hull cleaning costs by extending the time between haulouts. He has used a slip liner for a few months and has realized savings on hull cleaning.

Another has asked his hull cleaner to clean the coating just until the surface is smooth without trying to remove all the fouling from pits and grooves. He is satisfied with the coating.

The third was concerned about cleaning costs and perceived slowness during races. However, during the demonstration he reported that the sailboat had won some races with the nontoxic coating. He is considering:

a. switching from a service that uses hand-cleaning tools to one that uses powered, rotary brushes to reduce cleaning time; or

b. applying a copper-based paint over the ceramic-epoxy coating.

Another boat owner would recommend the silicone-rubber coating to serious, sailboat racers, but not to the typical, weekend racer, due to the high maintenance cost.

These results confirm the findings of our economic study (Carson et al. 2002; Johnson and Miller 2003). In other words nontoxic, epoxy or ceramic-epoxy coatings may be cost effective in the long-term, if the boat does not need to be hauled frequently for other maintenance purposes. In the short-term, copper paints are more cost-effective.

Silicone-rubber coatings that are cleaned very often perform well in races. Racing performance of epoxy and ceramic-epoxy coatings may suffer somewhat in the short-term. Frequent cleaning with powered brushes may smooth an epoxy coating and restore its racing performance in the long-term.

Although our demonstration included a small number of boats, the results suggest that nontoxic coatings can be a good choice for some boat owners. The epoxy and ceramic-epoxy coatings may serve other boat owners as durable, barrier coats. New coatings that are still in development may prove to be suitable for those who wish or are required to use environmentally-friendly alternatives to copper-based, antifouling paints.

(Jamie Anne Gonzalez)

Sailboat-Silicone-Rubber (1 year)

How Did We Share Our Results and What Difference Did It Make?

The UC Sea Grant Extension Program presented information about the results from the nontoxic boat bottom paint demonstration project and economic incentives study in a series of 16 seminars, 7 conferences, 4 booth events and 2 Field Days. Over 1800 boat owners and representatives of boating and coating industries, government agencies and environmental organizations attended.

The events:

- explained the field demonstration;
- presented reports and photographs from the visual assessments at the end of the field demonstration;

(Jamie Anne Gonzalez)

Presenting Demonstration Project Results

- provided simple statistics such as means and ranges; and
- presented findings from the economic study that would be useful to boat owners in deciding whether to switch to nontoxic antifouling strategies.

The Field Days also featured live, underwater hull cleaning via an underwater video camera, a chance to inspect project boats after they were hauled out of the water at the end of the demonstration and speak with participants.

Of those who completed an evaluation after the seminars, conferences, and Field Days:

- 65% learned about the elevated copper levels in San Diego Bay, Newport Bay, and Marina Del Rey;
- 63% learned about the effects of elevated copper levels on marine organisms;
- 70% learned that as much as 90% of the copper in San Diego Bay comes from boat bottom paints;
- 77% learned that nontoxic coatings must be cleaned about twice as often as copper-based antifouling paints;
- 72% learned that epoxy coatings may last several years longer than copper-based antifouling paints;
- 67% learned that nontoxic paints will not adhere to existing, copper-based paints;
- 64% learned that unpainted hulls and hulls that need to have old paint layers stripped are the most cost-effective candidates for nontoxic coatings;
- 81% learned that phasing out copper antifouling paints on recreational boats in San Diego Bay over 7 years could cost $20 million, but only $1 million if they were phased out over 15 years;
- 79% would switch to a nontoxic paint if it was required by law; and
- 49% would switch to a nontoxic paint if it was not required by law.

(Carol Anderson)

Independent Studies on Nontoxic Bottom Coatings Are Needed in a Variety of Locations under Various Operating Conditions

Two booklets, ***What You Need to Know about Nontoxic Antifouling Strategies for Boats*** (October 2002) and ***Making Dollars and Sense of Nontoxic Antifouling Strategies for Boats*** (November 2003), were disseminated at the seminars and Field Days that took place after their publishing date. Another 5000 copies were mailed to boat owners and representatives of boating and coating industries, government agencies and environmental organizations. They are described at the end of this report.

Readers reported in the evaluations that:

- ***What You Need to Know…*** provided a common foundation of knowledge about nontoxic antifouling strategies, antifouling policies and the effects of copper pollution; and
- ***Making Dollars and Sense…*** provided new information on the economics of nontoxic coatings, particularly with regard to switching to a nontoxic epoxy coating and important policy implications.

What Nontoxic Antifouling Strategies Are On the Market?

The field of alternative bottom coatings has expanded since our first booklet was published in 2002. More coatings are reaching the market and every major paint company is studying biocide-free paints (Kettlewell 2000).

Consult the **Nontoxic Antifouling Strategies Sampler** in this booklet to learn about nontoxic coatings and companion strategies that are already available. It was compiled to assist boat owners in learning about a variety of products. Note that we have not tested them and inclusion in the **Sampler** is not an endorsement or recommendation of any kind. Information in the **Sampler** was provided by manufacturers. Consult local boat repair yards and hull cleaning companies for recommendations on products and cleaning schedules that have proved successful in the area.

Paint and coating companies continue to develop innovative, antifouling approaches to meet the expected need for alternatives to copper-based boat bottom paints. Some act as repellents and others use a toxic agent other than copper. They are beyond the scope of this booklet, but boat owners should be aware that many new products are on the market and more can be expected in coming years.

What's on the Horizon?

Several years ago, tributyl tin-based antifouling paints were banned for use on recreational boats. Now, restrictions on copper-based paints have been proposed for recreational boats in San Diego Bay and have been imposed in some parts of Europe. If many boat owners switch to a new, toxic antifoulant that accumulates in boat basins, a new problem will likely be created and yet another change in antifouling strategies will be needed.

The goal of the UC Cooperative Extension – Sea Grant Extension Program is to help boat owners and boating businesses protect marine life and prepare for restrictions on copper-based antifoulants in a cost-effective fashion by providing the best available information on nontoxic antifouling strategies.

Our field demonstration of three types of nontoxic coatings for one year in San Diego Bay and the related, economic research found that they show promise as sustainable solutions. Other nontoxic products and other alternatives to copper-based paints may also be viable choices.

We briefly tracked a fourth coating that had performed well on commercial vessels in northern Europe. Unfortunately, a local tubeworm fouled this coating very quickly and heavily in San Diego Bay.

Clearly, the types of fouling growth present in each area, how the boat is used and stored, and local climate affect which antifouling strategy is best for each boat. Further, new and developing, nontoxic and other, alternative antifouling strategies work in various ways. As a result:

- No single, nontoxic or other, alternative antifouling strategy will suit every boat; and
- Independent studies of new strategies are needed in different geographic areas and on different types of boats.
- Boat owners should investigate carefully to determine which coating best suits their situation!

Our evaluations indicate that compared to five years ago:

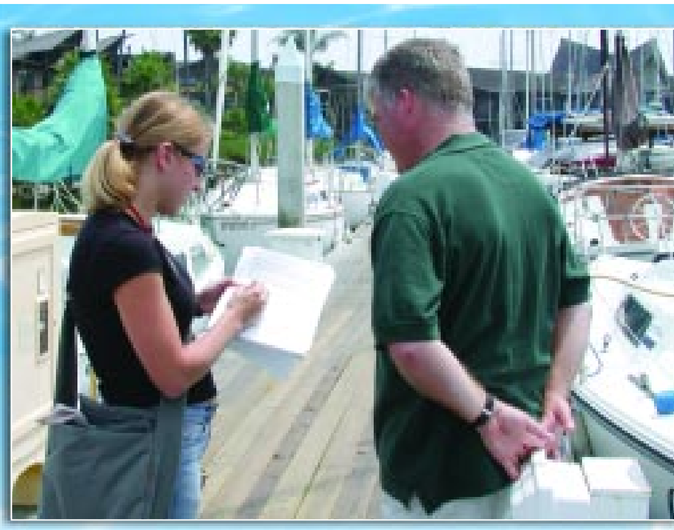
- More boaters are considering switching to nontoxic bottom coatings;
- More boat repair yards and hull cleaning companies are gaining experience with these coatings and their performance capabilities; and
- Marinas and yacht clubs in San Diego Bay are considering ways to comply with proposed restrictions on discharges of copper from tenant boats.

Our work will not be the final word in new antifouling strategies. It is just the first chapter in the story of a revolution in sustainable, antifouling strategies!

Where Can You Learn More about Nontoxic Antifouling Strategies?

The University of California Cooperative Extension – Sea Grant Extension Program has produced fact sheets, two other booklets and a television documentary. Our fact sheets and the first booklet in our series, ***What You Need to Know about Nontoxic Antifouling Strategies for Boats,*** can be downloaded from our Internet site at **http://seagrant.ucdavis.edu.**

The second booklet in our series, ***Making Dollars and Sense of Nontoxic Antifouling Strategies for Boats,*** summarizes results from our study of economic incentives for boat owners to switch to nontoxic boat bottom coatings (Carson et al. 2002). It also includes a boat owners' worksheet for calculating costs of using copper-based and nontoxic coatings. Visit our Internet site to learn how to obtain a copy.



Surveying Recreational Boat Owner

The television documentary, ***Time for a Change – Alternatives to Copper-Based Boat Bottom Paint,*** can be viewed in streaming format on our Internet site. It presents an overview of the issue and comments by representatives of: boat owners; marinas; a port; boat repair yard, hull cleaning and coating companies; an environmental organization; and a regulatory agency. It is also available in DVD format with English and Spanish programs; visit our Internet site to learn how to obtain a copy.

Dedication

We want to express our deep appreciation to Carol S. Anderson whose skills as an artist, computer whiz, and organizer have helped us stay afloat throughout this project. We wish her a wonderful retirement doing whatever strikes her fancy!

Nontoxic Antifouling Strategies Sampler

Although nontoxic coatings will not slow growth, they can be effective when used in a strategic combination with other methods. Nontoxic antifouling strategies may combine nontoxic coatings with mechanical hull cleaning, slip liners, or boat lifts. **Prices and information listed are effective as of July 2004.**

Follow manufacturers' instructions regarding application and maintenance. Most coatings are not compatible with existing ones. **Many coatings require professional application!** These products are relatively new and experience with them is limited. Independent evaluations of long-term costs, benefits, and performance of products are needed. Investigate products carefully! Ask manufacturers for copies of independent tests of their products and references to others who have purchased them in your area.

Some of the maintenance information presented here is provided by San Diego area boat repair yards and underwater hull cleaners. Ask local boat repair yards and hull cleaning services which coatings have performed well and what maintenance is needed in your area. Check local air and water quality regulations before selecting a paint.

This information on nontoxic alternatives to copper-based antifouling paints is intended for educational purposes only and does not constitute an endorsement or recommendation by the University of California or any of the organizations that funded the demonstration project or this publication. Coating information is compiled from manufacturers' data and has not been verified by the authors.

Nontoxic Antifouling Strategy Product Examples	Recommended Use	Maintenance*	Coating Characteristics	Longevity
EPOXY AquaPly M® (In UC demo project) Sound Specialty Coatings 2 part epoxy $280/2 gallons 450 sq ft/2 gallons http://www.soundspecialtycoatings.com	Roll on 2 coats; Wood, metal, fiberglass; Do not apply over old copper paint; Can be reapplied without removal	Use soft cloth, brush or burlap to remove growth	Coating is slippery; Use caution when placing boat in slings or on blocks; Osmotic blister barrier coat; Coating smooths out with wear	Longevity: 14 years and coating is still in good condition; Can be added in mold for new boats
CERAMIC-EPOXY CeRam-Kote Marine® (In UC demo project) Freecom, Inc. Ceramic epoxy binds ceramic particles in resin system $108/gallon 120 sq ft/gallon http://www.ceram-kote.com	2 coats @ 5 mils each; Fiberglass, steel, or aluminum; Do not apply over old copper paint; Can be field repaired and reapplied without removal	Clean every 2 weeks in summer and every 3–4 weeks in winter, according to local conditions	Abrasion and corrosion resistant; Protects against osmotic blistering; Coefficient of friction similar to Teflon, thus enhancing speed at same RPMs	Longevity: 10+ years; New formula has tighter molecular cross linking creating a harder surface that is easier to scrub
Ecospeed® Subsea Industries; Belgium Glass particles in matrix of resins cures in vinyl ester coating to create powerful bond to substrate www.ecospeed.be NOT ON CALIFORNIA MARKET July 04	Spray on fiberglass, steel, aluminum; Can be brushed on for small spot repairs	Maintenance as needed; Levels of fouling growth of up to 10 cm have been removed after one year without damage to coating	Glass-flake paint constructs a layered barrier that remains stable for long periods of time in corrosive environments	Longevity: Estimated to be lifetime of vessel; Hydrodynamic profile can give better efficiency to the vessel; Easy maintenance: hull cleanings possible without damaging coating smoothness

*Maintenance of coatings depends on vessel location and activity and diver availability. Generally coatings are more difficult to clean the longer the time between cleanings. In the San Diego area, divers recommend cleaning nontoxic coatings every 1-2 weeks in summer and 2 to 3 weeks in winter.

Nontoxic Antifouling Strategies Sampler

Nontoxic Antifouling Strategy Product Examples	Recommended Use	Maintenance*	Coating Characteristics	Longevity
SILICONE Intersleek® 425 International Paint Company Silicone based foul release coating $250/gallon 125 sq ft/gallon http://www.international-marine.com	Apply epoxy barrier coat; Tie coat and finish coat by airless spray for all vessels; Do not apply over old copper paint	Depends on usage; Designed for high speed (30 knots) vessels; Less maintenance needed if used more often	Caution: Slippery coating	Coating may damage easily if bumped or scraped or scrubbed hard
Si-COAT™ Fouling Release Coating CSL Silicones, Inc. Silicone coating http://www.cslsilicones.com NOT ON CALIFORNIA MARKET JULY 2004	1 coat primerless system; Fiberglass, steel, aluminum, and wood	Fouling releases when vessel moves; As vessel approaches 5 knots, fouling loosens; As vessel exceeds 13 knots, fouling clears†; Low pressure washing may also be used to release fouling	Caution: Slippery coating; 100% solids and VOC free	New formula for better surface finish, better adhesion, and more durability †Independent studies of silicone coatings suggest that fouling begins to slide off at 20 knots
Miracle Cover Marine® (In UC demo project) Miracle Cover, Inc. Water based silicone-rubber liquid sealer $40/gallon and $190/5 gallons 175 sq ft/gallon www.terryjordan.com	1 coat; Apply to clean surface with brush, roller, sprayer or mix into oil and water-based coatings; Do not apply over old copper paint; Can be reapplied without removal	Fouling releases as vessel moves; Use nylon brush, soft cloth as needed	Caution: Slippery coating; Reduces drag allowing an increase in speed; Abrasion will wear the coating and the more the boat is used, the more abrasion will occur	Product has been on fishing boats for 5 years without reapplication; Stretches to accommodate structural movement up to 300%
Wearlon® Super F1-M Eccotech, Inc. Silicone epoxy water based coating $189/gallon 250 to 275 sq ft/gallon http://www.wearlon.com	1 coat for wood, aluminum, fiberglass, steel; Best sprayed on for uniform finish; Adheres to most barrier and primer coats	Self cleaning with more usage; Recommended for boats that are in frequent use; Foul-release, low-energy surface	Caution: Slippery coating; Inherent lubricity improves fuel economy and increases speed (when clean);Elastic modules enable it to deform and resist impact damage	Longevity: 2 to 3 seasons depending on usage; Abrasion leads to more wearing
SILOXANE MegaGuard® LiquiCote KISS-COTE Siloxane coating; Self-bonding polymers $175/4 oz 4 oz covers 2000 sq ft http://www.kiss-cote.com/apps/marine.htm	Thinner coating works best; Molecular layer follows contours of surface; Can be applied over gel coat or diluted version over existing bottom paint	Soft cloth or water to clean	Caution: Slippery coating; Improves speed and reduces fuel consumption; Prevents corrosion	Longevity depends on substrate; Reduces drag and surface friction and creates water repellent finish

*Maintenance of coatings depends on vessel location and activity and diver availability. Generally coatings are more difficult to clean the longer the time between cleanings. In the San Diego area, divers recommend cleaning nontoxic coatings every 1-2 weeks in summer and 2 to 3 weeks in winter.

Nontoxic Antifouling Strategies Sampler

Nontoxic Antifouling Strategy Product Examples	Recommended Use	Maintenance*	Coating Characteristics	Longevity
FOUL-RELEASE POLYURETHANE No-Tox™ Fouling Release Control FPU® 51NT150™ 21st Century Coatings Hard, nonablative, fluorinated polyurethane coating $400/gallon 250 sq ft/gallon http://www.21st-centurycoatingscanada.com/Marine.htm	Minimum of 1 coat; Ambient cured spray applicable for all pleasure craft; Do not apply over old copper paint	Low surface energy creates slick surface that wipes easily with sponge	Caution: Slippery coating	Longevity: 6 to 7 years; No leaching
WATER-BASED URETHANE Sea-Slide® American Marine Coatings Water based urethane overcoating $49.95/quart covers most 25 foot vessels http://www.copperpoxy.com/newfiles/seaslide.html	Apply by brush, sponge or roller; Antifouling paints will function normally when used under Sea-Slide®	Clean as needed	Caution: becomes slippery when wet; Water based polyurethane resin that dries to a clear, hard finish	Longevity: 8 to 12 months; Drag-reducing overcoating
BOTTOM WAX Easy On® Bottom Wax Alex Milne Associates Ltd Foul release bottom wax coating $34.95CDN/450ml treats up to 24 ft boat http://www.alexmilne.com www.marinetex.com	Applies easily with a soft cloth; The thinner it is applied, the better it works; For fiberglass and aluminum boats; Can be applied over old existing antifouling paint	Clean as required or when fuzz develops with sponge, deck brush or white abrasive pad; Clean surface as above and apply thin overcoat each season; Can be totally removed with high Ph cleaner	Caution: Slippery coating; For full season freshwater and intermittent saltwater use; Ideal for racked and trailered boats, pontoon, sail, power, inflatables	Seasonal coating; Clear, soft movable surface; Repels water from hull; Increases top end speed and reduces fuel consumption; Can be coated on outdrives and electronic sensors; Helps prevent osmosis
H.P. Bottom Wax® with VS721 Aurora Marine Industries Inc. Super hydrophobic bio release barrier coating 450 mls/$31.49 covers 400 sq ft http://www.auroramarine.com	Applies with damp sponge; 2 coats to fiberglass, aluminum, hard painted surfaces; Do not apply over existing antifouling paint	Regular use self-cleans hull; For stationary and light use boats in high growth areas clean every 4 to 8 weeks by wiping off slime with sponge	Caution: Slippery coating; Inert, clear, shiny barrier polymer coating reduces surface friction on hull; Seals fiberglass to prevent osmosis	Seasonal coating; Durability: Coating stayed on race boats up to 145 mph with no degradation; Sailboats report speed increases up to 2 mph
POLYMER Repelin® Aurora Marine Industries Inc. Super hydrophobic bio release barrier coating 220 ml/$18.95 covers 200 sq ft http://www.auroramarine.com	For inflatable boats; 2 coats to Hypalon, PVC, fiberglass, aluminum, hard painted surfaces; Use Poly Guard as protective barrier for Hypalon and PVC; Apply direct to other substances	Regular use self-cleans hull; For stationary and light use boats in high growth areas clean every 4 to 8 weeks by wiping off slime with sponge	Caution: Slippery coating; Inert, clear, shiny barrier polymer coating reduces surface friction on hull; Reduced fuel consumption; Higher speed; Seals fiberglass to prevent osmosis	Seasonal coating; Reduces attachment of exhaust soot and diesel stains and facilitates removal

*Maintenance of coatings depends on vessel location and activity and diver availability. Generally coatings are more difficult to clean the longer the time between cleanings. In the San Diego area, divers recommend cleaning nontoxic coatings every 1-2 weeks in summer and 2 to 3 weeks in winter.

Nontoxic Antifouling Strategies Sampler

Boat Lifts, Boat Scrubbing Systems, Slip Liners, and Underwater Hull Cleaning Services

BOATLIFTS	
AirBerth® Boat Lifts http://www.airberth.com	Eliminates need for antifouling paint and underwater hull cleaning if boat is always returned to lift Wide range of models available to fit variety of boats and dock applications Note: May not be allowed in some marinas
Galva-Foam® Marine Industries Boat Lifts http://www.shoremaster.com/galvafoam	
HydroHoist® International, Inc. Boat Lifts http://www.boatlift.com	
Boat Lift® Distributors http://www.boatliftdistributors.com	
BOAT SCRUBBING SYSTEMS	
BoatScrubber® http://www.boatscrubber.com	EcoAntifouling™ system combines regular scrubs with nontoxic paint Through regular cleaning without need for chemicals, can eliminate need for toxic antifouling coatings and fuel efficiency improves Entered US market in 2004; Not yet available in all states including California as of July 2004.
SLIP LINERS	
Bottom Liner® $1040 for 25 ft vessel UV inhibited vinyl coated liner with foam flotation collar http://www.bottomliner.com	Characteristics Eliminates need for antifouling paint and underwater hull cleaning if boat is always returned to liner Add freshwater into slip enclosure to reduce fouling (check local regulations) Liner will contain any spills from vessel at slip Outside of liner must be maintained Caution: Lines that suspend liner may stretch and sag
Armored Hull™ liner Armored Hull™ Air-gate™ system lowers and raises with valve and hand pump so that lines or ropes are unnecessary	
UNDERWATER HULL CLEANING SERVICES	Mechanical cleaning by hand or with power tools Cleaning frequency and type of cleaning tool depends on water temperature, type of paint, frequency and speed of boat use

Please see our website at http://seagrant.ucdavis.edu for more information on alternatives to copper-based antifouling paints.

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Publication Design by Chris O'Connor

EVALUATION: STAYING AFLOAT WITH NONTOXIC ANTIFOULING STRATEGIES FOR BOATS

Would you please help us to evaluate the effectiveness of our booklet by completing and returning the evaluation form? Thank you!

Please put an X by all of the groups to which you belong:

_____ Recreational Boat Owner

_____ Marina or Yacht Club Manager

_____ Boat Repair Yard Company

_____ Paint/Coating Company

_____ Port or Harbor Authority Commissioner

_____ Other Elected/Appointed Official

_____ University Researcher

_____ Boating Association

_____ Trade Association Manager

_____ Environmental Organization

_____ Underwater Hull Cleaning Company

_____ Port or Harbor Authority Staff

_____ Other Government Agency Staff

_____ Consultant

_____ Other:____

Please circle the number that indicates how much you agree with the following statements, using this rating system:
1 = Do not agree, 2 = Agree slightly, 3 = Agree somewhat, 4 = Agree very much, 5 = Agree extremely

1 2 3 4 5 The information in the booklet will be USEFUL TO ME in understanding and making decisions about antifouling STRATEGIES for recreational boats.

1 2 3 4 5 The information in the booklet will be USEFUL TO ME in understanding and making decisions about antifouling POLICIES for recreational boats.

Please place an X beside each topic in the booklet that provided you with NEW information:

_____Copper-based antifouling paints can create a problem for marine life in boat basins.

_____Nontoxic antifouling strategies include a nontoxic coating and a companion strategy.

_____The availability of nutrients, the texture of the surface, the chemical reactions taking place on it, and the movement of surrounding currents influence where fouling growth settles.

_____TMDL studies are being completed in Southern California for dissolved copper.

_____Several European countries are monitoring dissolved copper in boat basins and copper-based bottom paints have been banned or restricted in Sweden, Denmark, and the Netherlands.

_____The objective of nontoxic antifouling strategies is to control fouling growth while protecting the environment and the boat's bottom coating.

_____ Nontoxic coatings must be cleaned about twice as often as copper-based antifouling paints.

_____ Most nontoxic bottom paints will not adhere to existing, copper-based paints.

_____The most cost-effective time for switching to a nontoxic coating is when the boat is new and unpainted or when the copper-based coating needs to be stripped.

Please continue on next page……

_____Best Management Practices, such as cleaning frequently and using the gentlest possible tool, can extend the life of a coating.

_____In our demonstration project, the epoxy and ceramic-epoxy coatings have the potential to last many more years than copper-based coatings and the silicone coating.

_____ In our demonstration project, the silicone coating was preferred by boat owners who like to race and were willing to invest in very frequent cleaning and annual replacement.

_____In our demonstration project, the epoxy and ceramic-epoxy coatings appear to be a good choice for boat owners who want a nontoxic coating that may last long enough to compensate for costs incurred in more frequent cleaning and converting from a copper-based coating.

_____Our field demonstration of three types of nontoxic coatings for one year in San Diego Bay and the related economic research found that they show promise as sustainable solutions.

Please put an X by each topic with which you agree:

*Would you switch to nontoxic bottom paint: _____ If required by law? _____ If not required by law?

*If so, which type would you prefer? ____ Epoxy/Ceramic-Epoxy _____Silicone ____Other:_________________

* Why?____

Did you attend our Nontoxic Bottom Paints Field Day:
_____ At the Southwestern Yacht Club in San Diego in 2002?

_____ At the Shelter Island Boatyard in San Diego in 2003?

_____ Have you read our booklet *What You Need to Know about Nontoxic Antifouling Strategies for Boats*?

_____ Have you read our booklet *Making Dollars and Sense of Nontoxic Antifouling Strategies for Boats*?

_____ Have you read any articles about our nontoxic boat bottom paint project in a newspaper, newsletter or magazine?

If so, which one(s)?____

Did you participate in the Sea Grant Extension Program and UCSD Department of Economics economic study on incentives to switch to nontoxic paints? YES NO

Please comment or suggest other antifouling related information that would be useful to you:

Would you like to receive information on our new project to prevent transport of aquatic invasive species on boat and ship hulls? YES NO

Thank you for helping us to evaluate the effectiveness of our research and education programs!!
Please fax or mail the completed evaluation to:

Leigh Taylor Johnson, Marine Advisor, University of California Cooperative Extension
Sea Grant Extension Program, County of San Diego MS O-18, 5555 Overland Avenue Suite 4101
San Diego, CA 92123 Phone (858) 694-2852 FAX (858) 694-2849
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