Copper Loading Assessment from In-Water Hull Cleaning Following Natural Fouling

Shelter Island Yacht Basin
San Diego Bay, San Diego, California

Prepared for:

Port of San Diego
3165 Pacific Highway
San Diego, California 92101

Submitted by:

AMEC Earth & Environmental, Inc.
9210 Sky Park Court, Suite 200
San Diego, California 92123
858.300.4300

24 May 2006
Project No. 6151000502

Unified Port of San Diego

COPPER LOADING ASSESSMENT FROM IN-WATER HULL CLEANING FOLLOWING NATURAL FOULING

SHELTER ISLAND YACHT BASIN
SAN DIEGO BAY
SAN DIEGO, CALIFORNIA

Principle Investigators:
Paul Brown[1]
Rolf Schottle[2]

Prepared for:
[1]Port of San Diego
3165 Pacific Highway
San Diego, California 92101

Submitted by:
[2]AMEC Earth & Environmental, Inc.
9210 Sky Park Court, Suite 200
San Diego, California 92123
(858) 300-4300

24 May 2006

Project No. 6151000502 0001

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

EXECUTIVE SUMMARY

Shelter Island Yacht Basin (SIYB), San Diego, California is popular recreational marina located in northern San Diego Bay. In 1996, the San Diego Regional Water Quality Control Board (SDRWQCB) listed SIYB as a Clean Water Act (CWA) Section 303(d) impaired water body due to elevated levels of dissolved copper. A TMDL implementation plan requiring an overall reduction of residual copper loading by 76% in SIYB was developed and adopted by the SDRWQCB on February 9, 2005 to meet water quality objectives and to protect beneficial uses over a 17 year period. The State Water Resources Control Board subsequently approved the TMDL on September 22, 2005.

SIYB is home to approximately 2,200 recreational vessels painted with copper-containing antifoulant hull paints. Although the passive leaching of dissolved copper from pleasure craft has been previously studied (Schiff et al. 2004), the release of copper into the water column as a result of in-water hull cleaning has not. SDRWQCB (2005) estimated a mass load of 2,000 kg/year of dissolved copper attributed to passive leaching of bottom paints. To estimate the contribution of copper to SIYB as a result of in-water hull cleaning operations, the Port of San Diego (Port) teamed with AMEC Earth & Environmental, Inc., and the Navy to develop and implement a field and laboratory study.

The objective of the study was to quantify both the dissolved and particulate fractions of copper emitted from copper-based antifouling coatings in-situ as a result of routine and intermittent hull cleaning of recreational vessels. In-situ samples were collected using a specially designed enclosed chamber, which could be attached to the hull of actual pleasure craft berthed in SIYB to obtain discrete samples using various hull-cleaning methods. These cleaning methods ranged from minimally abrasive “best management practices” (BMPs) using a soft carpet, to more abrasive scouring pads and nylon brushes. Two popular paints, Proline 1088™, a hard modified epoxy, and Interlux Ultra Kote™, a hard vinyl-based paint, were selected for testing as these paints represent approximately 80% of hull coatings applied to recreational vessels within SIYB. Copper emissions were measured after 1 month of fouling condition representative of “routine” maintenance and after 3 months of fouling to represent an intermittent hull-cleaning schedule.

The results of the study were compared with previous related studies. Emission results from this study estimated a total loading from all recreational vessels within SIYB of 116.5 kg/year of dissolved copper from routine (1-month) hull-cleaning activities compared to 100 kg/year estimated from 1 month of fouling results published in the SDRWQCB TMDL Technical Report (SDRWQCB 2005). Similarly, hull cleaning generated an average emission rate of 10.0 $\mu g/cm^2$/event in this study compared to an estimated 8.5 $\mu g/cm^2$/event that was calculated in the SDRWQCB TMDL Technical Report. Of note, this emission rate is representative of the immediate copper release associated with removal of the fouling layer. A leaching spike of dissolved copper has been observed in other studies (McPherson and Peters 1995; Valkirs et al. 2003). This passive flux rate is highest immediately after cleaning and returns to baseline after approximately 3 days. This passive flux was not included in the estimates of dissolved copper emissions due solely to in-water hull-cleaning operations.

A significant data gap identified in previous related studies was the limited quantitative estimates of particulate copper generated as a result of hull cleaning. Particulate copper has been found to settle quickly out of the water column and subsequently incorporate into sediment via adsorption, therefore rendering it unavailable to organisms within the water column (Valkirs et al. 1994; Chadwick 2002). Due to the affinity of sediment to bind metals, the dissolved copper released from sediments is considered negligible. None the less, the buildup and persistence of copper in sediments can potentially become a source of dissolved copper and impact sediments. This study estimated that the average particulate copper emissions mass for all recreational vessels in SIYB is 2,080 kg/year from routine hull-cleaning operations which is equal to approximately 2 pounds per vessel on an annual basis.

Quantitative comparisons of cleaning methods were made to determine whether significant reductions in copper emissions could be obtained from instituting hull-cleaning BMPs relative to both routine 1-month and 3-month fouling conditions. Similar to other studies, using the least abrasive material typically generated the lowest total copper emissions. Notably, dissolved copper emissions did not significantly increase under the higher 3-month fouling condition relative to the 1-month fouling condition, but particulate copper emissions increased by approximately one-third.   Based on these results, consistent BMP implementation could reduce copper burdens into SIYB; however, the magnitude of the possible reduction of dissolved copper emissions is relatively small compared to the passive leaching of dissolved copper and particulate copper loading from hull-cleaning activities.

1.0 INTRODUCTION

Portions of San Diego Bay have been identified as areas of impaired water quality due to elevated contaminant levels in waters and sediments, and/or due to degraded benthic communities. Shelter Island Yacht Basin (SIYB), San Diego, California is popular recreational marina located in northern San Diego Bay. In 1996, the San Diego Regional Water Quality Control Board (SDRWQCB) listed SIYB as a Clean Water Act (CWA) Section 303(d) impaired water body due to levels of dissolved copper that exceeded National Ambient Water Quality Standards. A TMDL for dissolved copper in SIYB was developed and adopted by the SDRWQCB on February 9, 2005 to meet water quality objectives and to protect beneficial uses (Resolution No. R9-2005-0019 Basin Plan Amendment). The State Water Resources Control Board subsequently approved the TMDL on September 22, 2005.

.The SDRWQCB TMDL Implementation Plan dictates that an overall reduction of 76% in dissolved copper loading is needed to meet the TMDL of 567 kg of copper/year. The Implementation Plan specifies reductions of 81% due to passive leaching of copper bottom paints, and 28% as a result of in-water hull cleaning (SDRWQCB 2005). The primary objective of this study was to quantify the total loading of copper into SIYB from in-water hull-cleaning activities, including (1) fractionation between dissolved and particulate copper, (2) variations associated with cleaning method and antifouling coating type, and (3) evaluation of these parameters under “routine” fouling and “high” fouling conditions. A secondary objective of this study was to confirm the dissolved copper emission estimates obtained in previous panel test studies after 1 month of natural fouling progression.

This report provides the methods used for this in-water hull-cleaning assessment at SIYB in San Diego Bay (Figure 1), a description of the materials used, and a summary of the results. A primary goal of this study was to address identified data gaps regarding the present status of copper loading caused by antifouling hull coatings and their cleaning techniques. The results of this study provide a quantitative measure of the total and dissolved copper fractions relative to the above key parameters and also aid in evaluation of hull cleaning best management practices (BMPs) with regard to meeting the TMDL objectives for dissolved copper within the study area. The study was conducted in two phases.

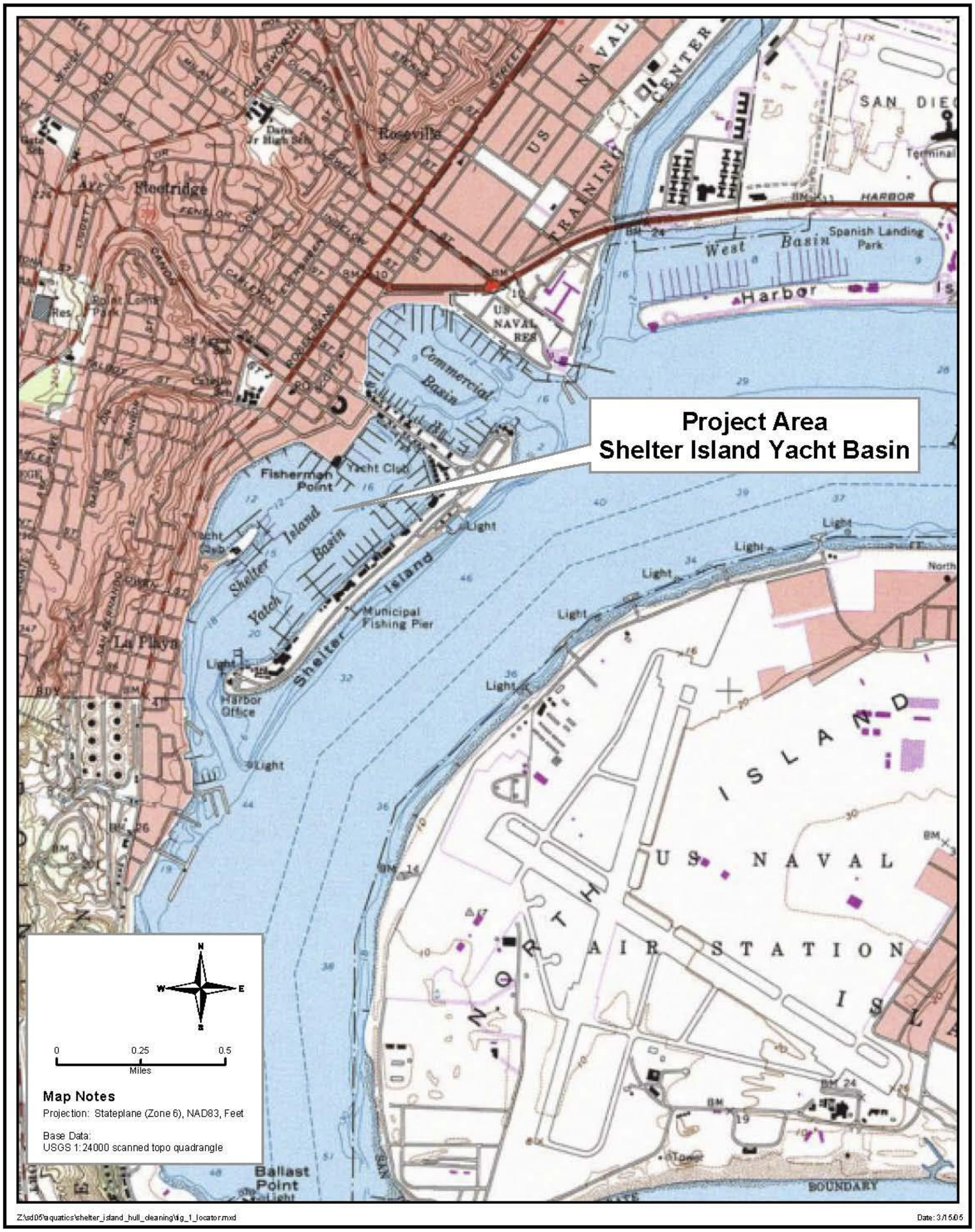
- Phase 1 of this study focused on the collection and testing of in-situ samples obtained at the 1-month fouling condition representative of boats that are subject to customary cleaning frequency as performed by most professional hull-cleaning services.

- Phase 2 addressed conditions of higher fouling after two additional months of fouling (a total of 3 months of natural fouling).

The study also incorporated various pleasure craft, both sail and power, with antifouling paints ranging in age from approximately 6 to 21 months in water from the date of application. These variables were selected to provide a representative spectrum of antifouling paints on the vessels berthed at SIYB. Lastly, to obtain baseline and a comparison dataset to a 2004 study by Schiff et al., a single ablative coating and a set of test panels were similarly tested. Ablative coatings are described in detail in Section 2.1.

The study was performed in accordance to the approved *Sampling and Analysis Plan, Copper Loading Assessment of In-water Hull Cleaning Shelter Island Yacht Basin, San Diego Bay, San Diego, California, dated April 21, 2005* (AMEC). Any deviations to this Sampling and Analysis Plan are discussed in the appropriate sections of this report.

Figure 1. Shelter Island Yacht Basin Study Area



amec

Project Site Location
Shelter Island Yacht Basin

FIGURE
1

1.1 Background

Vessel hulls are coated with antifouling paints to prevent attachment and growth of aquatic organisms, such as algae and barnacles. Copper and zinc are the primary active (toxic) components added to antifouling coatings to prevent attachment of fouling organisms. Other common biocide additives include diuron, pyrithione and Irgarol 1051. The toxic components of antifouling coatings leach into the water passively and have the potential to be mobilized during hull cleanings.

SIYB was created between 1936 and 1942 as a semi-enclosed yacht basin located in the north end of San Diego Bay (US Navy 2001). With an approximate depth of 3 to 4 meters, SIYB is an area of reduced tidal flushing. Approximately 2,200 recreational boats painted with copper-leaching antifouling coatings are moored in SIYB marinas, the greatest number of moored vessels in all of the marinas in San Diego Bay (Harbor Police 1999). In general, San Diego Bay's recreational vessel hull-painting frequency ranges from 1 to 3 years, with most boats repainted every 2 years on average (Johnson et al. 1998; MacPherson and Peters 1995).

1.2 Select Previous Studies

Copper-rich paints designed for antifouling purposes operate on the principle that copper ions will gradually dissolve into the surrounding water and create a microlayer in the vicinity of the vessel hull that is inhospitable to marine organisms. The copper passively released from the antifouling paints remains in dissolved form in the water column and eventually deposits into harbor sediments at a rate of 4 to 7% a day (Chadwick et al. 2002). Deposition is due to chelation of dissolved copper ions into stable organic molecules, which subsequently form particulates that are incorporated into the basin sediments. Inorganic copper complexes are also formed and quickly reach an equilibrium state. Tidal flushing also reduces the total copper loading into SIYB although the effects of flushing were not evaluated in this study.

Copper emissions from diver-conducted cleaning of recreational vessels have recently been evaluated (Schiff et al. 2004). The Schiff study assessed the contributions of dissolved copper to receiving water via antifouling coatings from both passive leaching and hull-cleaning activities, utilizing a Navy-developed in-situ measuring device (Seligman et al. 2001; Valkirs et al. 2003). Results indicated a significant increase in copper leaching (5 to15 $\mu g/cm^2/day$) after hull cleaning with a return to baseline conditions within 3 days. Schiff estimated that only 5% of the pleasure craft loading of dissolved copper to bay waters came from in-water hull-cleaning activities. A primary question addressed by the Schiff study was directed to quantifying passive leaching; therefore, the study did not evaluate particulate copper loading.

The SDRWQCB also conducted a study that measured the plume of dissolved copper that resulted from in-water hull cleaning (McPherson and Peters 1995) using BMPs, in this case a soft cloth. Dissolved copper concentrations in this study increased from an average baseline concentration of 12 µg/L to an average concentration of 56 µg/L and returned to pre-cleaning levels after 10 minutes. The study was limited, however, to one boat. This one boat was considered representative of a typical boat within SIYB and the type of paint, age of paint, and time since the last hull cleaning were not documented.

2.0 STUDY DESIGN AND METHODS

The sampling approach for this study was designed to quantify the release of dissolved and particulate copper fractions in relation to (1) cleaning method, (2) antifouling coating type, and (3) fouling condition. An in-situ sampling device was used to sample naturally fouled hulls to capture both the dissolved and particulate metal released during the cleaning event. Field logs documenting sampling activities are presented in Appendix A. The documentation of the anti fouling paint applied to each hull and cleaning history of each vessel is presented in Appendix B.

2.1 Sampling Design

The primary objective of the sampling design for this study was to accurately estimate the ongoing copper loading that results from common in-water hull-cleaning practices employed within SIYB. This study does not include further assessment of passive leaching of copper. This study is designed to address dissolved and particulate copper dispersion during the course of cleaning, and to address certain limitations of previous panel test methods (Schiff et al. 2004).

During the preparation and review of the sampling and analysis plan developed for this study, consideration was given to complementing other related studies. Specifically, consideration was given to the overall study objectives, to fill identified data gaps and ensure adequate quality assurance and quality control to provide meaningful and defensible results for a defined number of variables. The primary variables assessed in this test design were type of paint (modified epoxy, vinyl-based, and ablative), cleaning material (soft carpet, medium scour pad, and moderately aggressive nylon brush), dispersion (dissolved and particulate copper) and cleaning frequency (1- and 3-month fouling condition). The project design elements and parameters for this study are detailed below.

To accurately simulate real world conditions, all sampling was performed on the hulls of actual pleasure craft moored within SIYB, where the paint type and maintenance records of the vessels were well documented. Test boats selected for the study were painted a minimum of 60 days prior to testing to ensure an adequate conditioning period for new paint and were cleaned by a commercial in-water hull-cleaning operator 1 month prior to the first sample collection. The hull condition at the time of cleaning was documented by the professional hull cleaner and is presented in Appendix C. The overall sampling design incorporated six individual pleasure craft to provide a representative subset of test hulls (i.e., three boats with modified epoxy, two with hard vinyl, and one with an ablative coating) on a variety of vessel types (sail and power). Other commercially available paints not included in this study include those that are non-toxic, biocide-containing paints, or those with special binders such as silicone or ceramic.

Two widely used paint types (Proline 1088™, a modified epoxy, and Interlux Ultra Kote™, a vinyl-based coating) were selected for this study and represent approximately 80% of the paint types currently in use in SIYB (Driscoll and Nielsen. 2005 Johnson and Miller 2002). Bottom paints can vary considerably in copper concentration, ranging from approximately 20 to 76% by weight of cuprous oxide. This study was limited to one brand each of the modified epoxy and hard vinyl coatings. Both brands selected were of relatively high copper content (>67% cuprous oxide). Since the application of hard vinyl paints is waning relative to epoxy-based paints, only two vessels with hard vinyl coatings and three vessels with modified epoxy were tested. One ablative coating (Jotan 60A2002 Hydroclean Blue™) was also tested since this paint type represents a majority of the "other" alternative hull coatings routinely used and was considered a data gap from previous studies.

Ablative paints are "sloughing" in nature and designed to be "self-cleaning." As such, the BMP for ablative coatings is to not clean the hull but to repaint as required. Although counter to the prescribed BMP of not cleaning an ablative coating, these coatings may be subject to minor soft cleaning by divers, particularly if the coating is poorly maintained. The ablative coating was tested using light cleaning only (i.e. soft carpet), in triplicate after approximately 4 months of fouling. As discussed, results from a cleaning test for vessels with ablative paints require special consideration since the cleaning of this coating type represents a non-BMP.

A set of test panels painted with the same coating (Pettit Trinidad™ modified epoxy) used in the Schiff et al. (2004) study was included to provide comparative data of the in-situ sampler used in this study. These test panels were sampled in triplicate after 1 month of fouling only.

Samples were collected in triplicate to assess the reproducibility of results on a given test hull for each of the cleaning methods. The variability of results obtained from the replicate testing of individual boats provides a measure of the variability of the sampling device (due to design and use) and some measure of the inherent variability of surface fouling and coating on a given boat. In addition to the overall variability, the average mean of the replicates provides a better estimate of the actual copper loading from each cleaning method.

In addition to evaluating three of the most commonly applied paint types, three cleaning methods (gentle, moderate, and moderately aggressive) at two fouling levels (1 month and 3 months of fouling time) were assessed. The BMPs for this study have been simplified to mimic (1) a minimal disruption of the paint using carpet as a cleaning material, (2) a moderately aggressive and common cleaning practice using a "green" scour pad (medium duty, Scotch-Brite™ General Purpose Scouring Pad, No. 105), and (3) a more abrasive and aggressive cleaning material, consisting of a nylon bristle brush to simulate a rotary cleaning device used by commercial hull-cleaning services.

The sampling matrix for this study and the total number of samples collected are shown in Table 1.

Table 1.
Sampling Matrix for 1- and 3-Month Fouling Condition

Hull Coating	Cleaning Method	1- and 3-Month Samples[1]
PHASE 1 (1-Month Fouling Condition)		
Hard Vinyl (two vessels: V-1, V-2)	Carpet	Two vessels, 3 replicates each, n=6
	3M Scouring Pad (green)	Two vessels, 3 replicates each, n=6
	Nylon Rotary Brush	Two vessels, 3 replicates each, n=6
Modified Epoxy (three vessels, E-1, E-2, E-3)	Carpet	Three vessels, 3 replicates each, n=9
	3M Scouring Pad (green)	Three vessels, 3 replicates each, n=9
	Nylon Rotary Brush	Three vessels, 3 replicates each, n=9
Sampling Device (Equipment) Blanks	Not applicable	n=3, one each per cleaning method
Background Bay Water [2]	Not applicable	n=3
Total Samples Collected for Phase 1		**45 primary + 3 background + 3 equipment blanks**
Total Number of Analyses (dissolved and particulate fractions)		**96**
PHASE 2 (3-Month Fouling Condition)		
Hard Vinyl (two vessels: V-1, V-2)	Carpet	Two vessels, 3 replicates each, n=6
	3M Scouring Pad (green)	Two vessels, 3 replicates each, n=6
	Nylon Rotary Brush	Two vessels, 3 replicates each, n=6
Modified Epoxy (three vessels, E-1, E-2, E-3)	Carpet	Three vessels, 3 replicates each, n=9
	3M Scouring Pad (green)	Three vessels, 3 replicates each, n=9
	Nylon Rotary Brush	Three vessels, 3 replicates each, n=9
Sampling Device (Equipment) Blanks	Not applicable	n=3, one each per cleaning method
Background Bay Water [2]	Not applicable	n=5
Ablative (4-month fouling only)	Carpet	One vessel, 3 replicate each, n=3
Panel- Modified Epoxy (1-month fouling only)	Carpet	Three panels, 1 replicate each, n=3
Total Samples Collected for Phase 2		**51 primary + 5 background + 3 equipment blanks**
Total Number of Analyses (dissolved and particulate fractions)		**110**

[1] *Primary samples, dissolved and particulate fractions were separated at the laboratory. Does not include laboratory internal QC samples.*

[2] *Background water samples analyzed for total copper only. Areas sampled subject to location of vessels.*

2.2 In-situ Sampling Device

The specialized in-situ sampling device used for this study was designed and built by Marine Environmental Survey Capability (MESC, SPAWAR Systems Center San Diego) Navy engineers. The basic design of the in situ sampling device was based on modifications to a similar sampling dome designed by the US Navy that was used to measure the passive leaching of antifoulant coatings (Valkirs et al, 2003). The sampling device was designed to provide standardized in-situ sampling of naturally fouled hulls in a manner that captures both the dissolved and particulate metals released during the cleaning event. A photograph of the sampling device and cleaning heads is shown in Figure 2. The body of the device consists of a clear polycarbonate cylinder, with an inside diameter of approximately 11 cm and a sample volume of approximately 1500 ml. At one end of the cylinder, a flange and gasket system is integrated to provide a seal against the hull of the boat. The other end of the cylinder is sealed with a polycarbonate cap. A shaft passes through an O-ring seal in the cap and attaches to a disk inside the cylinder. The cleaning device (carpet, scour pad, or nylon brush) is secured to the disc by a removable fastener so that it can be removed between sample replicates. A handle on the shaft on the exterior side of the cylinder allows the cleaning device to be rotated for a predetermined number of revolutions at a controlled speed (10 to 15 RPM). A spring mounted on the shaft inside the cylinder ensures that the cleaning device is depressed with a constant pressure. The spring can be modified to accompany the three different cleaning methods as described in Subsection 2.2.2. Once the appropriate number of rotations have been completed (and sample has accumulated inside the cylinder), a flat plate is slid between the hull and flange/gasket system to trap the sample. This capture gate is carefully slid in place so that flat plate does not come in contact with the hull surface and does not scrape or remove paint. This also breaks the seal from the hull and allows the diver collecting the sample to transport the resealed sample to the sea surface for processing. The clearance between the disc and the cylinder wall is small (<3 mm) to minimize exchange of sample with surrounding waters during removal. A photograph of the sampling device in use is shown in Figure 3.

2.2.1 In-situ Sampling Method

A total of 110 whole seawater samples including field replicates, equipment blanks, and background samples were collected for Phase 1 and Phase 2 using the in-situ sampling device. Observations of weather, fouling condition, cleaning methods, effort, and number of rotations were recorded in field logs during the course of sampling (Appendix A). A total of eight background whole bay water samples were collected adjacent to several of the test vessels to determine area-specific background concentrations. These unfiltered ambient samples were analyzed for total copper. In addition, three in-situ equipment blanks of the sampling device were collected for each phase, one for each cleaning method. These equipment blanks, one per cleaning method, were analyzed for total copper. Results from the equipment blanks and phase specific background samples were used to correct the hull-cleaning sample results. Therefore, the total copper results for the whole bay water samples do not directly account for possible differences measured relative to partitioning but represent the highest ambient background concentrations of copper present adjacent to the test hulls. This assumption may introduce a slight high bias background relative to each fraction. Results for the equipment blanks did not indicate any significant copper contribution from the sampling device.

Photograph of In Situ Sampling Device and Cleaning Heads

FIGURE

2

FIGURE 3

Photograph of In Situ Sampling Device in Use

Graphics/AquaticSciences/SanDiegoBayTMDL/PhotoSet3.fh8

Prior to and between discrete sample collections, the device was rinsed with 3 full volumes of fresh water from the dockside municipal water supply. Ambient bay water was then used to prime the sampling cylinder device before each cleaning episode to avoid any cross contamination during replicate sampling events. In addition, each cleaning method was tested using a test pad on the hull prior to collecting the sample to validate the number and rate of rotations required to complete successful cleaning. This was done to avoid insufficient or excessive cleaning that would ultimately affect the copper concentration in the sample. A SCUBA diver operated the primed in-situ sampling device. The diver depressed the device against the hull to form a seal. The diver then rotated the handle for a set number of rotations to achieve the desired cleaning actions. While sampling, caution was taken to avoid re-suspension of the bay sediment. Once completed, the diver sealed the cylinder with the capture gate and returned to the surface where the device was handed off to an assistant. The sample was poured directly into a pre-labeled, non-acidified plastic 4-L sample bottle and stored at 4 degrees centigrade (wet ice) until delivery to the designated laboratory under standard chain of custody protocol. Samples were filtered in the laboratory as soon as possible (<12 hours after collection). Sample preparation and testing are detailed in Section 2.3.

2.2.2 Cleaning Methods

The BMP for all hull-cleaning methods dictates that the least abrasive material as practical be used. In this study, the diver removed the fouling organisms by applying the minimum amount of pressure and minimal number of rotations required for removal for both BMP and non-BMP methods. The BMP method of a low abrasion shag carpet is designed to be the least abrasive of the cleaning methods. This method is appropriate for a frequent (i.e. monthly) cleaning schedule, dependent on the season and other fouling factors. One full rotation of the sampling device was deemed effective to remove the accumulated fouling layer using carpet.

The moderately aggressive green scouring pad was included in the study design to measure release by a more coarse material that is used for a greater spectrum of fouling. Due to the efficiency, durability, and versatility of scouring pads to remove various amounts of fouling, scouring pads are frequently preferred by professional divers who perform hull cleaning. It was determined that minimal force over one-half of a rotation was sufficient to remove marine growth using the scouring pad.

The nylon brush testing was designed to simulate the moderately aggressive mechanical (pneumatic or hydraulic) rotary brushing method. Of note, commercial hull cleaners can switch the cleaning head of most types of power rotary brushes. These cleaning heads vary in bristle thickness with diameters of 0.028 and 0.032 inch being the most commonly used. The bristle thickness for the nylon brush used for testing in this study was 0.032 inch. Minimal force was employed with the brush; one full turn was deemed effective to remove the accumulated fouling layer.

The three cleaning methods mentioned above were tested at 1 and 3 months of fouling. Very coarse, abrasive brushes with metal bristles and scraping tools may be employed for heavy marine growth found on poorly maintained hulls and were not included in this study.

2.2.3 Antifouling Coating Type

The three copper-based antifouling coatings examined in this study included a hard vinyl, a modified epoxy, and an ablative. As noted, the paint brands selected for this study are the most commonly applied. The modified epoxy and hard vinyl paints are known to be on boats in SIYB and are a similar matrix of coatings as examined by Schiff et al. (2004) although the hard vinyl paint used in the Schiff study contained 37.25% cuprous oxide by weight vs. the 67.6% hard vinyl paint (Proline 1088™) used in this study. The cuprous oxide concentrations of the modified epoxy paints were 66.5% (Interlux Ultra Kote™) used in this study compared to 57.7% in the Pettit Trinidad paint selected by Schiff et al. (2004). The Schiff et al. (2004) study also tested a biocide free paint in contrast to the ablative paint tested in this study. Copper concentrations and associated paint ingredients can vary between type (i.e. hard vinyl, modified epoxy, ablative) and manufacturer and within product line.

Vessel documentation of the coating types and date of application involved in this study are summarized in Appendix B. The names of the vessels used for this study have been removed from field logs and the vessel documentation summary and given a generic alphanumeric designation for purposes of this report (“E” for epoxy coatings, “V” for vinyl, and uniquely numbered).

2.2.4 Fouling Condition

Typical biofouling progression is complex and subject to many factors. Water temperature, sunlight, nutrient availability, and ambient concentrations of fouling organisms are all factors in addition to the condition and type of paint used. After a routine cleaning, the surface of a clean hull equilibrates chemically after about 1 hour. Once the initial equilibrium is reached, the paint surface is subject to bacterial and unicellular colonization, composed mostly of diatoms, and a “slime layer” appears. The slime layer typically develops after 2 to 3 days depending on hull coating and ambient water conditions. This biofouling layer slows the release of copper and allows for the subsequent growth of multi-cellular organisms, such as algae and sea animals (tube worms and tunicates). For purposes of this study, the biofouling layer and any copper retained in this layer are considered byproducts of the hull-cleaning process and are released into the surrounding environment during the course of cleaning.

As noted, Phase 1 of this study assessed a 1-month fouling condition. Phase 2 tested for a high fouling condition (i.e. collected after approximately 3 months of fouling) and was performed to assess the practice of less frequent cleaning. The results from both phases provide the basis for comparison of copper loading relative to fouling conditions and the frequency effects of hull-cleaning activities relative to BMPs.

2.2.5 Study Design Limitations and Considerations

Fouling conditions are seasonal and subject to both temporal and spatial variability. Growth rates at the water line and south-facing hull surfaces will be higher due to available light. Test areas on the boat hulls were visually selected by divers and based on approximating the average degree (most representative) of fouling observed over the entire hull. Details of the degree of fouling are documented in the field notes (Appendix A).

Seasonality also plays an important role in growth rates as sunlight and warm water temperatures significantly increase fouling. A typical BMP during summer in southern California may include cleaning the hull every 2 to 3 weeks; whereas, the same hull may only require cleaning every 6 to 8 weeks in winter or conversely more or less effort to adequately clean the hull. The Phase 1 (1 month) sampling was conducted in early June and appeared to mimic normal fouling rates based on typical seasonal variability.

The sampling methods used in this study are subject to certain limitations. For example, testing of a commercial rotary brush cleaning method is troublesome to reproduce in the hand-operated sampling device. A commercial rotary brush has a larger surface area, the speed may be variable, and the vortex of the spinning brush forms a negative pressure (suction) onto the hull, in addition to the brush thickness selected. These conditions cannot easily be re-created in an enclosed in-situ sampling device. However, for purposes of measuring a moderately aggressive ("medium" abrasiveness) cleaning regime and addressing a commonly used cleaning method and material, a specially fabricated nylon brush was used as a surrogate measurement for a motorized rotary brush.

Other documented factors that may influence the measured results and the respective mitigating controls for these factors included:

Factor	Mitigation
Age and condition of boat paint	Selected test recreation vessels were painted at least 60 days prior to testing subject to routine cleanings.
Location of boat in bay	Background concentrations of dissolved copper were measured.
Re-suspension of particulate copper in sediment	Divers used caution to ensure sediment was not disturbed during sample collection.
Copper concentration in various paints	Formulas for antifouling paint generally vary from approximately 20-76% copper by weight. Brands with higher initial copper concentrations may yield higher dissolved and or particulate concentrations from similar hull-cleaning force action. The most commonly applied high copper paint brands were selected for this study.
Time of sample collection	Samples were collected during slack tides to the extent practical and at least 3 days after rain or storm conditions.

Due to the above noted limitations, caution should be applied to extrapolation of analytical results as absolute values of a specific cleaning material and cleaning method for a given degree of hull fouling. In spite of these known limitations and considerations, the sampling and analysis activities conducted for this study are designed to provide a representative assessment of the fate and transport of copper resulting from industry standard cleaning practices currently used in SIYB.

2.3 Analytical Methods

The samples collected using the in-situ device were assumed to contain both dissolved and particulate copper. Concentrations of dissolved and particulate copper were measured in the filtered solution and the <0.45-micron filtrate of each primary sample. Sample filtration was performed in a class-100 all polypropylene working area, following trace metal clean techniques recommended by the U.S. Environmental Protection Agency (US EPA 1995) and National Oceanographic and Atmospheric Administration (NOAA 1998). Following sample collection, the laboratory filtered a representative sub sample (i.e. 100 to 200 ml of ~1.5 L of homogenized parent sample) through a pre-weighed 0.45 µm pore-size filter. The filtered solution was acidified to pH 2 with reagent grade nitric acid and analyzed for total dissolved copper by direct injection by stabilized temperature platform graphite furnace atomic absorption (STPGFAA).

After collection of the sample for total dissolved copper, the filter was allowed to dry in a class-100 bench. The dry weight was then measured for evaluation of particle mass. The filter pads were digested using both trace metal grade nitric and hydrochloric acids. The concentrations of copper in the filter pads were measured using EPA Method 6010 ICP due to the relatively high copper content and these analyses were performed by Calscience Environmental Laboratories, Inc. The low concentration filtered solution samples were analyzed by SPAWAR scientists using a low level STPGFAA method.

2.3.1 Analytical Quality Assurance and Quality Control (QA/QC)

Laboratory QC samples include filter, filtrate and analytic duplicates, method and filter blanks, laboratory control samples, and standard reference material (SRM). Method of standard additions was used to compensate for any potential interference for STPGFAA analyses. A summary of laboratory QC results for both Phases I and 2 are presented below.

Laboratory Duplicates

Filter replicates for particulate copper showed good overall agreement demonstrating sufficient homogenization prior to filtration. Relative Percent Difference (RPD) and standard deviation in the case of triplicates did not exceed 10%, less three pairs of low level filter duplicates that had reported RPDs of up to 50%.

Of the primary dissolved fraction samples that were analyzed, 19 were analyzed in duplicate. The RPD for these laboratory duplicates did not exceed 6% for all sample pairs.

Analytical Method QC

All post-digestion spikes, post-digestion spike duplicates, and laboratory control sample results were with control limits for all EPA Method 6010 analyses for particulate fraction samples and STPGFAA analysis for the dissolved fractions.

Blanks

Method blanks were included in each sample batch and were found to be less than the detection limit of 1.0 µg/L for dissolved copper and 5.0 µg/L mass per volume for particulate copper.

Filter blanks were analyzed for copper using ambient seawater obtained from the harbor mouth of San Diego Bay. The seawater was pre-filtered with a 0.45-micron filter prior to use as a blank source. All filter blank results were not detectable on a mass basis (<0.0001 g/filter pad).

<u>Standard Reference Material (SRM)</u>

National Institute of Standards and Technology SRM 1643d recoveries averaged 19.0 ± 1.0 µg/L. SRM recoveries were within acceptability criteria for the true mass concentration of 20.5 ± 3.8 µg/L.

2.3.2 Field Quality Assurance and Quality Control (QA/QC)

Field QC samples consisted of background (ambient) seawater samples, equipment blanks, and three field replicates each for all pleasure craft sampled. A summary of the results of each of these QC sample types is presented below.

<u>Background (Ambient) Seawater</u>

Ambient seawater samples varied in concentration from 13 to 40 µg/L. These values appeared to be slightly elevated relative to previously reported average concentrations (SDRWQCB 2001). Results for dissolved copper were corrected for both background and equipment blank contributions on a Phase basis. The corrected ambient values may introduce a slight low bias although the samples concentrations were generally significantly higher (greater than tenfold) than the reported background concentrations. Sources for the elevated ambient levels could not be determined. However, the proximity of background sampling locations (adjacent to the dock of the test vessels) and relative low water cycling (“C” dock of the Shelter Island Yacht Club) SIYB are likely within normal ambient range for the toe of the SIYB.

<u>Equipment Blanks</u>

Equipment blanks averaged 20 µg/L and varied in concentration from 10 to 28 µg/L for each cleaning method tested. Equipment blanks included copper contributed from ambient seawater. Since these values are in good agreement with ambient background concentrations (~21 ppb on average), no appreciable copper was attributable to the cleaning materials used in the study.

<u>Field Replicates</u>

Three field replicates were analyzed for both dissolved and particulate fractions, for each cleaning method for each hull sampled. The coefficient of variation (CV) for each set of triplicates for the two paint types for each of the cleaning methods ranged from 3.4 to 54.9% (average CV of 20.7%) for the dissolved fraction and ranged from 2.8 to 138% (average CV of 36.3%) for the particulate fraction, reported on a µg/cm^2 basis. No significant precision bias was noted for any of the cleaning methods. With minor exception, the relatively low and consistent CV indicates acceptable method reproducibility for sample collection and good agreement of results collected from a single hull. Based on these precision results, less field replicates may be acceptable for future sampling events.

3.0 RESULTS AND DISCUSSION

This section summarizes the results obtained from the sampling conducted at the 1 month of "routine" biofouling condition and 3 months of "high" biofouling condition. Overall, the concentrations of dissolved copper measured in this study are in general agreement with a related hull-cleaning study (Schiff et al. 2004). The resultant data were evaluated for possible trends, including comparisons to previous studies, age of paint, coating type, boat use, and relative concentrations of dissolved and particulate copper. A comparison of the routine and high fouling results are summarized in tabular format in Tables 3 and 4. A separate detailed discussion of the particulate results is presented in Section 3.7.

3.1 Mass Emission Comparison to Previous Studies

For ease of comparison, concentration units are presented in the same units to similar studies (Schiff et al. 2004; Valkirs et al. 2003; SDRWQCB 2005) using the same assumptions where possible. Mass calculations were based on a stylized vessel size of 12.2-meter length and 3.4-meter beam. Surface areas below the water line vary according to hull design. For purposes of this study, surface area was estimated to be 35.3 m^2 using the formula wetted surface area equal to boat length*beam*0.85. Although application of hard vinyl paint is waning relative to modified epoxy, the proportion of vessels currently painted with each of these paint types berthed in SIYB is approximately equal (personal communication, Driscoll and Nielson 2005). Therefore, each paint type was assumed to contribute 50% of the emissions. The estimated maximum number of boats in SIYB is 2,363, and there are an estimated 14 cleaning events per year (SDRWQCB 2005). Similar to the loading average emission rates calculated for the TMDL, a 50% BMP carpet cleaning method and a 50% non-BMP scouring pad assumption were used to calculate a average rate. The nylon brush results from this study were not used in the emission estimates.

As in previous studies (Schiff et al. 2004), dissolved concentrations using BMPs (carpet) generated lower flux ($\mu g/cm^2$/event) than the 3M scouring pad, non-BMP. One exception was the non-BMP nylon brush, which generated less dissolved copper than the carpet BMP cleaning method. The lower dissolved copper observed may be attributable to the lesser surface area of the brush relative to that of the carpet or scouring pad and the minimal force action that was applied for all cleaning methods. The nylon brush did remove slightly more particulate copper than the corresponding carpet material suggesting higher penetration into the biofilm-paint surface layer(s). Table 2 summarizes the estimated average copper emissions rate for each paint type and cleaning method under "normal" and "high" fouling conditions.

Table 2.
Estimated Mean and Confidence Interval (CI) for Dissolved and Particulate Copper Mass Emissions Rates (µg/cm²) at 1 Month and 3 Months of Fouling in Shelter Island Yacht Basin

	Dissolved Copper +/- CI 1-Month Fouling (µg/cm²/event)	Dissolved Copper +/- CI 3-Month Fouling (µg/cm²/event)	Particulate Copper+/- CI 1-Month Fouling (µg/cm²/event)	Particulate Copper +/- CI 3-Month Fouling (µg/cm²/event)
Modified Epoxy				
Carpet (BMP)	3.8 ± 0.8	3.9 ± 1.1	8.9 ± 2.4	13.4 ± 2.7
Scouring Pad (non-BMP)	8.1± 1.4	10.5 ± 2.4	47.2 ±18.6	62.1 ± 21.1
Nylon Brush (non-BMP)	2.3 ± 0.8	4.3 ±0.3	11.6 ±1.8	44.4 ± 11.2
Hard Vinyl				
Carpet (BMP)	11.4 ± 3.8	10.1 ± 2.4	190 ± 38.5	241 ± 98.4
Scouring Pad (non-BMP)	16.7 ± 4.6	14.4 ± 1.6	468 ± 190	645 ±126
Nylon Brush (non-BMP)	8.9 ± 3.2	8.7 ± 4.7	234 ± 116	425 ± 493
Estimated Average Copper Emissions Rate (for modified epoxy and hard vinyl)[1]	10.0 ± 2.6	9.7 ± 1.9	179 ± 62.4	240 ± 161

BMP - Best Management Practice
CI – 95% Confidence Interval, as determined from 3 replicates each for n=3 epoxy-coated boats, n=2 vinyl-coated boats

[1] Estimated Average Copper Emissions based on averages of Carpet (BMP) and Scouring Pad (non-BMP) values. This is consistent with assumptions used in the SDRWQCB TMDL technical report (2005).

A test panel as used in the Schiff et al. study (2004) was included in this study to provide a general comparison of flux rates measured from the panel as compared to that of the test hull. The test panels yielded approximately 80 percent of the dissolved copper under the same cleaning conditions (e.g. carpet- BMP) and paint type indicating good general agreement relative to the results obtained from the test vessels. The test panel results were also within the ranges of dissolved copper mass emissions as estimated by Schiff, et al. (2004) although direct comparison is cautioned due to the study limitations as described in Subsection 2.2.5.

An ablative coating was included for baseline testing purposes using the in situ sampling device in spite of limitation of the non-BMP cleaning of an ablative coating. Emission results from the ablative coating yielded an estimated 2.7 µg/cm² of dissolved copper for a single event after approximately 4 months of natural fouling using a carpet and minimal cleaning action. Despite the relatively low estimated dissolved copper emissions from the ablative coating tested, these results are limited and warrant more rigorous study before embracing ablative coatings as a preferred strategy to reduce copper emissions.

As discussed, BMPs dictate that the least abrasive cleaning material be used to remove the natural fouling layer and to retain as much of the surface integrity of the antifouling paint as practical. Using this convention, carpet or similar soft cloth is anticipated to be the BMP of choice for typical 1-month fouling conditions at SIYB. This study indicates that this convention typically holds true, but is relatively insignificant in comparison to the dissolved copper burden that results from passive leaching (Schiff et al. 2004). In summary, BMPs should be used as part of the overall strategy to lower copper emissions under the current conditions, although BMPs alone would have a nominal effect on lowering the TMDL.

The average emission rate determined in the TMDL technical report was extrapolated from the results of the Schiff et al. (2004) study and yielded an estimated 8.5 µg/cm^2/event. This study estimated an average emission rate of 10.0 µg/cm^2/event using similar assumptions. This would increase the estimated TMDL annual load for hull cleaning proportionately from an estimated 100 kg/year burden to approximately 116.5 kg/year on a mass loading basis.

3.2 Age of Paint

The age of paints tested varied from 6 to 21 months in water after date of application. The average age of paint was 15 months for the modified epoxy and 12 months for the hard vinyl. Since paints of varying age were selected for study the resultant emissions should provide a range of values that are representative of the recreation vessels found at SIYB. No significant emissions trend based on the age of paint was observed.

3.3 Modified Epoxy Coating vs. Hard Vinyl Coating

Relative concentrations of dissolved copper observed were within expected ranges. The average dissolved copper emission rate for the hard vinyl coating was two to three fold higher than the modified epoxy paint results for each of the cleaning methods. This is consistent with the greater hardness of most epoxy-based paints (personal communication, Driscoll and Neilson, 2005). In addition, vinyl-based paints are prone to soften underlying coatings, which may further compromise the hardness of the surface coating. Other studies indicated lower dissolved copper concentrations for vinyl paints relative to epoxy (Schiff et al. 2004), although other factors, such as significantly lower cuprous oxide in the brand of hard vinyl paint and the apparent softer modified epoxy paint brand tested, likely contributed to the lower emissions observed. Based on the results of this study, the modified epoxy paint demonstrated lower copper emissions compared to the hard vinyl coating tested. However, due to other studies that indicate a large range of emissions based on paint type and the influence of other variables, selection of antifouling coating solely on the basis of the matrix as a means of reduced copper emissions is cautioned.

3.4 Boat Type and Usage

From a qualitative standpoint, significantly less fouling was observed on the powerboat hulls when compared to the sailboat hulls selected for the study. Discussion with the boat owners indicated relatively frequent active use of the powerboats and, combined with the given higher hull speeds compared to sail boats, less hull fouling resulted. Overall concentrations of dissolved copper for all three cleaning methods were a factor of approximately 2.5 times lower for the two powerboat samples compared to the three sailboats. The more direct comparison of test boat E-1 (a sailboat with modified epoxy paint) to E-2 and E-3 (powerboats with the same modified epoxy paint) showed approximately 50% greater dissolved copper emissions and 300% greater particulate emissions for the sailboat than for the powerboats. Although limited by sample size, the lesser fouling condition appears to correlate to lower copper emissions during the in-situ cleaning. While underway, the biofilm of the boat hull is subject to "incidental cleaning" from higher water flow, cleaning action via kelp abrasion, etc. The bulk of these copper emissions from pleasure craft would presumably occur outside the confines of SIYB. Sailboats are typically subject to less aggressive incidental cleaning and therefore may be subject to higher fouling within the confines of SIYB. This study indicates that boat usage could have a significant effect on total load contribution, particularly in semi-confined basins, and therefore may warrant further study. A more definitive study would be required to quantify emissions relative to boat usage.

3.5 Dissolved vs. Particulate Concentrations

Copper concentrations for the dissolved fraction compared to the particulate fraction were generally proportionate for each cleaning method. Average particulate emissions measured for modified epoxy paint were approximately 4 times higher for total particulate copper than for total dissolved copper and a factor of 22 times higher for the hard vinyl coating using the same emissions assumptions for mass loading. Based on these results, paint hardness appears to play a significant role in the amount of both dissolved and particulate copper released during routine hull-cleaning practices. Since the brands and types of paints used in this study were restricted to two, a more comprehensive study to specifically address paint matrix would be required. A summary of dissolved and particulate fractions reported on a grams-per-cleaning event basis is provided in Table 3. Potential particulate copper impacts to the water column and sediments are further detailed in the subsequent section addressing particulates.

3.6 Dissolved Emissions at 1 Month and 3 Months of Natural Fouling

Another objective of this study was to quantify what effect less hull-cleaning maintenance had on dissolved copper burdens since not all vessels are professionally cleaned on monthly basis. This study indicated that no significant increase in dissolved copper emissions was observed under the higher fouling scenario and nearly equal emissions of average dissolved copper were measured after the 2 additional months of natural fouling. There was good general agreement by cleaning method and paint type for the two fouling conditions, indicating no significant sampling bias. The similar temporal mass emissions of dissolved copper measured may be a result of insignificant additional fouling during the time span of the study, and/or a combination of other variables not included in the study design.

Phase 2 (3 months) samples were collected in August 2005 during which heavy seasonal fouling conditions were anticipated. However, only low to moderate fouling was noted after 3 months. The increase in water temperature appeared to have encouraged some new types of growth (red algae) and inhibited some early growth (green algae) that may have stymied heavy fouling. Since significantly higher particulate loading was observed, it appears that thicker biofouling layer developed after 3 months of natural fouling. Based on these results, it would appear that less frequent cleaning could theoretically lower the total mass dissolved copper released during hull cleaning. However, due to the inherent temporal and test parameter limitations of this study, the increased particulate loading observed, and other factors such as reduced boat performance, less frequent hull cleaning is not a recommended BMP without additional study.

3.7 Particulate Emissions

A primary goal of this study was to collect quantitative data on the particulate copper (particles that exceed 0.45 microns in size) released into the water column as a result of hull cleaning that will ultimately settle into the sediments of SIYB. Previous studies have found elevated levels of copper in sediments in SIYB (Valkirs et al.1994; SWRCB et al. 1996)

Metals, including copper, tend to accumulate in sediment through adsorption onto sediment particles or partitioning into pore water. The amount of copper incorporated into the sediment compared to the amount of dissolved copper leached from the sediment can be expressed as net flux rate. The US Navy has measured this net flux rate throughout San Diego Bay (Chadwick et al. 2002) and other studies (Valkirs et al. 1994) have determined an overall negative flux rate for copper indicating sediment is acting as a “sink.” Based on these studies, the SDRWQCB’s TMDL technical report has assumed that copper loadings from sediments in SIYB to the water column are zero under current loading conditions.

Although not considered a primary source of dissolved copper to the water column, the particulate copper bound in the sediment could generate a positive flux rate if future copper inputs were curtailed and is of concern due to the potential adverse effects to marine life. Coincidentally, total particulate burdens generated during hull-cleaning operations were found to be comparable on a mass basis (~2,100 kg/year) to the mass of copper estimated to be released via passive leaching (SDRWQCB 2005). Furthermore, particulate loading was approximately one-third higher (~2,800kg/yr) under the higher 3-month fouling condition. Particulate loading estimates for each of the cleaning methods measured are presented in Table 3.

These relatively high particulate copper emissions appear in agreement with a related study as evidenced by high (1.3-3.5 µg/mg dry weight) values measured in copper containing biofilms (French et al. 1984).

Table 3.
Estimated Mean and Confidence Interval (CI) for Dissolved and Particulate Copper Mass Emissions (grams/event) for Modified Epoxy and Hard Vinyl Coatings for Three Cleaning Methods for a 12.2-meter Recreational Vessel[1] at 1 Month and 3 Months of Fouling in Shelter Island Yacht Basin

	Dissolved Copper +/- CI 1-Month Fouling (grams/event)	Dissolved Copper +/- CI 3-Month Fouling (grams/event)	Particulate Copper +/- CI 1-Month Fouling (grams/event)	Particulate Copper +/- CI 3-Month Fouling (grams/event)
Modified Epoxy				
Carpet (BMP)	1.3 ± 0.2	1.4 ± 0.4	3.1± 0.8	4.7 ± 1.0
Scouring(non-BMP)	2.9 ± 0.6	3.7 ± 0.9	16.6 ± 6.5	21.9 ± 7.4
Nylon Brush (non-BMP)	0.8 ± 0.1	1.5 ± 0.1	4.1± 0.6	15.6 ± 3.9
Hard Vinyl				
Carpet (BMP)	4.0 ± 0.3	3.5 ± 0.9	66.8 ± 13.5	84.9 ± 34.7
Scouring (non-BMP)	5.9 ± 1.1	5.1 ± 0.6	165 ± 67.0	227 ± 44.5
Nylon brush (non-BMP)	3.1± 0.8	3.1 ± 1.7	82.4 ±- 40.9	150 ± 174
Estimated Average Copper Emissions Mass per 12.2m vessel for both modified epoxy and hard vinyl[2]	3.5 ± 0.6 (g/event)	3.4 ± 0.7 (g/event)	62.9 ± 22.0 (g/event)	84.6 ± 21.9 (g/event)
Estimated Average Copper Emissions per 12.2m vessel (grams/ year)[3]	49.3 ± 7.8 (g/yr)	47.8 ± 9.3 (g/yr)	880 ± 308 (g/yr)	1185 ± 307 (g/yr)
Estimated Average Copper Emissions Mass (kg/year) for all recreational vessels in SIYB [4]	117 ± 18 (kg/yr)	113 ± 22 (kg/yr)	2080 ± 727 (kg/yr)	2800 ± 724 (kg/yr)

BMP- Best Management Practices

CI- 95% Confidence Interval as determined from 3 replicates each for n=3 epoxy coated boats, n=2 vinyl coated boats

[1] *Average size of recreational vessel (12.2m length x 3.4m beam) used for estimating emissions in the SDRWQCB TMDL technical report (2004). Schiff et al. (2004) used an average size of vessel (9.1m length x 2.7 m beam).*

[2] *Estimated Average Copper Emissions based on averages of Carpet (BMP) and Scouring Pad (non-BMP) values. This is consistent with assumptions used in the SDRWQCB TMDL technical report (2005).*

[3] *Average number of events per year n=14. This is the same number of estimated events used in the SDRWQCB TMDL technical report (2005). Schiff et al. (2004) estimate was based on grams/month, a 28-day month or n= 13 events per year.*

[4] *Estimated number of slips or buoys in Shelter Island Yacht Basin, n=2,363 (Harbor Police 1999).*

4.0 REFERENCES

AMEC Earth & Environmental. 2005. Sampling and Analysis Plan, Copper Loading Assessment of In-water Hull Cleaning Shelter Island Yacht Basin, San Diego Bay, San Diego, California. April 21.

Chadwick, D.B., A Zirino, I Rivera-Duarte, C Katz, and A.C. Blake. 2002. Modeling the Mass Balance and Fate of Copper in the San Diego Bay. Space and Naval Systems Center (SPAWAR), San Diego, CA.

Driscoll, C. and T. Nielsen. 2005. Personal communication regarding hull coatings on vessel moored in Shelter Island Yacht Basin.

French, M.S., L.V. Evans, and R. Dalley. 1984. Raft Trial Experiment on Leaching from Anti Foulant paints. Trans. IMarE (C), Vol. 97, Conference 2, Paper19. 127-130.

Harbor Police. 1999. Annual Pleasure Craft Survey. San Diego Unified Port District. San Diego, California.

Johnson, H.D., J.G. Grovhoug, and A.O. Valkirs. 1998. Copper Loading to U.S. Navy Harbors. SPAWAR Systems Center San Diego Tech. Document 3052. 58 pp.

Johnson L., and J. Miller. 2002. Traditional and Reduced Biocide Coatings. University of California.—Sea Grant Program. June.

MacPherson, T.N. and G.B. Peters. 1995. “The Effect of Copper-based Antifouling Paints on Water Quality in Recreational Boat Marinas in San Diego and Mission Bay”. Unpublished manuscript.

NOAA. 1998. Sampling and analytical methods of the National Status and Trends Program Mussel Watch Project: 1993-1996 Update. NOAA Technical Memorandum NOS ORCA 130, 257 pp.

Schiff, K., D. Diehl, and A. Valkirs. 2004. Copper emissions from antifouling paint on recreational vessels. Marine Pollution Bulletin 48, pp. 371-377.

SDRWQCB. 2005. Resolution No. R9-2005-0019 Basin Plan Amendment and Technical Report, January 27, 2005 http://www.swrcb.ca.gov/rwqcb9/tmdls/shelter%20island.html.

SDRWQCB. 2001. Results of Sampling Survey at Shelter Island Yacht Basin for Dissolved Copper Concentrations, February 15, 2001.

Seligman, P.F., A.O. Valkirs, J.S. Caso. I. Rivera-Duarte, and E. Haslbeck. 2001. Copper release rates from antifouling marine coatings and its relationship to loading and toxicity in San Diego Bay, CA. In: Champ, M.A. (Ed), Symposium on Pollution Prevention from Ships and Shipyards. Oceanology International 2001, pp. 64-81.

State Board, NOAA, CDFG, Moss Landing. 1996. Chemistry, Toxicity and Benthic Community Conditions in Sediments of the San Diego Bay Region. Final Report. State Water Resources Control Board, National Oceanic and Atmospheric Administration, California

Department of Fish and Game Marine Pollution Studies Laboratory and Moss Landing Marine Laboratories.

US EPA. 1995. Method 1669, Sampling Ambient Water for Determination of Trace Metals in Environmental Samples. EPA/600-R-94-111.

US Navy. 2001. Dredging and Disposal Long-Term Management Strategy (LTMS), Navy Region Southwest. November.

Valkirs, A.O., P.F. Seligman, E, E. Haslbeck, and J.S. Caso. 2003. Measurement of copper release rates from antifouling paint under laboratory and in-situ conditions. Marine Pollution Bulletin 46, pp. 763-779.

Valkirs, A.O., B.M. Davidson, L.L Kear, R.L. Fransham, A.R. Zirino, and J.G.Grovhoug. 1994. Environmental Effects from In-Water Hull Cleaning of Ablative Copper Antifouling Coatings, Technical Document 2662. Naval Command, Control and Ocean Surveillance Center. RDT&E Division, San Diego, CA.

Appendix A

Field Sampling Logs

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **06/02/2005** Start time: **700** End time: **1650**

Weather Observations

Atmosphere
Sun / Clouds / **Overcast**
Temperature (^{o}C) **22 C**
Wind direction (knots) **SW, 3~10kt**
Rain in the last 48 hrs. Yes / **No**
Recorded amount (cm)- **trace/dri**

Additional observations: AM fog/drizzle turning to overcast mid morning, wind increasing throughout d

Seawater
Clear / Turbid / Red tide / Sewage
Visibility (ft.) **5-7ft**
Salinity (ppt.) not tested
Temperature (^{o}C) **19 C**
Surface conditions Wind chop / **Glassy**

Tide	Height	Time
Low	**0.7/1.0**	**1:15/12:38**
High	**4.0/6.1**	**7:05/19:09**

Tidal cycle: Reference sample tim
Current direction:**slight, NE**

Additional observations: sediment was not disturbed due to sampling. Sampling was delayed when adjacent boat was getting cleaned and soap suds were observed on surface.

In-situ Sample Collection

Sampling event # **1 month**
Date of initial cleaning (Time zero) **05/02/2005**
Days elapsed from initial cleaning **31**

Background Water Sample Note: background not collected at this location
ID# Location: Time:

Vessel: Amec ID: "**E-1**" Time:
Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock/ 26'sailboat**

Coating type Hard / **Epoxy** Paint brand name: **Interlux Ultra Kote** Date applied:**11/03**
Fouling condition None / **Light** / Medium / Heavy
Fouling organisms present: some surfical tube worms "scars" , paint in poor condition

Additional observations: infrequently used, moderate light fouling

Fouling conditions
Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae
Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)
Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling event # **1 month** Date: **06/02/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

\# of rotations: **1X** Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E1-1-C1**	**1040**	20
Rep 2	**E1-1-C2**	**1045**	20
Rep 3	**E1-1-C3**	**1050**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: curved hull , estimate 5% exchange with ambient

3M Scouring pad (non-BMP)

\# of rotations: **0.5X** Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E1-1-S1**	**1100**	20
Rep 2	**E1-1-S2**	**1105**	20
Rep 3	**E1-1-S3**	**1110**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

\# of rotations: **1X** Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E1-1-R1**	**1130**	20
Rep 2	**E1-1-R2**	**1140**	20
Rep 3	**E1-1-R3**	**1150**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: lighter fouling noted on area sampled for E1-1-R1

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **06/02/2005** Start time: **700** End time: **1650**

Weather Observations

Atmosphere

Sun / Clouds / **Overcast**

Rain in the last 48 hrs. Yes / **No**

Temperature (^oC) **22 C**

Recorded amount (cm)- **trace/drizzle**

Wind direction (knots) **SW, 3~10kt**

Additional observations: AM fog/drizzle turning to overcast mid morning, wind increasing throughout da

Seawater

Clear / Turbid / Red tide / Sewage

Visibility (ft.) **5-7ft**

Salinity (ppt.) not tested

Temperature (^oC) **19 C**

Surface conditions Wind chop / **Glas**

Tide	Height	Time
Low	**0.7/1.0**	**1:15/12:38**
High	**4.0/6.1**	**7:05/19:09**

Tidal cycle: Reference sample time

Current direction:**slight, NE**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **1 month**

Date of initial cleaning (Time zero) **05/02/2005**

Days elapsed from initial cleaning **31**

Background Water Sample

ID# **E2-1-A3** Location: **SIYC, C-30** Time: **1230**

Vessel: Amec ID: "**E-2**"

Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock/ 21'power**

Coating type Hard / **Epoxy** Paint brand name: **Interlux Ultra Ko** date applied:**1/05**

Fouling condition None / **Light** / Medium / Heavy

Fouling organisms present: no, paint in good condition

Additional observations: sporatic heavy use (80mi trip in rough water 1 week prior), very light fouling

Fouling conditions

Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae

Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)

Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling ever **1 month** Date: **06/02/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

of rotations: **1X** Pressure **Low** / Medium / High

Location on hull: Starboard / **Port**, Bow / Stern

Alignment of replicates: **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E2-1-C1**	**1245**	20
Rep 2	**E2-1-C2**	**1255**	20
Rep 3	**E2-1-C3**	**1300**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: curved hull,estimate 5% exchange with ambient, est.10% exchg on E2-1-C3

3M Scouring pad (non-BMP)

of rotations: **0.5X** Pressure **Low** / Medium / High

Location on hull: Starboard / **Port**, Bow / Stern

Alignment of replicates: **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E2-1-S1**	**1305**	20
Rep 2	**E2-1-S2**	**1310**	20
Rep 3	**E2-1-S3**	**1315**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

of rotations: **1X** Pressure **Low** / Medium / High

Location on hull: Starboard / **Port**, Bow / Stern

Alignment of replicates: **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E2-1-R1**	**1340**	20
Rep 2	**E2-1-R2**	**1350**	20
Rep 3	**E2-1-R3**	**1400**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **06/02/2005** Start time: **700** End time: **1650**

Weather Observations

Atmosphere
Sun / Clouds / **Overcast**
Temperature (^{o}C) **22 C**
Wind direction (knots) **SW, 3~10kt**
Rain in the last 48 hrs. Yes / **No**
Recorded amount (cm)- **trace/drizzle**

Additional observations: AM fog/drizzle turning to overcast mid morning, wind increasing throughout day

Seawater
Clear / Turbid / Red tide / Sewage
Visibility (ft.) **5-7ft**
Salinity (ppt.) not tested
Temperature (^{o}C) **19 C**
Surface conditions Wind chop / **Glassy**

Tide	Height	Time
Low	**0.7/1.0**	**1:15/12:38**
High	**4.0/6.1**	**7:05/19:09**

Tidal cycle: Reference sample time
Current direction:**slight, NE**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **1 month**
Date of initial cleaning (Time zero) **05/02/2005**
Days elapsed from initial cleaning **31**

Background Water Sample Note: background not collected at this location
ID# Location: Time:

Vessel: Amec ID: **"E-3"**
Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock/ 31'power**

Coating type Hard / **Epoxy** Paint brand name: **Interlux Ultra Kote** date applied:**9/03**
Fouling condition None / **Light** / Medium / Heavy
Fouling organisms present: scattered areas of tube worms removed during cleaning

Additional observations: moderately heavy use (used twice a week average), light fouling
paint in poor to fair condition

Fouling conditions
Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae
Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)
Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling event # **1 month** Date: **06/02/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

# of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port

Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E3-1-C1**	**1440**	20
Rep 2	**E3-1-C2**	**1445**	20
Rep 3	**E3-1-C3**	**1450**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: curved hull,estimate 5% exchange with ambient (all cleaning methods)

3M Scouring pad (non-BMP)

of rotations: **0.5X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port

Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E3-1-S1**	**1500**	20
Rep 2	**E3-1-S2**	**1505**	20
Rep 3	**E3-1-S3**	**1510**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port

Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E3-1-R1**	**1530**	20
Rep 2	**E3-1-R2**	**1540**	20
Rep 3	**E3-1-R3**	**1550**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **06/03/2005** Start time: **700** End time: **1200**

Weather Observations

Atmosphere
Sun / Clouds / **Overcast**
Temperature (^{o}C) **22 C**
Wind direction (knots) **NW, 3~10kt**
Rain in the last 48 hrs. Yes / **No**
Recorded amount (cm)- none

Additional observations: AM fog/drizzle turning to overcast mid morning, wind increasing throughout d

Seawater
Clear / Turbid / Red tide / Sewage
Visibility (ft.) **8-10ft**
Salinity (ppt.) not tested
Temperature (^{o}C) **19 C**
Surface conditions: Glassy to wind chop

Tide	Height	Time
Low	**0.0/1.4**	**2:04/13:17**
High	**3.9/6.4**	**8:07/19:42**

Tidal cycle: Reference sample tim
Current direction: **none**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **1 month**
Date of initial cleaning (Time zero) **05/04/2005**
Days elapsed from initial cleaning **30**

Background Water Sample Note: background not collected at this location
ID# **V1-1-A1** Location: **SIYC, C-15** Time: **930**

Vessel: Amec ID: **"V-1"**
Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock/ 29' sail**

Coating type **Hard** / Epoxy Paint brand name: **Proline 1088** date applied:**7/04**
Fouling condition None / **Light** / Medium / Heavy
Fouling organisms present: light green and brown algae

Additional observations: infrequent use, light fouling
paint in good condition

Fouling conditions
Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae
Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)
Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling event # **1 month** Date: **06/03/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V1-1-C1**	**830**	20
Rep 2	**V1-1-C2**	**835**	20
Rep 3	**V1-1-C3**	**840**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: curved hull,estimate 5% exchange with ambient (all cleaning methods)

3M Scouring pad (non-BMP)

of rotations: **0.5X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V1-1-S1**	**845**	20
Rep 2	**V1-1-S2**	**850**	20
Rep 3	**V1-1-S3**	**855**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V1-1-R1**	**900**	20
Rep 2	**V1-1-R2**	**910**	20
Rep 3	**V1-1-R3**	**920**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **06/03/2005** Start time: **700** End time: **1200**

Weather Observations

Atmosphere
Sun / Clouds / **Overcast**
Temperature (^oC) **22 C**
Wind direction (knots) **NW, 3~10kt**
Rain in the last 48 hrs. Yes / **No**
Recorded amount (cm)- none

Additional observations: AM fog/drizzle turning to overcast mid morning, wind increasing throughout d

Seawater
Clear / Turbid / Red tide / Sewage
Visibility (ft.) **8-10ft**
Salinity (ppt.) not tested
Temperature (^oC) **19 C**
Surface conditions: Glassy to wind chop

Tide	Height	Time
Low	**0.0/1.4**	**2:04/13:17**
High	**3.9/6.4**	**8:07/19:42**

Tidal cycle: Reference sample tim
Current direction: **none**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **1 month**
Date of initial cleaning (Time zero) **05/04/2005**
Days elapsed from initial cleaning **30**

Background Water Sample Note: background not collected at this location
ID# **V2-1-A2** Location: **SIYC, C-32** Time: **1000**

Vessel:
Amec ID: **"V-2"**

Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock/ 29' sail**

Coating type **Hard** / Epoxy
Paint brand name: **Proline 1088** date applied:**5/04**
Fouling condition None / **Light** / Medium / Heavy
Fouling organisms present: light green and brown algae

Additional observations: infrequent use, light fouling, paint in good to fair condition

Fouling conditions
Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae
Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)
Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling event # **1 month** Date: **06/03/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port

Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V2-1-C1**	**1005**	20
Rep 2	**V2-1-C2**	**1010**	20
Rep 3	**V2-1-C3**	**1015**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: curved hull,estimate 5% exchange with ambient (all cleaning methods)

3M Scouring pad (non-BMP)

of rotations: **0.5X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port

Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V2-1-S1**	**1020**	20
Rep 2	**V2-1-S2**	**1025**	20
Rep 3	**V2-1-S3**	**1030**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port

Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V2-1-R1**	**1045**	20
Rep 2	**V2-1-R2**	**1055**	20
Rep 3	**V2-1-R3**	**1105**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **06/02/2005** Start time: **700** End time: **1650**

Weather Observations

Atmosphere

Sun / Clouds / **Overcast**

Temperature (^{o}C) **22 C**

Wind direction (knots) **SW, 3~10kt**

Rain in the last 48 hrs. Yes / **No**

Recorded amount (cm)- **trace/drizzle**

Additional observations Wind picked up troughout day

Seawater

Clear / Turbid / Red tide / Sewage

Visibility (ft.) **5-7ft**

Salinity (ppt.) not tested

Temperature (^{o}C) **19 C**

Surface conditions Wind chop / **Glassy**

Tide	Height	Time
Low	**0.7/1.0**	**1:15/12:38**
High	**4.0/6.1**	**7:05/19:09**

Tidal cycle: Reference sample time

Current direction:**slight, NE**

Additional observations sediment was not disturbed due to sampling. Sampling was delayed when adjacent boat was getting cleaned and soap suds were observed on surface.

In-water Panel Sampling- NONE at 1 month- Pending equilibration period (60 days) before testing

Carpet (BMP)

Modified Epoxy Fouling condition None / Light / Medium / Heavy

Fouling organisms present:

# of rotations: Pressure Low / Medium / High

Sample	ID #	Time	Distance apart (~cm)
Rep 1			
Rep 2			
Rep 3			

Cleaning successful Yes / No

Photo taken Yes / No

Other Sampling: Date: **05/02/2005**

Sampling Device Blanks

of rotations carpet: **1X**

# of rotations 3M scouring pad : **0.5X**

# of rotations rotary brush: **1X** Pressure **Low** / Medium / High

Sample	ID #	Time	Cleaning method
Rep 1	**N1-1-B1**	**1315**	carpet
Rep 2	**N1-1-B2**	**1320**	3M Scouring pad
Rep 3	**N1-1-B3**	**1330**	Rotary brush

Cleaning successful Yes / No/**NA**

Photo taken Yes / **No**

Additional observations Used clean plastic sheet for biocide free hull and ambient seawater

Ablative- NONE at 1 month- Pending equilibration period (60 days) before testing

Carpet (BMP)

ablative paint Fouling condition None / Light / Medium / Heavy

Fouling organisms present:

# of rotations: Pressure Low / Medium / High

Sample	ID #	Time	Distance apart (~cm)
Rep 1			
Rep 2			
Rep 3			

Cleaning successful Yes / No

Photo taken Yes / No

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **08/04/2005** Start time: **900** End time: **945**

Weather Observations

Atmosphere

Sun / Clouds / **Overcast**

Rain in the last 48 hrs. Yes / **No**

Temperature (^oC) **22**

Recorded amount (cm)- none

Wind direction (knots) **<1kt**

Additional observations: AM overcast clearing to sunny skies

Seawater

Clear / Turbid / Red tide / Sewage

Visibility (ft.) **~10ft**

Salinity (ppt.) not tested

Temperature (^oC) **20**

Surface conditions Wind chop / **Glassy**

Tide	Height	Time
Low	**-0.5**	**4:23**
High	**6.4**	**21:30**

Tidal cycle: Reference sample tim

Current direction: **west, slight**

Additional observations: sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **3 month**

Date of initial cleaning (Time zero) **05/02/2005**

Days elapsed from initial cleaning **94**

Background Water Sample Note: background collected at adjacent slip location (C-30)

ID# Location: Time:

Vessel: Amec ID: **"E-1"** Time:

Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock**

Coating type Hard / **Epoxy** Paint brand name: **Interlux Ultra Kote** Date applied:**11/03**

Fouling condition None / Light / **Medium** / Heavy

Fouling organisms present: some surfical tube worms "patches", paint in poor condition,

Additional observations: infrequently used, moderate fouling,C-35 using detergent to clean topside causing surace bubbes, delayed sampling until current removed from vicinity

Fouling conditions

Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae

Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)

Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling event # **3 month** Date: **08/04/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull Starboard / **Port** Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E1-2-C1**	**900**	20
Rep 2	**E1-2-C2**	**905**	20
Rep 3	**E1-2-C3**	**910**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: curved hull , estimate 5% exchange with ambient

3M Scouring pad (non-BMP)

of rotations: **0.5X**

Pressure **Low** / Medium / High

Location on hull Starboard / **Port** Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E1-2-S1**	**915**	20
Rep 2	**E1-2-S2**	**920**	20
Rep 3	**E1-2-S3**	**925**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull Starboard / **Port** Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E1-2-R1**	**930**	20
Rep 2	**E1-2-R2**	**935**	20
Rep 3	**E1-2-R3**	**945**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: lighter fouling noted on area sampled for E1-1-R1

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **08/04/2005** Start time: **1010** End time: **1055**

Weather Observations

Atmosphere

Sun / Clouds / **Overcast**

Temperature (^oC) **22 C**

Wind direction (knots) **SW, 3~5kt**

Rain in the last 48 hrs. Yes / **No**

Recorded amount (cm)- none

Additional observations:

Seawater

Clear / Turbid / Red tide / Sewage

Visibility (ft.) **~10ft**

Salinity (ppt.) not tested

Temperature (^oC) **19 C**

Surface conditions Wind chop / **Glassy**

Tide	Height	Time
Low	**-0.5**	**4:23**
High	**6.4**	**21:30**

Tidal cycle: Reference sample time

Current direction:**slight, NE**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **3 month**

Date of initial cleaning (Time zero) **05/02/2005**

Days elapsed from initial cleaning **94**

Background Water Sample

ID# **E2-2-A3** Location: **SIYC, C dock** Time: **1230**

Vessel:

Amec ID: "**E-2**"

Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock/ # 30/ 21'power**

Coating type Hard / **Epoxy** Paint brand name: **Interlux Ultra Kote** date applied:**1/05**

Fouling condition None / **Light** / Medium / Heavy

Fouling organisms present: no, paint in good condition

Additional observations: sporatic heavy use, moderate patchy fouling

Fouling conditions

Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae

Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)

Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel:

Sampling event # **3 month** Date: **08/04/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

of rotations: **1X** — Pressure **Low** / Medium / High

Location on hull: Starboard / **Port**, Bow / Stern — Alignment of replicates: **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E2-2-C1**	**1010**	20
Rep 2	**E2-2-C2**	**1015**	20
Rep 3	**E2-2-C3**	**1020**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

3M Scouring pad (non-BMP)

of rotations: **0.5X** — Pressure **Low** / Medium / High

Location on hull: Starboard / **Port**, Bow / Stern — Alignment of replicates: **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E2-2-S1**	**1025**	20
Rep 2	**E2-2-S2**	**1030**	20
Rep 3	**E2-2-S3**	**1035**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

of rotations: **1X** — Pressure **Low** / Medium / High

Location on hull: Starboard / **Port**, Bow / Stern — Alignment of replicates: **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E3-2-R1**	**1040**	20
Rep 2	**E3-2-R2**	**1045**	20
Rep 3	**E3-2-R3**	**1055**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **08/04/2005** Start time: **1135** End time: **1215**

Weather Observations

Atmosphere

Sun / Clouds / Overcast

Rain in the last 48 hrs. Yes / **No**

Temperature (^oC) **22 C**

Recorded amount (cm)- none

Wind direction (knots) **SW, 5-10kt**

Additional observations: wind increasing throughout day

Seawater

Clear / Turbid / Red tide / Sewage

Visibility (ft.) **~10ft**

Salinity (ppt.) not tested

Temperature (^oC) **20**

Surface conditions Wind chop / **Glassy**

Tide	Height	Time
Low	**-0.5**	**4:23**
High	**6.4**	**21:30**

Tidal cycle: Reference sample tim

Current direction: **slight, NE**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **3 month**

Date of initial cleaning (Time zero) **05/02/2005**

Days elapsed from initial cleaning **94**

Background Water Sample Note: background not collected at this location

ID# Location: Time:

Vessel: Amec ID: "**E-3**"

Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock**

Coating type Hard / **Epoxy** Paint brand name: **Interlux Ultra Kote** date applied:**9/03**

Fouling condition None / **Light** / Medium / Heavy

Fouling organisms present: scattered areas of tube worms removed during cleaning

Additional observations: moderately heavy use (used twice a week average), light fouling
paint in poor to fair condition

Fouling conditions

Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae

Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)

Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling event # **3 month** Date: **08/04/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull Starboard / **Port** Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E3-2-C1**	**1135**	20
Rep 2	**E3-2-C2**	**1140**	20
Rep 3	**E3-2-C3**	**1145**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: curved hull,estimate 5% exchange with ambient (all cleaning methods)

3M Scouring pad (non-BMP)

of rotations: **0.5X**

Pressure **Low** / Medium / High

Location on hull Starboard / **Port** Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E3-2-S1**	**1150**	20
Rep 2	**E3-2-S2**	**1155**	20
Rep 3	**E3-2-S3**	**1200**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull Starboard / **Port** Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**E3-2-R1**	**1205**	20
Rep 2	**E3-2-R2**	**1210**	20
Rep 3	**E3-2-R3**	**1215**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **08/05/2005** Start time: **850** End time: **945**

Weather Observations

Atmosphere

Sun / Clouds / **Overcast**

Temperature (^oC) **22 C**

Wind direction (knots) **SW, 3~10kt**

Rain in the last 48 hrs. Yes / **No**

Recorded amount (cm)- none

Additional observations: AM fog/drizzle turning to overcast mid morning, wind increasing throughout d

Seawater

Clear / Turbid / Red tide / Sewage

Visibility (ft.) **8-10ft**

Salinity (ppt.) not tested

Temperature (^oC) **19 C**

Surface conditions: Glassy to wind chop

Tide	Height	Time
Low	**-0.4**	**4:32**
High	**6.4**	**22:01**

Tidal cycle: Reference sample tim

Current direction: **none**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **3 month**

Date of initial cleaning (Time zero) **08/05/2005**

Days elapsed from initial cleaning **93**

Background Water Sample

ID# **V1-2-A1** Location: **SIYC, C-15** Time: **950**

Vessel:

Amec ID: **"V-1"**

Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock**

Coating type **Hard** / Epoxy Paint brand name: **Proline 1088** date applied:**7/04**

Fouling condition None / **Light** / Medium / Heavy

Fouling organisms present: light green and brown algae

Additional observations: infrequent use, light fouling
paint in good condition

Fouling conditions

Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae

Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)

Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling event # **3 month** Date: **08/05/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port
Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V1-2-C1**	**850**	20
Rep 2	**V1-2-C2**	**855**	20
Rep 3	**V1-2-C3**	**900**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: curved hull,estimate 5% exchange with ambient (all cleaning methods)

3M Scouring pad (non-BMP)

of rotations: **0.5X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port
Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V1-2-S1**	**915**	20
Rep 2	**V1-2-S2**	**920**	20
Rep 3	**V1-2-S3**	**925**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port
Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V1-2-R1**	**930**	20
Rep 2	**V1-2-R2**	**935**	20
Rep 3	**V1-2-R3**	**945**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **08/05/2005** Start time: **1030** End time: **1130**

Weather Observations

Atmosphere

Sun / Clouds / Overcast

Temperature (^{o}C) **22 C**

Wind direction (knots) **SW, 3~10kt**

Rain in the last 48 hrs. Yes / **No**

Recorded amount (cm)- none

Additional observations:

Seawater

Clear / Turbid / Red tide / Sewage

Visibility (ft.) **8-10ft**

Salinity (ppt.) not tested

Temperature (^{o}C) **19 C**

Surface conditions: Glassy to wind chop

Tide	Height	Time
Low	**-0.4**	**4:32**
High	**6.4**	**22:01**

Tidal cycle: Reference sample tim

Current direction: **none**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **3 month**

Date of initial cleaning (Time zero) **05/04/2005**

Days elapsed from initial cleaning **93**

Background Water Sample Note: background not collected at this location

ID# **V2-2-A2** Location: **SIYC, C dock** Time:

Vessel: Amec ID: **"V-2"**

Marina/dock/slip #/ type **Shelter Island Yacht Club/C dock/ # 32/ 29' sail**

Coating type **Hard** / Epoxy Paint brand name: **Proline 1088** date applied:**5/04**

Fouling condition None / **Light** / Medium / Heavy

Fouling organisms present: light green and brown algae

Additional observations: infrequent use, light fouling

paint in good to fair condition

Fouling conditions

Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae

Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)

Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling event # **3 month** Date: **08/05/2005**

In-water Hull Cleaning Samples

Carpet (BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V2-2-C1**	**1030**	20
Rep 2	**V2-2-C2**	**1035**	20
Rep 3	**V2-2-C3**	**1040**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations: curved hull,estimate 5% exchange with ambient (all cleaning methods)

3M Scouring pad (non-BMP)

of rotations: **0.5X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V2-2-S1**	**1100**	20
Rep 2	**V2-2-S2**	**1105**	20
Rep 3	**V2-2-S3**	**1110**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Rotary brush (non-BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern

Alignment of replicates **keel to waterline**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**V2-2-R1**	**1115**	20
Rep 2	**V2-2-R2**	**1120**	20
Rep 3	**V2-2-R3**	**1130**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **08/04/2005** Start time: **1345** End time: **1355**

Weather Observations

Atmosphere

Sun / Clouds / Overcast

Temperature (^{o}C) **22 C**

Wind direction (knots) **W, 5-10kt**

Rain in the last 48 hrs. Yes / **No**

Recorded amount (cm)- none

Additional observations:

Seawater

Clear / Turbid / Red tide / Sewage

Visibility (ft.) **~10ft**

Salinity (ppt.) not tested

Temperature (^{o}C) **20**

Surface conditions **Wind chop** / Glassy

Tide	Height	Time
Low	**-0.5**	**4:23**
High	**6.4**	**21:30**

Tidal cycle: Reference sample tim

Current direction:**slight, south**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **3 month**

Date of initial cleaning (Time zero) **03/22/2005**

Days elapsed from initial cleaning **75 days**

Background Water Sample

ID# **A1-2-A4** Location: **Shelter Island Police Dock** Time: **1400**

Vessel:

Amec ID: **"A-1"**

Marina/dock/slip #/ type **Shelter Island Police Dock**

Coating type **Ablative**

Paint brand name: **Jotun 60A2002 Hydroclean Blue**

Fouling condition None / **Light** / Medium / Heavy date applied:**3/22/05**

Fouling organisms present: very light fouling, patchy

Additional observations: moderately use, paint in good condition

Fouling conditions

Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae

Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)

Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

Vessel: Sampling event # **Phase 2** Date: **08/04/2005**

Ablative Coating Carpet (BMP)

of rotations: **1X** Pressure **Low** / Medium / High

Location on hull **Starboard** / Port Bow / Stern Alignment of replicates **bow to stern**

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**A1-2-C1**	**1345**	20
Rep 2	**A1-2-C2**	**1350**	20
Rep 3	**A1-2-C3**	**1355**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

3M Scouring pad (non-BMP)

of rotations: Pressure Low / Medium / High

Location on hull Starboard / Port Bow / Stern Alignment of replicates keel to waterline

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**not sampled**		
Rep 2	**not sampled**		
Rep 3	**not sampled**		

Cleaning successful Yes / No

Video or Photo taken Yes / No

Additional observations:

Rotary brush (non-BMP)

of rotations: Pressure Low / Medium / High

Location on hull Starboard / Port Bow / Stern Alignment of replicates keel to waterline

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**not sampled**		
Rep 2	**not sampled**		
Rep 3	**not sampled**		

Cleaning successful Yes / No

Video or Photo taken Yes / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **08/04/2005** Start time: **1455** End time: **1510**

Weather Observations

Atmosphere

Sun / Clouds / Overcast

Rain in the last 48 hrs. Yes / **No**

Temperature (^{o}C) **22 C**

Recorded amount (cm)- none

Wind direction (knots) **W, 10kt**

Additional observations:

Seawater

Clear / Turbid / Red tide / Sewage

Visibility (ft.) **~10ft**

Salinity (ppt.) not tested

Temperature (^{o}C) **20**

Surface conditions Wind chop / **Glassy**

Tide	Height	Time
Low	**-0.5**	**4:23**
High	**6.4**	**21:30**

Tidal cycle: Reference sample tim

Current direction:**slight, NE**

Additional observations: Sediment was not disturbed due to sampling.

In-situ Sample Collection

Sampling event # **1 month**

Date of initial cleaning (Time zero) **07/13/2005**

Days elapsed from initial cleaning **23**

Background Water Sample

ID# **P1-2-A5** Location: **Driscoll Boatyards** Time: **1510**

In-water Panel Sampling

Amec ID: **"P-1"**

Marina/dock/slip #/ type **Driscoll Boatyards**

Coating type **Modified Epoxy** Paint brand name: **Pettit Trinidad 1277**

Fouling condition None / **Light** / **Medium** / Heavy date applied: **5/13/05**

Fouling organisms present:

Additional observations: paint in good condition, approximate 1 month fouling condition fouling condition 23 days since last cleaning due to summer weather

Fouling conditions

Light - filamentous algae; early unicellular eukaryotic colonization from chiopophytes (green) and phaeophytes (brown) algae

Medium - filamentous algae 0.0-3 cm; unicellular colonization from chiopophytes (green) and phaeophytes (brown) algae, early Rhodophytes and multicellular colonization (encrusting organisms) of ploychaeta (tube worms) and tunicates (seasquirts)

Heavy - >3 cm algae, >5 per m2 encrusting organisms

In-situ Sample Collection (continued)

In-water Panel Sampling

Sampling event # **23 days** Date: **08/04/2005**

Carpet (BMP)

of rotations: **1X**

Pressure **Low** / Medium / High

Location on hull- **NA** Starboard / Port Bow / Stern

Alignment of replicates bow to stern

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**P1-2-C1**	**1455**	20
Rep 2	**P1-2-C2**	**1500**	20
Rep 3	**P1-2-C3**	**1505**	20

Cleaning successful **Yes** / No

Video or Photo taken **Yes** / No

Additional observations:

3M Scouring pad (non-BMP)

of rotations:

Pressure Low / Medium / High

Location on hull- **NA** Starboard / Port Bow / Stern

Alignment of replicates keel to waterline

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**not sampled**		
Rep 2	**not sampled**		
Rep 3	**not sampled**		

Cleaning successful Yes / No

Video or Photo taken Yes / No

Additional observations:

Rotary brush (non-BMP)

of rotations:

Pressure Low / Medium / High

Location on hull- **NA** Starboard / Port Bow / Stern

Alignment of replicates keel to waterline

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**not sampled**		
Rep 2	**not sampled**		
Rep 3	**not sampled**		

Cleaning successful Yes / No

Video or Photo taken Yes / No

Additional observations:

Port of San Diego
In-water Hull Cleaning Assessment Project
Shelter Island Yacht Basin, San Diego Bay

Date: **08/05/2005** Start time: **955** End time: **1005**

Weather Observations

Atmosphere
Sun / Clouds / **Overcast**
Temperature (^{o}C) **22 C**
Wind direction (knots) **SW, <3kt**
Rain in the last 48 hrs. Yes / **No**
Recorded amount (cm)-

Additional observations: Wind picked up troughout day

Seawater
Clear / Turbid / Red tide / Sewage
Visibility (ft.) **10 ft**
Salinity (ppt.) not tested
Temperature (^{o}C) **19 C**
Surface conditions Wind chop / **Glassy**

Tide	Height	Time
Low	**-0.4**	**4:32**
High	**6.4**	**22:01**

Tidal cycle: Reference sample time
Current direction: **slight, NE**

Additional observations: sediment was not disturbed due to sampling.

In-water Panel Sampling

Date: **08/04/2005**

Carpet (BMP) Modified Epoxy Fouling condition None / **Light** / **Medium** / Heavy
Fouling organisms present:

# of rotations: **1X** Pressure **Low** / Medium / High

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**P1-2-C1**	**1455**	20
Rep 2	**P1-2-C2**	**1500**	20
Rep 3	**P1-2-C3**	**1505**	20

Cleaning successful **Yes** / No
Photo taken **Yes** / No

Other Sampling: Date: **08/05/2005**

Sampling Device Blanks

of rotations carpet: **1X**
# of rotations 3M scouring pad : **0.5X**
# of rotations rotary brush: **1X** Pressure **Low** / Medium / High

Sample	ID #	Time	Cleaning method
Rep 1	**N1-2-B1**	**1000**	carpet
Rep 2	**N1-2-B2**	**1005**	3M Scouring pad
Rep 3	**N1-2-B3**	**955**	Rotary brush

Cleaning successful Yes / No/**NA**
Photo taken Yes / **No**

Additional observations: Used clean plastic sheet for biocide free hull and ambient seawater

Ablative Coating

Date: **08/04/2005**

Carpet (BMP) ablative paint Fouling condition None / **Light** / Medium / Heavy
Fouling organisms present:

# of rotations: Pressure Low / Medium / High

Sample	ID #	Time	Distance apart (~cm)
Rep 1	**A1-2-C1**	**1345**	20
Rep 2	**A1-2-C2**	**1350**	20
Rep 3	**A1-2-C3**	**1355**	20

Cleaning successful **Yes** / No
Photo taken **Yes** / No

Appendix B

Vessel Documentation

Vessel: "E-2"
Marina / dock / slip #/boat San Diego Yacht Club / C-XX/ 21' power
Coating type: Epoxy Paint brand name: Interlux Ultra Kote
Initial date of coating application: 1/05, paint in good condition Date of last cleaning: May 2, 2005

Vessel: "E-3"
Marina / dock / slip/ boat # San Diego Yacht Club / C-XX/ 31' power
Coating type: Epoxy Paint brand name: Interlux Ultra Kote
Initial date of coating application: 9/03, paint in poor condition Date of last cleaning: May 2, 2005

Vessel: "E-1"
Marina / dock / slip #/ boat San Diego Yacht Club / C-XX/ 26' Ranger sailboat
Coating type: Epoxy Paint brand name: Interlux Ultra Kote
Initial date of coating application: 11/03, paint in poor to fair condition Date of last cleaning: May 2, 2005

Vessel: "V-1"
Marina / dock / slip #/ boat San Diego Yacht Club / C-XX/ 29' sailboat
Coating type: Hard Vinyl Paint brand name: Proline 1088
Initial date of coating application: 7/04, paint in good condition Date of last cleaning: May 4, 2005

Vessel: "V-2"
Marina / dock / slip #/ boat San Diego Yacht Club / C-XX/ 29' sailboat
Coating type: Hard Vinyl Paint brand name: Proline 1088
Initial date of coating application: 5/04, paint in good to fair condition Date of last cleaning: May 4, 2005

Vessel: "A-1"
Marina / dock / slip # Shelter Island Yacht Basin
Coating type: Ablative Paint brand name: Jotun 60A2002 Hydroclean Blue
Initial date of coating application: 3/22/05, paint in good condition Date of last cleaning: NA

Other: Test Panels
Marina / dock / slip # re painted on May 13, 2005, suspended at Driscoll Boatyards
Coating type: Epoxy and Hard Vinyl Paint brand name:Pettit Trinidad 1277,
Initial date of coating application: 5/13/05 Date of last cleaning: 7/13/05

Appendix C

Hull Condition Report

PRESLEY PRECISION DIVING INC.

(619) 223-3234 ACCOUNT NO: 0303-3

INSPECTION REPORT "E-1"

MAY 2, 2005

YACHT: 26' RANGER [redacted]
MARINA: SAN DIEGO YACHT CLUB
SLIP: [redacted]

PAINT CONDITION: FAIR TO POOR CONDITION

ANTI FOULING (Marine Growth Inhibitor): POOR CONDITION

HULL: SCATTERED 1/4" DIAMETER GEL COAT BLISTERS
AREAS OF PAINT MISSING ON HULL

KEEL: AREAS OF PAINT MISSING ON KEEL

ELECTROLYSIS: NO SIGNS OF ELECTROLYSIS

PROP:

SHAFT:

STRUT:

RUDDER: AREAS OF PAINT MISSING ON RUDDER

THRU HULLS:

OTHER:

ZINC'S: NONE

MARINE GROWTH REMOVED: MEDIUM TO HEAVY GREEN AND BROWN ALGAE
SCATTERED AREAS OF MEDIUM TUBE WORM CORAL

METHOD OF CLEANING: HAND CLEANED WITH METAL SCRAPER AND BROWN PAD

PRESLEY PRECISION DIVING INC.

(619) 223-3234 ACCOUNT NO: 0303-1

INSPECTION REPORT

"E-2"

MAY 2, 2005

YACHT: [redacted]
MARINA: SAN DIEGO YACHT CLUB
SLIP: [redacted]

PAINT CONDITION: GOOD CONDITION

ANTI FOULING (Marine Growth Inhibitor): GOOD CONDITION

HULL: GOOD CONDITION

KEEL: GOOD CONDITION

ELECTROLYSIS: NO SIGNS OF ELECTROLYSIS

PROP: OKAY

SHAFT:

STRUT:

RUDDER:

THRU HULLS:

OTHER:

ZINC'S: OUTBOARD BAR IS IN GOOD CONDITION

MARINE GROWTH REMOVED: LIGHT BROWN AND GREEN ALGAE

METHOD OF CLEANING: HAND CLEANED WITH WHITE PAD

PRESLEY PRECISION DIVING INC.

(619) 223-3234 ACCOUNT NO: 0303-2

INSPECTION REPORT

MAY 2, 2005 "E-3"

YACHT: [redacted]
MARINA: SAN DIEGO YACHT CLUB
SLIP: [redacted]

PAINT CONDITION: FAIR TO POOR CONDITION
SEVERAL AREAS WHERE PAINT IS THIN AND FLAKING

ANTI FOULING (Marine Growth Inhibitor): POOR CONDITION

HULL: GOOD CONDITION

KEEL: GOOD CONDITION

ELECTROLYSIS: NO SIGNS OF ELECTROLYSIS

PROP: okay

SHAFT: okay

STRUT: ALL PAINT IS MISSING ON STRUTS

RUDDER: ALL PAINT IS MISSING ON RUDDERS

THRU HULLS: okay

OTHER:

ZINC'S: TRIM TAB WAFERS ARE IN FAIR CONDITION
RUDDER WAFERS ARE IN FAIR CONDITION
COLLARS ARE IN FAIR CONDITION
PLATE IS IN VERY POOR CONDITION

MARINE GROWTH REMOVED: MEDIUM TO HEAVY GREEN AND BROWN ALGAE
SCATTERED AREAS OF MEDIUM TUBE WORM CORAL

METHOD OF CLEANING: HAND CLEANED WITH METAL SCRAPER AND BROWN PAD

PRESLEY PRECISION DIVING INC.

(619) 223-3234 ACCOUNT NO: 0303-4

INSPECTION REPORT

"V-1"

MAY 4, 2005

YACHT: [redacted]
MARINA: SAN DIEGO YACHT CLUB
SLIP: [redacted]

PAINT CONDITION: GOOD CONDITION

ANTI FOULING (Marine Growth Inhibitor): GOOD CONDITION

HULL: GOOD CONDITION

KEEL: GOOD CONDITION

ELECTROLYSIS: NO SIGNS OF ELECTROLYSIS

PROP: okay

SHAFT: okay

STRUT: okay

RUDDER: okay

THRU HULLS: okay

OTHER:

ZINC'S: COLLAR IS IN GOOD CONDITION

MARINE GROWTH REMOVED: VERY LIGHT GREEN AND BROWN ALGAE

METHOD OF CLEANING: HAND CLEANED WITH WHITE PAD

PRESLEY PRECISION DIVING INC.

(619) 223-3234 ACCOUNT NO: 0303-5

INSPECTION REPORT

"V-2"

MAY 4, 2005

YACHT: [redacted]
MARINA: SAN DIEGO YACHT CLUB
SLIP: [redacted]

PAINT CONDITION: GOOD TO FAIR CONDITION

ANTI FOULING (Marine Growth Inhibitor): GOOD TO FAIR CONDITION

HULL: GOOD CONDITION

KEEL: GOOD CONDITION

ELECTROLYSIS: NO SIGNS OF ELECTROLYSIS

PROP: okay

SHAFT: okay

STRUT: okay

RUDDER: okay

THRU HULLS: okay

OTHER:

ZINC'S: COLLAR IS IN GOOD TO FAIR CONDITION
STRUT WAFER IS MISSING

MARINE GROWTH REMOVED: VERY LIGHT GREEN AND BROWN ALGAE

METHOD OF CLEANING: HAND CLEANED WITH WHITE PAD