

Elsevier Editorial System(tm) for Journal of Environmental Management  
Manuscript Draft

Manuscript Number:

Title: A Binational, Supply-Side Evaluation for Managing Water Quality and Invasive Fouling Species on California's Coastal Boats

Article Type: Research Paper

Keywords: fouling control costs; antifouling paint pollution; aquatic invasive species; environmental policy; California and Baja California

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# COOPERATIVE EXTENSION

## UNIVERSITY of CALIFORNIA – COUNTY of SAN DIEGO



4-H YOUTH & FAMILY – AGRICULTURE – HORTICULTURE – NATURAL RESOURCES – NUTRITION & CONSUMER SCIENCE

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August 4, 2010

Journal of Environmental Management  
c/o Elsevier Inc. (Branch Office)  
525 B Street, Suite 1800  
San Diego, CA 92101

Dear Editors:

After making the requested changes, I wish to resubmit the following manuscript to be considered for publication in the Journal of Environmental Management:

A Binational, Supply-Side Evaluation  
for Managing Water Quality and Invasive Fouling Species  
on California's Coastal Boats

The authors are myself, Leigh T. Johnson (first and corresponding) and Linda M. Fernandez.

I have added line numbers and will submit the numbered tables separately from the manuscript body.

Thank you for the opportunity to resubmit this work. I look forward to your reply.

Sincerely yours,

A handwritten signature in blue ink that reads 'Leigh T. Johnson'.

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1                   **A Binational, Supply-Side Evaluation for Managing Water Quality and Invasive**  
2  
3                                   **Fouling Species on California’s Coastal Boats**

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5  
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15  
16  
17 **Abstract**

18           Recreational boats discharge copper from antifouling paints to marine harbors, in some  
19 cases exceeding government standards. Such boats are implicated in coastal transport of invasive  
20 species that occur among the fouling organisms attached to their hulls. Policy development must  
21 consider capacity, as well as economic and environmental sustainability, in managing these  
22 issues. This paper presents a supply-side evaluation useful in developing policies to manage  
23 water quality and invasive fouling species on recreational boats travelling along the coasts of  
24 California, Baja California and California’s Sacramento-San Joaquin Delta. Analyses include  
25 evaluation of comprehensive costs to use antifouling and nontoxic hull coatings and the capacity  
26 of marine service businesses to apply them and control fouling on them. Supply-side  
27 perspectives on boat-owner behaviors, such as travel patterns, awareness of hull-coating choices  
28 and selection of hull coatings, are also examined. The issues raised will become broadly  
29 applicable as policy makers in coastal areas consider how to reduce pollution of harbor waters by  
30 copper discharged from antifouling paints, while preventing transport of aquatic invasive species  
31 on recreational boat hulls.

32 **Keywords:** fouling control costs; antifouling paint pollution; aquatic invasive species;  
33 environmental policy; California and Baja California

34

## 35 **1. Introduction**

### 36 **1.1 Management Challenges**

37 Organisms that attach to hulls of boats are called hull-fouling organisms and create friction or  
38 “drag” that slows sailboats and increases fuel consumption by powerboats (Townsin 2003). As a  
39 result, boat hulls have been identified as vectors for transporting aquatic invasive species along  
40 California’s coast (Cohen *et al.* 2002, Wasson *et al.* 2001). California boats navigating along the  
41 Baja California peninsula of Mexico increase risks of transporting invasive species and may  
42 encounter differences in available supplies and services for fouling control. California water  
43 quality agencies are increasingly concerned about impacts of copper antifouling paint discharges  
44 on water quality in coastal marinas. Thus, a binational approach is needed for co-managing  
45 invasive species and water quality via control of fouling organisms that colonize hulls of  
46 California’s coastal pleasure craft.

47 We conducted a supply-side, binational survey to provide necessary information for  
48 addressing this co-management challenge. Our study naturally follows from the demand-side  
49 study conducted earlier that focused strictly on water quality issues in San Diego Bay (Carson *et al.*  
50 *al.* 2009). First, we asked about the capacity of and costs charged by boat maintenance  
51 businesses to provide fouling control products and services that could reduce risks of invasive  
52 species transport on hulls of boats transiting the coasts and bays of California and Baja  
53 California and the Sacramento-San Joaquin Delta estuary of California. Second, we asked about  
54 the capacity of and costs charged by these businesses to provide alternative products and services  
55 that could reduce risks of pollution posed by copper-based paints that are typically applied to

56 hulls for fouling control. Third, we asked managers of marinas a series of questions designed to  
57 capture information about boat owners as a group, for example, boat-slip rental costs, slip  
58 capacity and occupancy rate, boat activity patterns, types of alternative fouling control measures  
59 they allowed tenants to use, and so forth. Finally, we asked industry representatives for their  
60 perceptions of customers' awareness of alternatives to copper-based antifouling paints.

61 Note that in much of the study area, copper antifouling paints cannot entirely control hull  
62 fouling. Thus, "companion strategies" are also needed to control invasive and other fouling  
63 species. Periodic, hull cleaning removes early stages of fouling growth, preventing maturation  
64 and allowing gentler cleaning techniques that reduce abrasion of the hull's surface coating.  
65 Another approach is to isolate the boat from propagules of fouling organisms by surrounding it  
66 with a slip liner or elevating it on a boat lift. Such strategies are important when the hull is coated  
67 with copper antifouling paint and critical when it is coated with nontoxic or less-toxic material.

68 The paper is organized as follows. The Introduction offers the policy context of the study.  
69 The Methods section includes details of the survey and statistical analyses. The Results and  
70 Discussion section presents text and tables with results and interpretations of the analyses. The  
71 Conclusions section summarizes key findings and conclusions.

72

## 73 **1.2 Policy Context**

74 Our study is timely, as management agencies are interested in acting upon invasive  
75 species and water quality problems. California Department of Pesticide Regulation (CDPR),  
76 United States Environmental Protection Agency (US EPA) and the European Commission (EC)  
77 are re-evaluating pesticidal paints used to control hull fouling organisms (CDPR 2010,  
78 Singhasemanon 2007, US EPA 2010, EC 2007). Toxicants from these paints impair water

79 quality and beneficial uses when they accumulate to levels that exceed 3.1 µg/l (US EPA 2000).  
80 A Total Maximum Daily Load program of the California State Water Resources Control Board  
81 (CSWRCB) requires a 76% reduction of copper discharges from antifouling paints in Shelter  
82 Island Yacht Basin of San Diego Bay by 2023 (CRWQCB-SDR 2004, CSWRCB 2005). State of  
83 Washington policies RCW 90.48.080 and WAC 173-201A prohibit in-water hull cleaning for  
84 vessels with soft (ablative and sloughing), toxic hull coatings (WDOE 2010).

85 Water quality assessments in Lower Newport Bay (Orange County Coastkeeper 2007, US  
86 EPA 2002) and a joint survey of 23 California marinas by CDPR and CSWRCB (CSWRCB  
87 2008) found that toxicants discharged by antifouling paints affect coastal water quality in  
88 multiple regions of the state. The CSWRCB's proposed, regulatory permit for marinas would  
89 require reduction of copper discharges from antifouling paints (Munz 2009).

90 The situation is complicated by existing and proposed policies such as the "California  
91 Aquatic Invasive Species Management Plan" (CDFG 2008) and the bill, "Great Lakes  
92 Collaboration Implementation Act of 2009" (US Senate 2009) that recognize the role of  
93 recreational boats in spreading invasive, hull fouling species. The federal bill recommends  
94 cleaning recreational boats on land to prevent transportation of freshwater invasive species such  
95 as Eurasian mussels and water weeds. Such measures are economically feasible for smaller boats  
96 that are easily carried on trailers among lakes and rivers. In contrast, in-water hull cleaning, slip  
97 liners and boat lifts are used in conjunction with antifouling paints or nontoxic hull coatings to  
98 control fouling on larger, recreational boats that are kept in coastal harbors. Based on our  
99 analysis for California Policy Research Center, hauling boats for hull cleaning would cost nine  
100 times as much as in-water cleaning and would increase time demands on busy boat owners  
101 (Johnson and Gonzalez 2005). Further, nontoxic coatings require periodic hull cleaning twice as

102 often as copper antifouling paints, so the situation would be exacerbated if boaters switched to  
103 nontoxic and less toxic coatings to comply with pending and anticipated water quality  
104 regulations (Johnson and Gonzalez 2006).

105 Scientists have found that some aquatic invasive species, which foul hulls in San  
106 Francisco Bay (Crooks *et al. in press*) and in Australia (Piola and Johnston 2005), have  
107 developed tolerance for copper. Thus, some boaters may seek cost effective alternatives to  
108 copper paints, whether or not restrictions on copper antifouling paints increase.

109 Boat owners and boating business operators face increased costs from new water quality  
110 programs addressing pesticidal, antifouling, boat-bottom paints and from potential, hull-borne  
111 invasive species regulations. California boat owners enjoy a moderate, household income level  
112 that is somewhat higher than that of the general population (CDBW 2002b). Both groups have  
113 expressed to us a strong need for detailed, cost-effectiveness information on alternative hull  
114 coatings and companion, fouling-control strategies at meetings, by telephone and e-mail.  
115 Agencies, policy makers, boat owners and boating businesses, coating companies, academics,  
116 and environmental organizations will need such research-based information in the next few years  
117 to make cost-effective decisions and create sustainable policies for protecting water quality while  
118 controlling native and invasive, hull-fouling species.

119 We provide the supply-side capacity and cost data and analysis that are needed to support  
120 co-management decisions on water quality protection and control of native and invasive hull-  
121 fouling species that are economically, technically and environmentally effective for California  
122 boats kept in saltwater. Cost ranges for various parameters are needed to reflect variations in boat  
123 sizes, types, usage and maintenance patterns. Data also need to be aggregated for analysis on a

124 per unit basis to compare across alternative supplies and services. Supply-side data on boat  
125 owner behavior is provided as context for industry capacity and cost analyses and discussions.

126

## 127 **2. Methods**

128 A Project Advisory Committee was convened in June 2007 and members were also  
129 consulted individually throughout the project. They represented California Department of  
130 Boating and Waterways (CDBW), CDPR, marinas/harbors/yacht clubs; boat repair, hull  
131 cleaning, coating and slip liner companies; and boat-owner and environmental organizations  
132 from regions of California that were included in the survey, except Central Valley.

133 Survey pre-test instruments, survey instruments, investigators and project staff members  
134 were approved by the UC Davis Institutional Review Board under Protocol No. 200816030-1.  
135 Five boating industry groups were surveyed in 2008, following pre-testing and revision of survey  
136 instruments. Groups included in the survey were: marinas (marinas, harbors and yacht clubs), in-  
137 water hull cleaners, boat repair yards, slip liner and boat lift companies. Because they were few  
138 in number, slip liner companies were sampled from the US West Coast and boat lift companies  
139 were sampled nationally; neither group was sampled in Mexico. The target sample size was set at  
140 30% of subject populations. Surveys were administered via mail, e-mail, telephone and in  
141 person.

142 Marinas, boatyards and hull cleaners were sampled proportionately from California and  
143 Baja California coasts and bays; marinas and boatyards were also sampled from the Sacramento-  
144 San Joaquin Delta. Marina, boatyard and hull cleaner sampling efforts were stratified by regions  
145 of the California coast, bays, and Delta *as per* CDBW's survey (CDBW 2002a) and by the  
146 Ensenada, Los Cabos and La Paz areas of Baja California and Baja California Sur *as per* Packard

147 Foundation's survey (Conlon 2002). The sample included 92 Californian and 8 Mexican marina,  
148 harbor and yacht club managers; 28 Californian and 5 Mexican boat repair yard operators; 23  
149 Californian and 4 Mexican hull cleaners; 3 slip liner companies on the US West Coast  
150 (California, Oregon, Washington); and 17 boat lift companies in the US.

151 Survey regions in California included: North Coast (Del Norte, Humboldt, Mendocino,  
152 Sonoma Counties); San Francisco Bay area (Alameda, Contra Costa, Marin, Napa, San  
153 Francisco, San Mateo, Santa Clara, Solano Counties); Central Coast (Santa Cruz, Monterey, San  
154 Luis Obispo Counties); South Coast (Santa Barbara, Ventura, Los Angeles, Orange Counties,  
155 Santa Catalina Island); San Diego (County); Sacramento Basin (Butte, Colusa, El Dorado,  
156 Glenn, Lake, Nevada, Placer, Plumas, Sacramento, Shasta, Sierra, Sutter, Tehama, Trinity, Yolo,  
157 Yuba Counties); and Central Valley (Amador, Calaveras, Fresno, Kern, Kings, Madera,  
158 Mariposa, Merced, San Benito, San Joaquin, Stanislaus, Tulare, Tuolumne).

159 Survey regions in Mexico included: Baja California Ensenada area (Ensenada, Puerto  
160 Salina); Baja California Sur Los Cabos area (Cabo San Lucas, San Jose del Cabo); and Baja  
161 California Sur southern Sea of Cortes area (La Paz).

162 We analyzed economic data for marinas, in-water hull cleaners and boat repair yards. The  
163 data were compiled from the survey in Stata™ and organized according to the various categories  
164 of the boating industry. Stata™ was then used to calculate summary statistics of the data by  
165 category such as mean, median, standard deviation, corresponding to all answers from survey  
166 questions that are reported in the results section.

167 We also analyzed economic data for slip liner and boat lift companies, visitor data for  
168 marinas, and selected, qualitative responses. Quantitative data were compiled from the survey in  
169 SPSS.™ They were organized for slip liners and boat lifts by ranges of cost and dimensions and

170 for marina visitors by regions of origin and destination. Qualitative responses were evaluated by  
171 summarization and comparative analyses.

172

### 173 **3. Results and Discussion**

#### 174 **3.1 Marinas**

175 A total of 98 Californian and 8 Mexican marina (and harbor and yacht club) managers  
176 completed a survey instrument. Regions by percentage of total sample included: San Francisco  
177 Bay area (34%), California South Coast (32%), San Diego (12%), Delta (7%), Mexico (7%),  
178 Central Coast (4%) and North Coast (3%).

179 Marinas reported a wide range of 20-3,675 slips with a mean of 369, a median of 259 and  
180 a large, standard deviation of 433.83. Ninety-seven marinas reported their percentage of filled  
181 slips with a mean of 86.8%, median of 95% and standard deviation of 19.24. This suggests that  
182 in 2008 it was very common for marinas to be full; those that were not full had a low vacancy  
183 rate.

184 Sixty-two marinas reported that tenure for regular tenants was 5-48 years with a mean of  
185 9.4 years, a median of 5 years and standard deviation of 10.8. Thus, tenants typically rented from  
186 a marina for 5-9 years but some stayed much longer. Ninety-two marinas reported that 0%-95%  
187 of regular tenants rarely left the slip with a mean of 47.9%, a median of 51.5% and standard  
188 deviation of 25.94. This mirrors CDBW's 2002 finding that about half of boat owners rarely  
189 travelled more than 100 miles from home port. Because half of boats rarely leave the marina,  
190 they would be good candidates for nontoxic or less-toxic fouling control strategies in areas where  
191 copper pollution from antifouling paints is a concern.

192 Of 92 marinas reporting, the minimum monthly slip rate was \$2.50-\$27.60 per foot of boat

193 length with a mean of \$10.37, a median of \$9.00 and standard deviation of 4.89. The maximum  
194 rate range was much greater: \$6.55-\$52.72 per foot with a mean of \$18.88, median of \$15.88 and  
195 standard deviation of 11.88.

196 Nearly all (84%) of 91 marinas overall and all 7 Baja Californian marinas reported that  
197 boat repair facilities were nearby; 21% in California and 25% in Baja California, respectively,  
198 reported they were onsite. Facilities to haul boats for fouling removal and hull refinishing are  
199 thus readily available to boaters traveling on California's coast and Delta and in Ensenada, Los  
200 Cabos and La Paz areas of Baja California.

201 Of 100 marinas reporting, 81% permitted in-water hull cleaning in their facilities; 88% of  
202 8 Baja California marinas allowed it. Further, 35% of 99 marinas recommended hull-cleaning  
203 companies to customers and 63% of 8 Baja California marinas did so. Baja California hull  
204 cleaners were typically marina employees, thus hull cleaning was a marina revenue source. Of 89  
205 marinas 51% allowed slip liners and 45% allowed boat lifts. None reported having in-water  
206 scrubbing stations. Thus, if restrictions on copper antifouling paints spread, boat owners with  
207 nontoxic or less-toxic hull coatings would have considerable access to hull-cleaning services  
208 and, to a lesser extent, slip liners or boat lifts to assist them in controlling fouling locally and  
209 while traveling.

210 Marinas were asked about their experience with various types of hull coatings. Of 73  
211 marinas, 38% reported experience with nontoxic hull coatings. Their experience with specific  
212 types of nontoxic hull coatings included: 11% with ceramic-epoxy hull coatings; 5% with  
213 silicone hull coatings; and 4% with siliconized-epoxy hull coatings.

214 They were also asked about types of hull coatings on customers' boats. Of 55 marinas  
215 overall, the mean percentage of customers' boats with copper bottom paint was 70%; 8 Baja

216 California marinas reported that all of their customers' boats had copper bottom paint. 38  
217 marinas reported a mean of 13% of customers' boats had zinc bottom paint; 1 Baja California  
218 marina reported 5% of customers had zinc paints and another reported 50% of customers had  
219 zinc paints. Given the dominance of copper bottom paints reported below by boat repair yards  
220 and hull cleaners, these figures suggest that customers do not consistently report their boat  
221 bottom paint types to marinas.

222         Of 37 marinas, the percentage of customers' boats with nontoxic hull coatings was 0%-  
223 100% with a mean of 10% and median of 0%. The mean is high, but the median estimate for  
224 marinas is in line with hull cleaners' and boat repair yards' reports of the share of their  
225 businesses represented by nontoxic epoxy and slick coatings.

226         Fifty-four marinas (51 Californian, 3 Mexican) reported on average that 41% of  
227 customers were aware of nontoxic hull coatings versus only 20% awareness one-two years ago  
228 (50 marinas, including 48 Californian, 2 Mexican). Of 78 marinas (74 Californian, 4 Mexican)  
229 82% said they would recommend nontoxic hull coatings to their customers; of 66 marinas (63  
230 Californian, 3 Mexican) 64% would recommend other alternatives to copper-based paints.

231         These findings suggest that, although they may not know details of customers' hull  
232 coatings, a substantial proportion of marinas had discussed hull coatings with their customers.  
233 Further, their belief that customers' awareness of alternatives to copper-based paints had doubled  
234 in the past 1-2 years suggests that educational programs have been effective.

235         Most marina managers would be willing to recommend alternatives to copper  
236 antifoulants, yet they would need more information on such products. The exception was at  
237 Shelter Island Yacht Basin of San Diego Bay, where a regulatory program to reduce copper  
238 emissions from boat bottom paints had begun and marinas' familiarity with such alternatives to

239 copper boat bottom paints was high.

240           Overnight visitors are an indicator of risks for invasive species transport by recreational  
241 boats. Marinas were asked the percentages of slips rented by overnight visitors from Northern  
242 (San Francisco Bay area to Oregon border), Central (Santa Cruz, Monterey, San Luis Obispo  
243 Counties) and Southern (Santa Barbara County to Mexican border) California coastal areas,  
244 Sacramento-San Joaquin Delta area, Baja California, Baja California Sur, Mainland Mexico and  
245 other states or countries. Responses indicated considerable traffic of boats occurs along the  
246 California and Baja California coasts and between the coast and the Sacramento-San Joaquin  
247 Delta.

248           Northern California boats traveled widely, suggesting that the most active vessels  
249 represent a significant, potential vector for long-distance coastal transport of invasive species.  
250 One Central California marina reported that 60% of its slips were rented to overnight visitors  
251 from Northern California; in Southern California four marinas reported 5%- 25% of slips were  
252 rented to Northern California overnight visitors; one marina in Los Cabos and one marina in La  
253 Paz each reported 10% of slips were rented to Northern California visitors.

254           Delta boats traveled most commonly to San Francisco Bay, where 11 marinas reported  
255 that 5%-88% of slips were rented to overnight visitors from the Delta. One Central Coast marina  
256 reported 5% of slips and one North Coast marina reported 20% of slips were rented to Delta  
257 visitors. This suggests that Delta boats represent a smaller proportion of the risk for transporting  
258 invasive species along the coast. Further, as Delta waters range from brackish to fresh, invasive  
259 species are likely to be killed as boats move in either direction between the Delta and San  
260 Francisco Bay.

261 The heaviest traffic by Central California boats was to San Francisco Bay, where 10  
262 marinas reported that 1%-100% of slips were rented to overnight visitors from Central  
263 California. One North Coast marina reported 10% of slips, five Southern California (South Coast  
264 and San Diego) marinas reported 0.25%-10% of slips, and one marina in La Paz reported 10% of  
265 slips were rented to Central California visitors. Reports of heavy traffic by Central California  
266 boats to San Francisco Bay are in line with studies of Elkhorn Slough (which drains to Monterey  
267 Bay) that found large numbers of invasive species common to San Francisco Bay, likely brought  
268 by local boats returning from that destination (Cohen *et al.* 2002).

269 The heaviest traffic by Southern California boats was to Mexico, where four Ensenada  
270 marinas reported that 80%-100% of slips and where one Los Cabos marina and one La Paz  
271 marina each reported that 50% of slips were rented to overnight visitors from Southern  
272 California. However, one North Coast marina reported that 30% of slips were rented to Southern  
273 California visitors. In contrast six San Francisco Bay marinas reported that 0.3%-15% of slips,  
274 one Delta marina reported 1% of slips, and one Central Coast marina reported that 8% of slips  
275 were rented to Southern California visitors.

276 Events, such as races, celebrations, holidays and fishing seasons may attract boats from  
277 many areas. The 4<sup>th</sup> of July was the single, most important event as it was cited by 29%-33% of  
278 marinas in the San Francisco Bay, South Coast and San Diego areas and by 20%-25% of marinas  
279 in the North and Central Coast areas. Most marinas reported that boaters stayed 2-3 nights for  
280 this event; two marinas reported 4-night stays. Other events that drew boats included Fleet Week,  
281 boat shows and parades, local festivals, Labor Day and Kaboom (San Francisco Bay). Races  
282 generally drew boaters from other areas for 2-5 nights, including numerous local sailboat,  
283 powerboat, Jet Ski™, hydroplane and yacht club races. Named races were Spinnaker Cup, ATT

284 Pro Am, PHRF Championships, Marina Del Rey, King Harbor, Oceanside to Southwestern  
285 Yacht Club, and Cabrillo Series.

286 Bi-national races were particularly popular. The annual Baja Haha race proceeds by  
287 stages from San Diego to the southern Baja California peninsula. It was cited as a source of  
288 overnight visitors by 39% of San Diego marina managers, 50% of Los Cabos area marina  
289 managers and 100% of La Paz area marina managers who responded to the survey. Fleet  
290 Underway to Baja Rally (FUBAR) race begins in San Diego and ends in La Paz, where one  
291 marina reported that boaters might stay for 30 nights after this event. Mexican marina managers  
292 reported that Baja Haha race visitors stayed for 5-6 nights. The Newport to Ensenada race was  
293 cited by 75% of Ensenada marina managers who reported that visitors stayed 2-4 nights. One  
294 South Coast and one San Diego marina each reported that visitors stayed 3 nights for this race.  
295 Thus, boaters gathered before the races and some lingered at waypoints and/or destinations for a  
296 few days.

297 Two seasons were cited as drawing boats from other areas. Fishing season was reported  
298 by 67% of North Coast marinas, 15% of San Francisco Bay marinas and 25% of Central Coast  
299 marinas. This is likely the commercial fishing season, as one San Francisco Bay marina reported  
300 that boats stayed 90 nights for crab season and 30 nights for salmon season. Summer season was  
301 reported by 10% of South Coast marinas.

302 These findings suggest that actively traveling, Northern, Central and Southern California  
303 boats represent a significant, potential vector for long-distance transport of invasive species  
304 along California's coast and between California and Baja California. Active Central California  
305 vessels also represent a significant, potential vector for invasive species from and to San  
306 Francisco Bay. Delta boats represent a much smaller share of coastwise traffic and invasive

307 species are likely to be killed by changes in salinity as boats move from and to the Delta.  
308 Anecdotal comments suggest that some vessel owners use these salinity variations to enhance  
309 control of hull fouling.

310 Findings also suggest that events may increase risks for long-distance, invasive species  
311 transport by encouraging trips beyond the home area to locations where boats from multiple  
312 areas may mingle, increasing exposure to various species that may not be present in the home  
313 port. Longer stays further heighten risks that invasive species will become established on hulls of  
314 visiting boats and be transported to the next waypoint or to the boat's home port. Yet, events also  
315 provide points of contact for targeted education programs that explain invasive species risks and  
316 encourage participants to be especially diligent about fouling control and seawater system  
317 flushing in association with the event.

318

### 319 **3.2 Hull-Cleaning Companies**

320 A total of 23 Californian and 4 Mexican hull cleaners responded, including 37% from the  
321 South Coast, 30% from the San Francisco Bay area, 15% from Mexico, 11% from San Diego  
322 County and 7% from the Central Coast. Thus, nearly half of the hull cleaners responding to the  
323 survey were located in Southern California and nearly a third were in the San Francisco Bay  
324 area. They were sampled proportionately among California regions, except for the North Coast  
325 and Delta, for which no surveys could be completed. California hull cleaners were typically  
326 independent businesses; Mexican hull cleaners were typically marina employees. Hull cleaner's  
327 customers were primarily from Southern California; a mean of 54% of Californian hull cleaners'  
328 customers and a mean of 69% of Mexican hull cleaners' customers were from this area.

329           The median number of boats serviced was 260 in California and 100 in Mexico. Copper  
330 hulls on average represented 83% of hull cleaners' business and the median was 100%. Mexican  
331 data was only available for copper hull coatings; all non-copper data was Californian and came  
332 from only 10 respondents. Clearly, copper hulls dominated the market. Only 10 hull cleaners  
333 provided data on most variables for non-copper hull coatings. Zinc hulls on average represented  
334 9% of business, but the median was 0%. Overall, the percentage of boats with nontoxic coatings  
335 represented a very small part of the hull cleaning business with a mean value of 4.35%. Almost  
336 all respondents claimed to have experience with epoxy (nontoxic) coatings and a little more than  
337 half specified ceramic-epoxy. Less than 40% reported experience with slick (nontoxic) hull  
338 coatings, specifically silicone, siliconized epoxy or siloxane. Mexican hull cleaners reported no  
339 experience with zinc and nontoxic slick coatings; only one reported any experience with  
340 nontoxic, ceramic-epoxy coatings.

341           Generally, cleaning times and costs were influenced by length and type of boat, type of  
342 hull coating and season of the year. Hull cleaning charges were quoted per foot of boat length for  
343 25-foot to 60-foot boats. Hull cleaning in California required on average 1 person and 28-78  
344 minutes and in Mexico required on average 1.5 persons and 50-150 minutes. These binational  
345 differences likely reflect the fact that powered cleaning tools were more common among  
346 California hull cleaners. They may also reflect differences in labor costs.

347           Hull-cleaning times varied considerably (Table 1), although on average sailboats cost less  
348 and took less time to clean than powerboats. Overall, copper hulls cost less and were cleaned  
349 faster than other coatings. Although it is not apparent in the ranges shown in the table, data  
350 analysis found that on average Mexican hull cleaners charged less than their California  
351 counterparts to clean copper hull coatings. Zinc coatings were second cheapest to clean. Prices

352 ranged from \$1.65 per foot for copper coatings on smaller sailboats to \$2.55 per foot for epoxy  
353 (nontoxic) coatings on powerboats.

354         If cleaning time exceeded the average by 25-30 minutes or more, additional charges  
355 ranged from \$2.68 per foot for copper to \$4.74 per foot for epoxy (nontoxic). Roughly 80% of  
356 hull cleaners would recommend that the boat have its hull coating replaced, if the average  
357 cleaning time was exceeded by at least 25-30 minutes. Similar responses were received from  
358 Mexican and Californian hull cleaners.

359         On average metal-based coatings were cleaned less often than nontoxic coatings (Table  
360 2). Each coating type was cleaned most often in summer, except that nontoxic slick coatings  
361 were cleaned with the same frequency year-round, possibly reflecting their popularity for year-  
362 round, racing boats. Epoxy coatings were cleaned more often than all other coatings in  
363 California. Higher cleaning frequencies for copper coatings in Mexico may be influenced by the  
364 overall higher water temperatures in Mexico; we found in 2002-2003 that water temperature was  
365 the most important factor in growth rates of hull fouling. (Johnson and Gonzalez 2004) It may  
366 also reflect our current finding that Mexican hull cleaners were often marina employees, creating  
367 an incentive for marinas to remind customers about hull cleaning services.

368         Hull cleaners reported that on average approximately 34% of their customers were aware  
369 of nontoxic hull coatings versus 26% one year ago. Mexican hull cleaner responses were similar  
370 with respective means of 30% and 27.5%. 77% of respondents said they would recommend  
371 nontoxic hull coatings and 73% said they would recommend other alternatives to copper.  
372 Mexican hull cleaners were less inclined than the total population to recommend non-toxic or  
373 alternative coatings with respective means of 67% and 33%.

374 In summary, copper hull coatings dominated the market for hull cleaning services.  
375 Copper coatings were cheapest to clean among all coatings in California and Mexico on  
376 sailboats, powerboats and for additional cleaning charges when time exceeded the average by at  
377 least 25-30 minutes. Mexican hull cleaners charged less on average and took longer to clean  
378 copper hull coatings than did California hull cleaners. Shorter, average cleaning times in  
379 California may reflect greater use of powered, hull-cleaning tools than in Mexico.

380 Results indicate that hull-cleaning services are readily available for recreational boats in  
381 the areas of San Francisco Bay, California South Coast, San Diego, Ensenada, Los Cabos and La  
382 Paz. Thus, a base, hull-cleaning capacity exists in the major Californian and Baja Californian  
383 saltwater, recreational boating harbors for preventing transport of invasive species on  
384 recreational boats. However, since few hull cleaners reported having experience with nontoxic  
385 hull coatings, especially in Mexico, the industry would need to increase capacity to control  
386 fouling on such coatings if restrictions on using copper-based, antifouling paints spread beyond  
387 Shelter Island Yacht Basin of San Diego Bay.

388

### 389 **3.3 Boat Repair Yards**

390 A total of 33 boat repair yards (28 Californian and 5 Mexican) responded to the survey.  
391 The South Coast region represented approximately 42% of the total with the rest distributed as  
392 15% San Francisco Bay area, 15% Mexico, 10% San Diego, 10% Central Coast and 6%  
393 Sacramento-San Joaquin Delta. The South Coast was somewhat over-represented in the sample;  
394 other regions were at or near the 30% sampling target. Boatyards reported that locations from  
395 which their customers originated were similar to the locations of the yards. However, customers  
396 from Southern California (South Coast, San Diego) and Northern California (North Coast, San

397 Francisco Bay) were over-represented relative to the actual number of boatyards in those areas  
398 (50% and 23% of customers respectively). Mexican boat owners comprised 11% of customers  
399 reported in the survey. No boat repair yards were located in Humboldt Bay in Northern  
400 California; the Harbor District will haul boats from the water and place them on blocks where  
401 owners can conduct maintenance, repairs and hull refinishing.

402 Copper coatings dominated the market for coating applications, representing a mean of  
403 78% and a median of 90% of business among all boat repair yards (Table 3). Among California  
404 boatyards, nontoxic epoxy coatings represented only 3% of mean business, zinc coatings  
405 represented only 1% of mean business and nontoxic slick coatings were rare at 0.04% of mean  
406 business. The scarcity of alternative coating applications in California was underscored by  
407 median values of 0% of business. Alternative coatings were even rarer in Mexican boat repair  
408 yards; none reported applying nontoxic epoxy or slick coatings and only one reported applying  
409 zinc coatings to just 10 boats per year, representing 10% of that yard's business.

410 Questions on the amount of business represented by alternative coatings received 28  
411 responses for zinc coatings, 27 responses for nontoxic epoxy coatings and 27 responses for  
412 nontoxic slick coatings. All other questions received 10 or fewer responses for each of these  
413 alternative hull coatings.

414 Table 4 presents mean costs per foot of boat length versus categories of boat lengths. The  
415 mean total cost to prepare for and apply copper paints to sailboats increased with boat length,  
416 ranging from approximately \$33/ft for a 15-20 foot boat to \$52/ft for a 91-100 foot boat.  
417 Mexican boatyards gave a range of \$16.71/ft for 31-35 foot sailboats to \$65/ft for 91-100 foot  
418 sailboats. Powerboat costs were similar, increasing with length from \$34/ft for the shortest boat  
419 to \$52/ft for the longest. There were many responses for boats up to 60 feet in length and few

420 responses for boats over 60 feet, which suggests that few boaters have such large boats. Mexican  
421 boatyards gave a range from \$17.21/ft for 31-35 foot sailboats to \$65/ft for 91-100 foot sailboats.  
422 Data were rare for slick coatings, including one report of \$150/ft for 15-20 foot long boats and  
423 one report of \$101/ft for 61-70 foot long boats.

424         Although approximately half of respondents said they would recommend nontoxic hull  
425 coatings and other alternatives to copper, very few reported applying non-copper coatings. Data  
426 must be considered in that light. However, boatyards that worked with nontoxic epoxy or slick  
427 hull coatings reported that copper represented only 70% of business versus 95% of business for  
428 other yards. They were also significantly larger than average, coating a median of 700 boat  
429 bottoms per year compared to 200 copper boat bottoms for a typical boatyard. None were in  
430 Mexico.

431         The mean total cost to prepare for and apply zinc paints increased with boat length,  
432 ranging from approximately \$34 per foot for a 15-20 foot boat to \$66 per foot for a 91-100 foot  
433 boat. Mean total cost per foot to prepare for and apply epoxy (nontoxic) coatings increased as  
434 boat length increased, except that it was much lower for the largest boats. Mean cost per foot was  
435 \$112.33 for 15-20 foot boats, \$114.50 for 21-25 foot boats, and \$115.50 for 26-35 foot boats.  
436 However, it was \$82.50 per foot for 91-100 foot boats. The minimum cost for all boat lengths  
437 was \$50 per foot. The mean total cost to prepare for apply slick (nontoxic) \$150 per foot for 15-  
438 20 foot boats and \$101 per foot for 61-70 foot boats.

439         Preparation costs for nontoxic coatings likely reflect the fact that old, metallic coatings  
440 typically must be stripped at a mean cost of \$89/ft before nontoxic epoxy or slick coatings can be  
441 applied. The median number of boats whose hulls were stripped was 17.5 per year; the mean was  
442 32 boats, reflecting a few, high-capacity boatyards.

443 Table 5 shows detailed cost breakdowns for boat repair yards to apply hull coatings.  
444 Overall, labor comprised the largest share of costs to prepare for and apply hull coatings with  
445 means of 55%-57% for metallic coatings and 63% for nontoxic coatings. Mean materials costs as  
446 a percentage of total costs ranged from 30% for nontoxic slick to 41% for zinc coatings.  
447 Environmental fees as a percentage of total costs ranged from 2% for nontoxic epoxy to 5% for  
448 copper coatings. Other costs as a percentage of total costs ranged from 0% for nontoxic epoxy to  
449 3% for nontoxic slick coatings. Higher labor costs for nontoxic coatings may reflect that many  
450 must be applied after metallic coatings have been stripped off the hull and that special  
451 application techniques are needed for some products. Improvements in products and stripping  
452 techniques may reduce these cost factors for nontoxic coatings.

453 The mean frequency of new copper coating applications was once every 2.5 years for the  
454 whole population and once every 3.5 years for Mexican boatyards. Very few boatyards provided  
455 replacement frequency for non-copper coatings, so data must be considered in that light. The  
456 mean frequency of new zinc coating applications was once every 1.8 years. The mean frequency  
457 of new nontoxic epoxy coatings was once every 3 years. The mean frequency of new, nontoxic  
458 slick coating applications was 5 years. Note that our research in San Diego found that a nontoxic  
459 epoxy coating lasted eight years on one boat. (Gonzalez and Johnson 2007)

460 Boat bottoms must be stripped of old paint, if water has penetrated the coating, creating  
461 blisters, if paint is chipping, and often before applying nontoxic coatings. The mean charge to  
462 strip a boat bottom was \$89/ft. The median number of boats stripped per year was 17.5 with the  
463 mean being 32 boats due to a few, high-capacity boatyards. The mean number of boats stripped  
464 by Mexican boatyards was 22, roughly in line with the numbers handled by California boatyards.  
465 Thus, capacity to prepare hulls for nontoxic coatings exists in California and Mexico.

466 Results point to a low, boatyard capacity for applying alternatives to copper antifouling  
467 paints. Some alternatives require processes and/or equipment that differ from those used for  
468 copper paints. Should local, regional or state restrictions be instituted for copper antifoulants in  
469 response to water quality concerns, more boatyards would need to develop this capacity in order  
470 to meet demand. At least some of the boatyards in the San Diego region have developed this  
471 capacity. One boatyard in the San Francisco Bay has contacted the authors regarding their intent  
472 to shift much or all of their coating application business to nontoxic coatings. Such “early  
473 adopters” may serve as models should demand increase for alternatives to copper antifouling  
474 paints.

475 Sixty-three percent of respondents offered haul-out and cleaning packages with no  
476 noticeable difference in frequency between California and Mexico. The cost per foot ranged  
477 from approximately \$11/ft for the shortest boat to \$12.94/ft for the longest boat. By comparison,  
478 hull cleaning companies (see above) charged from \$1.65/ft for the smallest sailboats to \$2.52/ft  
479 for the largest powerboats. Thus, substantial savings could be achieved by using hull cleaning  
480 services, instead of hauling boats out of the water, for routine fouling control on boats that are  
481 already in the local area. Only 10% of respondents, all of which were in Mexico, offered  
482 underwater hull cleaning services. No boatyards reported offering in-water scrubbing stations for  
483 boat hulls.

484 All except one boatyard claimed to use pressure hoses to remove biofouling. Fourteen  
485 percent of all and 25% of Mexican respondents claimed to leave boats out of water to remove  
486 biofouling. Just over half of boatyards disposed of biofouling by filtering it and throwing it into  
487 the trash; some disposed it as hazardous waste (28%). No Mexican boatyards reported on  
488 biofouling disposal. Thus, some capacity already exists among boatyards for proper disposal of

489 invasive species removed from hulls. Education of the remaining boatyards will be needed to  
490 further reduce risks from disposal of biofouling.

491

### 492 **3.4 Industry Perceptions: Customers' Awareness of Nontoxic Hull Coatings**

493 Marina, hull cleaning and boat repair industry representatives believed that customers'  
494 awareness of nontoxic hull coatings had increased in the past one to two years (Table 6).

495 Boatyard figures were probably most reliable, as they discuss with customers which coatings will  
496 be applied during hull refinishing. However, marinas in Shelter Island Yacht Basin of San Diego  
497 Bay were also having specific discussions with their tenants about bottom paints because they  
498 were required to reduce copper emissions in their facilities. The three Mexican boatyards that  
499 responded to this question reported mean customer awareness of 50% now and 42% one to two  
500 years ago, possibly indicating a preponderance of customers from Southern California who face  
501 restrictions on copper paints. Results suggest that educational programs have been effective.

502 Data on current awareness levels were included in the analysis of influences on coating choice  
503 discussed in section 3.4 below.

504

### 505 **3.5 Comprehensive, Average Cost To Use Each Paint Type**

506 The average cost to use each type of paint was calculated to provide a single,  
507 comprehensive unit of comparison among the paint types. The analysis included costs provided  
508 by marinas, hull cleaners and boat repair yards. Average costs were calculated in dollars per foot  
509 of boat length across both sailboats and powerboats and for all length categories. Time units  
510 varied among cost types.

511 Calculations were based on 51 observations for boats with copper antifouling paint, 12  
512 for boats with zinc antifouling paint and 12 for boats with nontoxic epoxy paint. Costs for boats  
513 with nontoxic slick paint were not calculated, because there were so few observations for this  
514 coating type.

515 Relative, comprehensive, average costs were found to be \$20.49/foot for copper  
516 antifouling paints, \$24.99/foot for zinc antifouling paints and \$36.33/foot for nontoxic epoxy  
517 paints. In other words, using a zinc antifouling paint would cost \$4.50/foot more on average than  
518 using a copper antifouling paint. Using a nontoxic antifouling paint would cost \$15.84/foot more  
519 on average than using a copper antifouling paint.

520 When choosing among paint types, based on cost of use, boat owners should also  
521 consider the expected service life. Economic research on phasing out metal-based antifouling  
522 paints on recreational boats in San Diego Bay also found copper-based antifouling paints are  
523 initially less expensive. However, nontoxic epoxy coatings tend to last much longer and thus  
524 may become more cost effective in the long run. (Carson *et al.* 2009) Boatyards reported mean  
525 service life of 2.5 years for copper paints, 1.8 years for zinc paints, 3.0 years for nontoxic epoxy  
526 paints and 5.0 years for nontoxic slick paints. This finding is also supported by our field research  
527 that found three nontoxic epoxy coatings had lasted from 5 to 5.5 years and a fourth lasted 8  
528 years on boats in San Diego Bay by October 2007. (Gonzalez and Johnson 2007) In contrast we  
529 identified a mean service life of 2.5 years for copper antifouling paints in our 2002 survey of 200  
530 boat owners. (Carson *et al.* 2009) The longer service life of nontoxic epoxy paints may balance  
531 the higher, average costs calculated in this analysis. In the current study, 48% of boat repair  
532 yards were uncertain whether boat owners could achieve cost savings by using nontoxic

533 coatings; 26% expected savings and 26% did not. This suggests a need for educating boat repair  
534 yards on this topic.

535

### 536 **3.6 Analysis of Influences on Coating Choice**

537 Statistical analyses (regressions) were conducted to test the influences of average coating  
538 cost, awareness of nontoxic coatings and location of the marina, hull cleaning or boat repair  
539 industry respondent in California or Mexico on choice of coating. Note that coating choice  
540 reflected the share of each respondent's business represented by the particular type of coating.  
541 With coating choice as the dependent variable, regressions were conducted using observations  
542 from both countries that were grouped by coating type (copper, zinc, nontoxic). The independent  
543 variables, average cost of the coating and awareness of nontoxic coatings, were measured in  
544 different units. The independent variable, binationalness, indicated whether the respondent was  
545 located in California or Mexico.

546 First, the average costs for copper, zinc and nontoxic coatings were calculated as the  
547 overall, mean charge for all boat sizes, for both sail and powerboats, and for marinas, boatyards  
548 and hull cleaners. Note that the average cost for nontoxic coating was calculated only for the  
549 epoxy coatings because very few surveys reported prices for slick coatings. Awareness of  
550 nontoxic coatings was measured in terms of the percentage of customers who knew about  
551 nontoxic coatings, according to each industry respondent's perception. The statistical analyses  
552 were conducted using a log-log form of the data, in order to deal with the different units of  
553 measure for the variables and still be able to compare the relative sizes of the estimated statistical  
554 coefficients of influence. (In other words, before the regressions were conducted, data were

555 transformed to logarithmic values that have no units. Note, however, that average costs discussed  
556 above for each coating type are based on actual figures, not their log transformations.)

557 Cost of the coating type and binationalness were not significant influences in any of the  
558 regressions. (Note that the regression for each coating type was run twice, once with and once  
559 without binationalness.) Awareness of nontoxic coatings was not a significant influence in the  
560 regressions for choice of copper or zinc coatings.

561 However, the regression for nontoxic coatings did yield a statistically significant result.  
562 In this analysis only the nontoxic epoxy coating observations were used, as there were so few  
563 observations for nontoxic slick coatings. With 29 observations in this case, at the 10%  
564 confidence interval level of statistical significance, an increased awareness of nontoxic coatings  
565 influenced the choice of nontoxic coating positively. This suggests that educational programs  
566 may be effective in influencing boat owners' decisions of coating choice. Further, boating  
567 industries may be effective in assisting customers to learn about and choose nontoxic coatings,  
568 should restrictions on copper-based bottom paints become more widely spread.

569

### 570 **3.7 Slip Liner and Boat Lift Companies**

571 Slip liners and boat lifts provide alternatives to periodic, in-water or haul-out hull  
572 cleaning for boats in saltwater. In California slip liner business appears to be concentrated in  
573 Southern California (South Coast and San Diego regions), whereas boat lift business appears to  
574 be concentrated in Northern California (North Coast and San Francisco Bay regions) and the  
575 Delta. Both products are available in a wide range of prices, sizes and shapes, customizable to  
576 individual boats. Slip liners (3 respondents) were on average less expensive with mean minimum  
577 cost \$1,046, standard deviation 372.26 and mean maximum cost \$6,800, standard deviation

578 1,311.41 than were boat lifts (17 respondents) with mean minimum cost \$3,319, standard  
579 deviation 4,642.23 and mean maximum cost \$27,150, standard deviation 26,797.9. Slip liner  
580 companies responding to the survey were far more likely (100%) to remove equipment  
581 abandoned at a marina than responding boat lift companies (12%). Slip liner removal would cost  
582 \$0-\$250.

583         Only one of the three, responding slip liner companies and none of the seventeen boat lift  
584 companies had experience with boats having nontoxic hull coatings. Yet, all three slip liner  
585 companies and 29% of boat lift companies would recommend nontoxic hull coatings and other  
586 alternatives to copper-based bottom paints to their customers. Both types of companies reported  
587 increased, customer awareness of nontoxic coatings now versus one or two years ago. (Note that  
588 their responses were not included in the statistical regression discussed in section 3.6.)

589 Concentration of slip liner companies in Southern California, where regulatory scrutiny of  
590 copper-based, antifouling paints is increasing, may have influenced their comments on nontoxic  
591 and other alternatives to copper paints.

592         Thus, capacity existed in some regions to provide slip liner and boat lift equipment for  
593 boat owners needing alternatives to copper bottom paints and to assist in preventing transport of  
594 aquatic invasive species. Such types of equipment may be cost effective, especially for smaller  
595 boats in areas where copper bottom paints may be restricted and if the marina permits them.

596

#### 597 **4. Conclusions**

598         Options for fouling control on recreational boat hulls were explored in California and Baja  
599 California through a supply-side analysis of private and public sector marina (and harbor and  
600 yacht club), hull cleaning, boatyard, slip liner and boat lift supply and service providers. The

601 survey and subsequent summary statistics offer a perspective of current and potential use of  
602 antifouling options with some characteristics of the binational boating traffic relevant for  
603 addressing two different realms of environmental policy: invasive species and copper  
604 accumulation in coastal marinas.

605         Approximately half of boats rarely leave the typical California coastal marina. Among  
606 those that do leave the marina, approximately half rarely travel more than 100 miles from home  
607 port. Such boats would be good candidates for nontoxic or less-toxic fouling control strategies in  
608 areas where copper pollution from antifouling paints is a concern. In contrast active, long-  
609 distance racing, cruising and fishing boats discharge relatively less copper pollution to a marina  
610 and pose greater risks for transporting invasive species. They may be better candidates for  
611 copper-based and other, pesticidal hull coatings.

612         Overnight visitors from other regions, states and nations were attracted by events such as  
613 holidays, celebrations, races and commercial fishing seasons. Events both increase risks of and  
614 provide an opportunity to educate participants on best practices to prevent introductions and  
615 transportation of invasive species along the coast.

616         A base, hull-cleaning capacity exists in the major Californian and Baja Californian  
617 saltwater, recreational boating harbors for preventing transport of invasive species on  
618 recreational boats. However, few hull cleaners have experience with nontoxic hull coatings,  
619 especially in Mexico. If restrictions on copper antifouling paints spread, the industry would need  
620 to increase its capacity to serve boat owners who had selected nontoxic or less-toxic hull  
621 coatings. To a lesser extent, slip liners or boat lifts are available to assist boat owners in  
622 controlling fouling in the home marina.

623           Hauling boats to remove fouling is substantially more costly than in-water hull cleaning.  
624   Thus, in-water cleaning services may be most appropriate for periodic fouling control on boats  
625   that remain in the home marina, harbor or port and thus do not pose a risk for transporting  
626   invasive, fouling species.

627           Boat repair facilities to haul boats and to provide fouling removal and hull refinishing are  
628   readily available to boaters traveling California's coast, Delta and the Ensenada, Los Cabos and  
629   La Paz areas of Baja California. The exception is Humboldt Bay, where the Harbor District will  
630   only haul boats from the water and place them on stands; boat owners must perform or hire  
631   contractors for fouling removal and hull refinishing services.

632           Boat hulls must often be stripped of old paint before nontoxic coatings are applied. Hull  
633   stripping capacity exists in California and Baja California but such services are costly. More  
634   cost-effective techniques or subsidies for hull stripping may be needed to foster conversions to  
635   nontoxic hull coatings by California's typically middle-income, recreational boat owners.

636           Relative, comprehensive, average costs to use hull coatings were found to be \$20.49/foot  
637   for copper, \$24.99/foot for zinc and \$36.33/foot for epoxy (nontoxic). However, the longer,  
638   service life of epoxy (nontoxic) hull coatings may balance the higher, average cost to apply and  
639   maintain them that was calculated in this analysis.

640           Results point to a low, boatyard capacity for applying alternatives to copper antifouling  
641   paints. Some alternatives require processes and/or equipment that differ from those used for  
642   copper paints. Should local, regional or state restrictions be instituted for copper antifoulants in  
643   response to water quality concerns, more boatyards would need to develop this capacity in order  
644   to meet demand. At least some of the boatyards in the San Diego region and one in the San

645 Francisco Bay area have developed this capacity. Such “early adopters” may serve as models  
646 should demand increase for alternatives to copper antifouling paints.

647         Some capacity exists among boatyards for proper disposal of aquatic invasive species  
648 removed from hulls. Over one-fourth dispose biofouling as hazardous waste and over half  
649 dispose it in the trash.

650         All five boating industry groups believed that boat owners’ awareness of nontoxic hull  
651 coatings had increased compared to one or two years ago, although the level of change varied  
652 among the groups. This suggests that they are talking with customers about alternatives to copper  
653 bottom paints.

654         A statistical regression found that increased, customer awareness of nontoxic coatings  
655 influenced the choice of nontoxic coating positively. This suggests that education programs have  
656 been effective and that boating industries may play a role in assisting customers to learn about  
657 and choose nontoxic coatings, should restrictions on copper-based bottom paints become more  
658 widely spread.

659         Capacity to provide slip liners is best developed in Southern California and capacity to  
660 provide boat lifts is best developed in Northern California and the Sacramento-San Joaquin Delta  
661 for boat owners needing alternatives to copper bottom paints and to assist in preventing transport  
662 of aquatic invasive species. Such types of equipment may be cost effective, especially for smaller  
663 boats in areas where copper bottom paints may be restricted and if the marina permits them.

664         In conclusion a base capacity to control invasive and other, fouling species exists among  
665 boating industries located in major, Californian and Baja Californian, coastal recreational  
666 boating harbors and in the Sacramento-San Joaquin Delta of California. However, capacity needs  
667 to be expanded to assist boat owners with control of fouling on nontoxic and less toxic hull

668 coatings. Further, cost-effectiveness will be critical in developing policies to co-manage invasive  
669 species and water quality via fouling control for boats owned by California's typically middle-  
670 income, recreational boaters. Education has proven effective in influencing coating choices and  
671 may thus be expected to be effective in influencing best practices for controlling invasive, hull-  
672 fouling species while protecting water quality.

673

#### 674 **Acknowledgments**

675 We wish to acknowledge the following people who also contributed to the research  
676 reported in this paper: Cesar Alvarez, Kevin Campbell, Jennie Daniels, Brad Franklin, Jamie  
677 Gonzalez and Monobina Mukherjee. We gratefully acknowledge the members of the Project  
678 Advisory Committee and the many boating industry members who provided data. The research  
679 was supported in part by: California Department of Boating and Waterways under Agreement  
680 No. 06-106-109; California Department of Pesticide Regulation under Agreement No. 06-0069C;  
681 NOAA Grants No. NA08OAR4170669 and NA04OAR4170038, California Sea Grant Project  
682 No. A/EA-1 through NOAA's National Sea Grant College Program, U.S. Dept. of Commerce;  
683 University of California Agriculture and Natural Resources; California Resources Agency; and  
684 County of San Diego. The statements, findings, conclusions and recommendations are those of  
685 the authors and do not necessarily reflect the views of the aforementioned organizations and  
686 individuals.

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Table 1. Hull Cleaning Mean Costs and Times for Various Coatings on Sail and Power Boats<sup>c</sup>

Coating Type and Location	Sail Boat Cost/Foot Mean std. dev.	Sail Boat Minutes Mean std. dev.	Power Boat Cost/Foot Mean std. dev.	Power Boat Minutes Mean std. dev.
Copper – ALL	\$1.65 0.66	31-89 18.42-37.82	\$1.83-\$2.03 0.71-0.63	37-103 16.55-37.30
Copper – MX	\$1.03-\$2.00 0.24-0.49	50-150 1.04-26.34	\$1.03-\$2.17 0.12-0.33	60-150 13.59-25.63
Zinc – CA	\$2.06 0.54	25-67 11.26-35.19	\$2.26-\$2.31 0.43-0.22	33-76 16.23-40.88
Epoxy – CA	\$2.04-\$2.15 0.53-0.66	34-94 13.33-25.57	\$2.52-\$2.55 0.56-0.31	45-108 3.78-40.71
Slick – CA	\$2.14-\$2.20 0.28-0.31	29-84 9.70-22.75	\$2.38-\$2.52 0.50-0.35	42-93 13.04-22.25

<sup>c</sup> Boat length range was 25-60 ft for estimates and std. dev.

Table 2. Hull Cleaning Mean Frequencies for Each 3-Month Season

Coating Type and Location	Spring		Summer		Fall		Winter	
	Mean	std. dev.	Mean	std. dev.	Mean	std. dev.	Mean	std. dev.
Copper – ALL	2.48	1.34	3.04	1.92	2.30	1.36	2.21	1.10
Copper – MX	4.00	0.86	5.33	0.79	3.33	0.51	3.33	0.47
Zinc – CA	2.50	2.12	3.00	1.73	2.50	2.12	2.67	1.53
Epoxy – CA	5.33	3.78	5.43	3.46	5.33	3.78	4.57	1.99
Slick – CA	3.50	2.08	3.50	2.08	3.50	2.08	3.50	2.08

Table 3. Boat Repair Yard Coating Applications

Coating Type and Location	Boats/Yr		Boats/Yr Median	% of Business		% of Business Median
	Mean	std dev.		Mean	std. dev.	
Copper – ALL	470	511.09	270	78%	28.07	90%
Zinc – CA	13	31.15	0	1%	2.71	0%
Epoxy – CA	23	79.87	0	3%	11.01	0%
Slick – CA	0.54	1.76	0	0.04%	0.19	0%

Table 4. Boat Repair Yard Costs to Apply Coatings: Mean Cost/Foot Versus Boat Length<sup>d</sup>

Coating Type	Boat Type and Location	15-20 Ft Boats		31-35 Ft Boats		91-100 Ft Boats	
		Mean	std. dev.	Mean	std. dev.	Mean	std. dev.
Copper	Sail – All	\$33	12.22			\$52	28.53
Copper	Power – All	\$34	11.90			\$52	28.53
Copper	Sail – MX			\$16.71	7.10	\$65	16.20
Copper	Power – MX			\$17.21	8.04	\$65	16.20
Zinc	Any – CA	\$34	13.50			\$66	39.32
Epoxy <sup>e</sup>	Any – CA	\$112.33	54.37	\$115.50	39.05	\$82.50	49.96

<sup>d</sup> Data not available for all cells.

<sup>e</sup> Preparation costs for nontoxic coatings may include stripping old, metallic paint.

Table 5. Boat Repair Yard Cost Categories for Applying Different Hull Coatings

Cost Category as % of Total Cost	Copper N = 23		Zinc N = 5		Epoxy N = 3		Slick N = 3	
	Mean	std. dev.	Mean	std. dev.	Mean	std. dev.	Mean	std. dev.
Labor	55.46%	16.14	57.00%	16.43	63.00%	20.42	62.67%	11.02
Materials	36.42%	14.23	40.60%	15.27	34.67%	18.45	30.00%	0.00
Environmental Fees	5.00%	4.90	3.20%	2.86	2.33%	2.52	4.00%	5.29
“Other”	2.35%	6.75	0.60%	1.34	0.00%	0.00	3.33%	5.77

Table 6. Mean Percentages: Boating Industry Customers' Awareness of Nontoxic Hull Coatings

Industry Group	Perceived Awareness by Customers Now	Perceived Awareness by Customers 1-2 Years Ago	Perceived Increases in Customer's Awareness
Marina, Harbor, Yacht Club	41%	20%	21%
Hull Cleaning Company	34%	26%	18%
Boat Repair Yard	23%	14%	9%