What You Need to Know About

Nontoxic Antifouling Strategies

For Boats

California Sea Grant College Program
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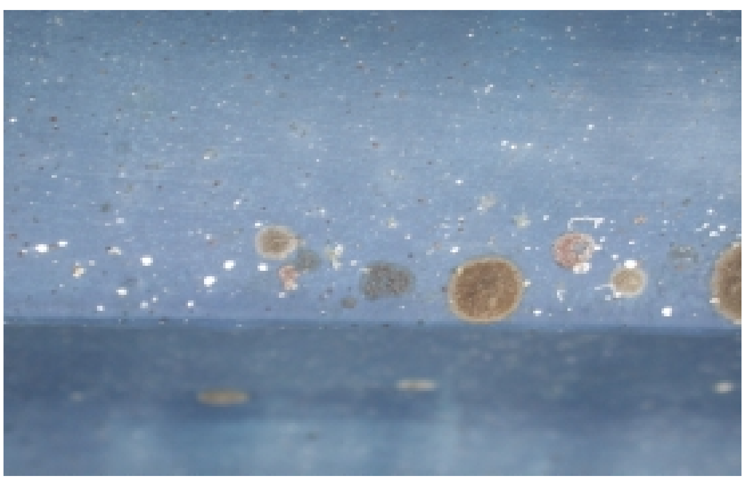
A Change is in the Wind for Antifouling Strategies - And It's Blowing Your Way!

Governments in southern California are concerned about toxic buildup of copper in boat basins and are acting to cut emissions of copper from boat bottom paints. Some European countries have already restricted copper-based bottom paints for pleasure craft. Paint companies anticipate that other areas of the United States and the world may regulate copper-based bottom paints within 5-10 years, so they are developing environmentally friendly alternatives. Other companies are developing mechanical approaches that can be used in combination with the new paints.

The purpose of this report is to help boat owners, boating businesses, paint companies, government agencies, scientists and policy makers learn about the need for cost effective and environmentally friendly antifouling strategies, what is available now, how to use them effectively and what else is needed for a successful transition. New products are developing a track record and even newer products are under development. The situation will continue to change and boat owners should stay informed.

Why Is It Important to Control Fouling Growth?

Every boat owner knows that fouling growth, such as algae, barnacles, mussels and worms, can slow sail boats and increase fuel consumption for power boats. A fouled boat bottom increases "drag" (resistance to movement through the water) by 7% to 10% (Lamb 1981). A rough hull can increase fuel consumption (and related pollution) by 0.3% to 1% or more, depending on the amount of fouling (Milne 1990). A badly fouled hull may also carry invasive species of marine life.



Barnacles, Tube Worms and Other Fouling Growth

How Do Popular Antifouling Strategies Work?

Mariners have tried for centuries to keep boat bottoms free of barnacles and other fouling growth. For example they have bolted sheets of copper metal to the hull or mixed tributyl tin (TBT) or cuprous oxide into bottom paint. These heavy metals are toxic to young stages of marine life that try to attach to boat bottoms.

A copper-based bottom paint, combined with underwater hull cleaning, is the most popular antifouling strategy for recreational boats in the San Diego, California area. These paints contain between 20% and 76% cuprous oxide and they act by continuously emitting copper. Antifouling coatings are designed to release copper into surface waters through passive leaching (hard paints) and ablation (soft paints). Underwater hull cleaning divers remove attached growth, allowing the bottom coating to work more effectively. Hull cleaning releases additional metal into the surrounding water (McPherson and Peters 1995; Valkirs et. al 1994; SDRWQCB 2001). Frequent hull cleaning removes soft, early stages of growth by gentle wiping that minimizes paint release. Ablative, or self-polishing, paints are designed to wear away, exposing new layers of copper, and should not be cleaned by divers, according to the California Professional Divers Association.

Why Are Copper-Based Paints a Problem?

The most popular bottom paints are pesticides that act by slowly releasing copper. Pleasure craft often spend much time at the slip, so most of the copper in the bottom paint is released there and builds up in waters and sediments. Because metals are elements, they don't degrade over time. Although TBT has been banned for recreational boats in many areas, cuprous oxide is still commonly used. Governments in southern California and in Europe are finding that dissolved copper in marina waters has reached toxic levels and that boat bottom paints are major sources of this copper.

Sediments that are contaminated with copper are more expensive to dredge from boat basins, because they require special handling and disposal methods. Boatyards also have high costs for environmental permits and to contain and dispose the copper paint they remove from boat bottoms. These costs are passed on to boaters and marinas.

Dissolved copper levels in boat basins of San Diego Bay and Newport Bay in southern California range from 2.6 to 29.0 parts per billion (ppb), according to the San Diego Regional Water Quality Control Board and the U.S. EPA. The federal and state regulatory standard for dissolved copper is 3.1 ppb (U.S. EPA 2000).

Scientific studies of mussels, oysters, scallops, sea urchins and crustaceans were reviewed to determine how dissolved copper at levels found in southern California marinas affects them. When exposed to dissolved copper at concentrations from 3.0 to 10.0 ppb, various species showed reduced or abnormal: embryo growth, development, swimming and survival; larval growth and survival; adult growth, spawning and survival; and adult digestive, reproductive and muscle tissues (Calabrese et al. 1984; Coglianese and Martin 1981; Gould et al. 1988; Lee and Xu 1984; Lussier et al. 1985; MacDonald et al. 1988; Martin et al. 1981; Redpath 1985; Stromgren and Nielsen 1991). Some of these studies and others (Krishnakumar et al. 1990; Redpath and Davenport 1988) found that many of the above effects became more severe and that feeding, respiration, and waste elimination of adult mussels were also affected at dissolved copper levels from 10.0 to 29.0 ppb.

Studies conducted before 1980 showed more types of toxic effects and for more species, including fishes, worms, comb jellies and algae. They were not included here, because "clean techniques" used to measure ultra-low dissolved copper concentrations were not available then (Seligman 2002).

These studies were conducted in laboratories. There is some debate about whether the results would have been different, if they had been conducted in open waters, where naturally occurring organic material binds copper ions and makes them less toxic (Kim et al. 1999; Sigg and Xue 1994; Sunda 1994). Free ions are the most toxic form of dissolved copper (Sunda 1994). There is also debate about the significance of these points for water quality standards.

In evaluating toxic effects of dissolved copper from bottom paints, it is important to consider the "big picture." Marine life in marina and harbor waters experience the cumulative effects of spilled lubricating oil, diesel, gasoline, cleansers, varnish, garbage, trash, sewage, zinc, copper, other pollutants from boats and those carried by storm drains. Increasingly, boaters are acting to cut releases of all forms of pollution and they will ultimately benefit from their actions!

Shelter Island Yacht Basin, San Diego, Califoirnia

How Will Boaters Benefit from Reducing Copper Pollution in Boating Waters?

Recreational boating, diving, sport fishing and bird watching are popular in and around coastal waters. California's boating industry was worth $11 billion dollars in 1995 (Rust and Potepan 1997), so it contributes to the state's economic well-being. High copper levels in the water affect the early and adult life stages of many marine species that provide food for birds and sport fish.

As boat owners shift to nontoxic coatings, copper releases to boatyards and to harbor sediments will fall. This should reduce environmental compliance costs for boatyards and harbor authorities. These savings may be passed to boaters.

Sailing San Diego Bay

Reducing dissolved copper levels will also promote a healthier and more abundant food chain for the fish, other marine life, shore birds and sea birds that boat owners, divers, anglers and bird watchers enjoy!

Cost effective and environmentally friendly antifouling strategies will help us achieve environmental benefits while maintaining the economic and recreational benefits of boating.

What Is an Environmentally Friendly Antifouling Strategy?

An environmentally friendly antifouling strategy is a coordinated approach to controlling fouling growth while reducing environmental damage. Bottom paints with heavy metals are popular, because they are relatively convenient and inexpensive. However, the environmental costs of these pesticides are no longer acceptable. Also, they don't stop fouling growth; they just slow it. Thus, periodic cleaning is already needed to remove soft, early stages of fouling growth.

New strategies are being developed that combine nontoxic or less toxic bottom coatings with mechanical methods to control fouling growth.

How You Can Control Fouling Growth with Environmentally Friendly Strategies

Currently available, nontoxic bottom coatings may be silicone-based, epoxy-based, water-based, or polymer-based. Nontoxic coatings do not slow fouling growth and they need more frequent cleaning than copper-based paints. Silicone-based paints should wipe clean easily; other types may need more aggressive cleaning.

Companion strategies that are sometimes used with nontoxic paints include: using the vessel more often; using it at high speed; storing it on land or hoisting it above the water at the slip; surrounding it with a plastic liner and adding 10-15% fresh water to reduce salinity; using an underwater hull cleaning dive service or a mechanical scrubbing system. *(Check local regulations on discharging fresh water to the marine environment)* Look for descriptions and examples of nontoxic coatings and companion strategies in the table included in this brochure.

The most effective combination of products and cleaning schedules or alternative devices varies for each area and boat owner, according to correspondents in Europe, Canada and different parts of the United States. Boat owners should ask marinas, boatyards and hull cleaners what is most effective in their local areas.

Many nontoxic coatings are relatively new and there has been little or no independent testing. Thus, the information in the table is provided for educational purposes; it does not endorse or recommend any product or service.

Paint companies are also developing innovative coatings that use short-lived, organic biocides, but they are beyond the scope of this report. There is much debate about whether bottom paints with lower copper levels or short-lived, cobiocides will solve the problem of copper buildup in boat basins.

Experience with Nontoxic Coatings in the San Diego, California Region

How Important Is the Bottom Paint Cleaning Schedule?

Bottom paint needs to be cleaned often enough to remove early stages of fouling growth. Once fouling organisms reach a certain stage, they begin to harden, develop a stronger hold and may penetrate and scar the paint. Then, more aggressive scrubbing is needed that may further damage or wear away paint. (Hoffman 2002) To avoid these problems, boat owners in the San Diego region commonly have a diving service clean copper-based bottom paint every four weeks. In summer many boat owners step up the cleaning schedule to every 3 weeks.

Powered Scrub Brushes for Underwater Hull Cleaning

San Diego area diving services that are familiar with nontoxic bottom paints generally agree they must be cleaned about twice as often as copper-based bottom paints. Some use powered scrub brushes to perform the aggressive cleaning that may be necessary. Silicone paints are relatively fragile, so they recommend frequent, gentle wiping to remove young stages of fouling growth. The California Professional Divers Association has developed best management practices and a diver training program for copper-based and nontoxic paints (Hoffman 2002).

How Important is the Paint's Durability?

A nontoxic paint, or coating, must be able to withstand more frequent and possibly more aggressive cleaning. Because it does not depend on the lifespan of copper, a durable, nontoxic paint may last longer than a copper-based paint. This would allow more time between haulouts and repainting and make up for extra hull cleaning costs. Nontoxic coatings are relatively new, so their actual lifespan, cleaning schedule and difficulty, and the cost of haulouts for safety inspections and topside work will need to be determined during the next few years.

Sprayer Application of Nontoxic Bottom Paint

Epoxy coatings are durable, require frequent and aggressive cleaning, and are expected to last for many years. A San Diego area sailboat received an epoxy coating almost four years ago. The diving service that cleans it reports it is still in good condition. Manufacturers of two nontoxic, epoxy-based coatings report their coatings have lasted from 6 to 12 years on some boats. In contrast, most San Diego area boat owners reapply copper-based bottom paint every two to three years.

Compared to epoxy coatings, silicone coatings are a rubbery material that is more easily nicked or abraded. They are sometimes called "fouling release" coatings, because fouling growth slides off when the boat exceeds a certain speed. Field tests found the critical speed varies for different coatings and organisms, although 20 knots is often cited (Swain 2000, 2001). Although many pleasure craft seldom or never operate at this speed, the slippery nature of these coatings means that fouling growth can be wiped off easily. San Diego area hull cleaners recommend frequent cleaning of silicone coatings, because they believe that later stages of fouling growth can penetrate these coatings and become more firmly established on the hull. Also, because silicone coatings are slippery, the boat owner must be sure to inform the boat repair yard that the boat has a silicone bottom coating and needs special handling.

How Do You Make the Change?

Boatyard operators in the San Diego region have some experience with applying nontoxic bottom paints on recreational boats. Although they believe that one-fourth of the boaters in the San Diego region are aware of nontoxic bottom paints, only a few boaters have requested these products. Epoxy- and silicone-based coatings are the most commonly applied nontoxic bottom paints in San Diego boatyards.

Stripping Old Copper-Based Bottom Paint

San Diego area boatyard operators have found that epoxy- and silicone-based coatings will not adhere to residual, copper-based bottom paints, so existing layers of paint must be removed. One boatyard estimates that it costs $150 per foot of boat length to haul the boat, remove old paint and apply nontoxic, epoxy-based paint, versus $25 to $50 per foot to haul and reapply copper-based bottom paint. Some of the difference is due to the higher cost of the nontoxic coating, but most is due to the cost of stripping old paint. Thus, it is more economical to apply nontoxic paint to new boats and to boats that need to have accumulated layers of old paint removed. A durable coating may last long enough to make up for some of the costs of converting to nontoxic paint and of cleaning it twice as often. Note that an epoxy undercoat must be applied to prevent water penetration of non-epoxy topcoats (Roberts 2002; Wilson 2002).

How Are We Learning About Performance and Economics of Nontoxic Coatings?

Harbor Police boats of the San Diego Unified Port District have been coated with nontoxic bottom paints and the University of California (UC) Sea Grant Extension Program is conducting an educational demonstration of nontoxic bottom paints. Both projects are tracking the performance of epoxy, ceramic-epoxy, fiber-epoxy and silicone coatings. The UC Sea Grant Extension Program's findings will be published after the demonstration concludes.

The UC Sea Grant Extension Program is also cooperating with Professor Richard Carson of the University of California at San Diego's Economics Department on a study of incentives for boat owners to use nontoxic antifouling strategies. Findings that may assist boaters in choosing a nontoxic antifouling strategy will be included in a future brochure.

Where Else in the World Is Copper Pollution a Problem?

United States

The U.S. EPA's Management Measures to Control Nonpoint Source Pollution recommends less toxic or nontoxic antifouling paints (U.S. EPA 2002a). California's Plan for Nonpoint Source Pollution Control recommends nontoxic products, such as bottom paints, for boat maintenance and mandates that toxic hull paints be phased out for state and local government vessels. (CSWRCB 2000)

Copper levels are higher than allowed under state laws in marinas and harbors: of Chesapeake Bay, Maryland (Hall et al. 1988); at Port Canaveral and Indian River Lagoon, Florida (Sheffield Engineering 1998; Trocine and Trefry 1993); in San Diego Bay, Dana Point Harbor and Newport Bay, California (San Diego Regional Water Quality Control Board 2001; Santa Ana Regional Water Quality Control Board 2000); and in areas of Washington (Washington State Department of Ecology 1999). Pleasure craft bottom paints and boatyard runoff contribute to high dissolved copper levels in these waters (Washington State Department of Ecology 1999; Hall et al. 1988; Srinivasan 2001; SDRWQCB 2001; SARWQCB 2000).

In response to the high copper levels in southern California harbors and bays, the San Diego Regional Water Quality Control Board and the U.S. EPA are conducting Total Maximum Daily Load programs for Shelter Island Yacht Basin in San Diego Bay (SDRWQCB 2001) and Newport Bay (U.S. EPA 2002b) to determine how much copper is present and how much can be allowed. Technical studies have been completed and regulations to reduce copper levels are being planned. Regulations will probably include nontoxic paints as an alternative for reducing copper pollution from boats.

Sailboat with New Nontoxic Bottom Paint

Interviewing Boat Owner About Bottom Paints

Overall, severe U.S. restrictions on the use of copper in antifouling paints within five years have been predicted by marine market analysts, due to increasing public concern about the environmental effects of copper-based paints. As the public becomes more aware of the toxic effects of copper, the copper load of paint may take on a negative connotation. To prepare for this, every major paint company is studying biocide-free paints. (Kettlewell 2000)

Europe

Along the east coast of Sweden (Swedish National Chemicals Inspectorate - KEMI 1998), in the Netherlands, and in Denmark's freshwater areas, copper-based antifouling paints have been banned for use on recreational vessels (Watermann 1999). Members of the European Union are implementing the Biocidal Products Directive (BPD) that took effect in May 2000. The BPD regulates pesticide production, including antifouling paint, and requires that biocides be authorized and proven safe in laboratory and field experiments (European Parliament and Council of the European Union 1998).

Sweden, Finland, Germany, France, and the United Kingdom are monitoring dissolved copper in coastal and inland waters. The European Union has asked the International Maritime Organization to ban all toxic boat bottom paints. (European Union Environmental Action Programme 2001). Sweden, Finland, and the United Kingdom are reviewing their antifouling policies with regard to copper pollution (Swedish Maritime Administration 2002; Nash 2002; United Kingdom Pesticide Safety Directorate 2002).

WWF Germany Study of Nontoxic Coatings

The World Wildlife Fund Germany and the Ministries of the Environment of Lower-Saxony, Hamburg, and Schleswig-Holstein are testing nontoxic bottom paints on commercial vessels operating in coastal and brackish waters (WWF Germany 2001). Participating paint companies include: Bayer AG, CeramKote, Chugoku, CK Witco, Hempel Germany, International-Akzo Nobel, Lotrec AB, Nanogate, Relius Coatings, Sealcoat, Sigma Coatings, Tenax Marine Paints, and Wilckens Farben/Kansai.

In 2000, 27 biocide-free products were applied as 80 test patches or full coat applications including: 13 nonstick coatings (mostly silicone based), 2 micro-fiber coatings, 9 self-polishing coatings, and 3 anticorrosive coatings. For comparison some of the ships were also coated with traditional, antifouling coatings. Early results have been published. To avoid promoting any one product, the study report lists products by codes, so individual results cannot be determined. They found in general that bottom paint performance depends on the climate and how the vessel is used (Cameron 2002). Another report is due in 2003.

Low-Copper and Other Alternative Paints

According to San Diego area boatyards, the most popular antifouling paints contain between 67% and 76% cuprous oxide; other products have much less.

The *Practical Sailor* ("Bottom Paints 2002") evaluated eleven, low-copper bottom paints that contain between 20% and 45% cuprous oxide. The coatings kept test panels free of soft growth for one season or allowed only a thin layer of growth. However, the performance of a low-copper, non-ablative paint depends mostly on its leach rate and on the temperature of the water where the boat is kept. If its leach rate is too low, a low-copper, non-ablative coating may not perform as well as a high-copper, non-ablative coating, so it may have to be replaced more often. (Hall 2002; Storfer 2002) In contrast, ablative paints, which are designed to shed layers, usually contain less copper. In order to prolong their life, according to manufacturers' specifications, they can be applied in more layers than non-ablative paints. (Hall 2002; Nicely 2002; Soeterik 2002; Storfer 2002) Thus, switching to low-copper paints may not reduce overall copper emissions.

The U.S. Navy is testing three types of hull coatings that release less or no copper: 1) test coatings with short-lived, organic biocides, 2) low-copper/cobiocide, self-polishing, copolymer test coatings and 3) commercial foul-release, silicone coatings. Navy vessels spend long intervals at sea and it is expensive to clean their hulls; the Navy cleans a hull coating after the first three years and then annually. (Ingle 2002) At the 11th International Congress on Marine Corrosion and Fouling held in San Diego in July 2002, university and coatings industry scientists reported on alternative, biocidal and nontoxic products that they are developing. For example, they are testing products that use enzymes, pharmaceuticals, short-lived organic compounds and phytochemicals. Environmental groups and some boat repair and maintenance businesses are concerned that such alternatives may shift, but not solve, the problem of pollution in boat basins.

Research on "erodable polymers" in antifouling paints was also reported at the Congress. If they prove to be effective, compatible with existing paints, nontoxic, suitable for recreational boats and have a suitable lifespan, they may be a good alternative. The proceedings of this meeting will be published in the scientific journal, *Biofouling*.

Nontoxic Antifouling Strategies Sampler

Although nontoxic coatings will not slow fouling growth, they can be effective when used in a strategic combination with other methods. Nontoxic antifouling strategies may combine nontoxic coatings with slip liners, boat lifts, mechanical hull cleaning and/or frequent use. The following table describes several alternatives, their benefits and challenges.

Information is compiled from manufacturer's data and experience of San Diego area boat repair yards and underwater hull cleaners. These products are relatively new, experience with them is limited and independent evaluation of long-term costs, benefits and performance is needed. The table is intended for educational purposes and does not constitute an endorsement or recommendation of any product. Investigate products carefully! Ask local boat repair yards and hull cleaning services which nontoxic coatings have performed well in that area. Ask manufacturers for copies of independent tests of their products and references to others who have purchased them.

Antifouling Strategy Product Examples [2]	Manufacturers' Comments on Benefits [1]	Manufacturers' Comments on Challenges [1]
Silicone Coatings Interlux Veridian* ($405/gallon covers 200 square feet) Protect Associates Water Shield (formerly Miracle Cover)* ($29/gallon covers 150 sq. ft.) Kiss-Cote MegaGuard* ($175/4 oz. covers 4000 sq. ft.) CSL Silicones Si-Cote 579* ($72/gallon covers 50 sq. ft.) Eccotech Wearlon* ($224/gallon covers 300 sq. ft.)	✓ Maintenance: Fouling easily removed if cleaned regularly/can be self-cleaning if vessel is used regularly ✓ Performance Capabilities: Can be used in variety of environments ✓ Slick Surface: Decreases drag and fuel consumption, improves speed, reduces engine load ✓ Creates slippery surface difficult for marine organisms to grow on ✓ Durability: Some products can last several years	○ Hull preparations vary for each coating ○ Boatyard needs dedicated application area and equipment[5] ○ Safety Consideration: Boat bottom may become slippery ○ Must use craft often to decrease fouling ○ Coating is easily nicked or abraded ○ Requires regular cleaning to retain performance benefits: Frequency dependent on water temperature and boat use
Siloxane Coatings Adsil AD-100 ($240/3 pints covers 200 sq. ft.) NewCoat Technology Sea-Speed ($350/gallon covers 144 sq. ft)	✓ Hard, smooth, slippery surface to which organisms have difficulty attaching ✓ Drag reduction decreases fuel consumption ✓ Can be applied to all surfaces including aluminum	○ Clean and sand surface before application ○ New products; contact manufacturers about cleaning schedule
Epoxy Coatings Sound Specialty Coatings Corporation AquaPlyM* ($280/2 gallons covers 450 sq. ft.)	✓ Maintenance: Early stages of marine growth can be removed with high pressure washing or scrubbing ✓ Provides fast, hard, and slippery surface for vessel ✓ Durability: Manufacturer reports some boats have had coating for ten years	○ Remove old coating before application ○ Bottom cleaning may be needed twice monthly in warmer waters[3]
Ceramic-Epoxy Coatings Freecom, Inc. CeRam-Kote 54* ($150/gallon covers 128 sq. ft.)	✓ Maintenance: Early stages of marine growth can be removed with high pressure washing or scrubbing ✓ Protection: Against corrosion, abrasion, blisters ✓ Durability: Manufacturer reports some boats have had coating for six years	○ Remove old copper paint, clean and sand hull ○ Spray on for best results ○ Requires regular cleaning depending on boat use to maintain performance benefits; bottom cleaning may be needed twice monthly in warmer waters[3]
Fiber-Epoxy Coatings Sealcoat ($50/gallon epoxy and $15/pound fibers)	✓ Maintenance: Organisms that attach should fall off eventually due to their weight ✓ Movement of fibers expected to help prevent attachment of organisms ✓ Protection: Against corrosion and condensation	○ Fibers can be damaged from rough scraping or close contact with chemicals ○ Remove old paint and apply barrier coat ○ Bottom cleaning may be needed twice monthly in warmer waters[3]
Polymer Coatings Performance Marine Corporation Marine Skin ($199.95/gallon covers 200-300 sq. ft.)	✓ Slick Surface: Reduces drag, cuts fuel costs, increases speed ✓ Creates slippery surface difficult for marine organisms to grow on ✓ Designed to replace standard antifouling paints	○ Recommended as a seasonal coating ○ Bottom cleaning may be needed twice monthly in warmer waters[3]

Nontoxic Antifouling Strategies Sampler (Continued)

Antifouling Strategy Product Examples [2]	Manufacturers' Comments on Benefits [1]	Manufacturers' Comments on Challenges [1]
Water-Based Urethane Interpolymer Dispersion American Marine Coatings Sea-Slide ($169.95/gallon covers 700-900 sq. ft.)	✓ Drag-reducing overcoating (can also be used as primary coating): Reduces friction between boat hulls and surrounding water	○ Once cured, the coating should not be scrubbed or sanded
Bottom Wax Boat Armor EasyOn Bottom Coating ($20.70/15 oz treats 24 foot vessel) Aurora High Performance Bottom Wax ($29.99/15 oz treats 24 foot vessel)	✓ Barrier coat that applies with a soft cloth or damp sponge over existing bottom paint or new surfaces ✓ Slick surface: Reduces hull drag, increasing speed and reducing fuel consumption	○ Seasonal coating (4-6 months) ○ Must be cleaned often to reduce fouling growth; bottom cleaning may be needed twice monthly in warmer waters[3]
Slip Liners Bottom Liner ($940 for 25 foot vessel) Armored Hull ($815 for 28 foot vessel)	✓ Eliminates need for antifouling paint and underwater hull cleaning (if boat is always returned to liner[5])	○ Add 10-15% freshwater into slip enclosure to reduce fouling (check local regulations[5]) ○ Outside of liner will foul ○ Lines that suspend it may stretch and sag[4]
Boat Lifts (Prices depend on dock, water depth, boat model and size) AirBerth, Galva-Lift, HydroHoist	✓ Eliminates need for antifouling paint and underwater hull cleaning (if boat is always returned to lift[5]) ✓ Wide range of models available to fit variety of boats and docks	○ Some models can be expensive for boaters who go out daily ○ May not be allowed or feasible in some marinas[5]
Mechanical Cleaning (Contact vendors for prices) Diving Service: Hand or Power Tools Scrubbing Stations: Boat Scrubber, Marina-Tec, (and others)	✓ Works together with bottom paint to remove fouling growth ✓ Allows growth to be removed in early stages before it becomes firmly established ✓ Cleaning frequency and type of cleaning tool for divers depend on water temperature, type of paint, frequency and speed of boat use ✓ Water and metals can be contained in tank recovery systems at scrubbing stations	○ Recommended to clean at regular intervals appropriate to water temperature and frequency of use of boat ○ Owner must schedule and pay for diving service to visit boat ○ Boat must be taken to scrubbing station

***1* Independent evaluation of long-term performance on recreational boats is needed for all products**
***2* Disclaimer:** These examples are provided for purposes of illustration and do not constitute an endorsement or recommendation. Prices listed were effective in June 2002. Ask your marine supply dealer or boat repair yard for current prices of each product of interest. (References for pricing are listed). Ask local boat repair yards and underwater hull cleaning services how each product has performed in your area. Ask manufacturers for product data and reports of independent testing.
***3* San Diego area experience**
***4* Author's observation**
***5* Reviewer's comments**

Special Notes:
Check with individual product labels for special considerations. Alternative hull coatings require a clean, smooth surface for best adherence. This varies with the type of nontoxic coating, the condition of the existing antifouling and undercoatings, and the condition of the hull.
*Epoxy and silicone based coatings generally require that dissimilar antifouling coatings be removed and an epoxy undercoat be applied (Wilson 2002; Roberts 2002).

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