PERCEPTIONS OF NEW AND ESTABLISHED WATERFRONT MATERIALS BY U.S. MARINE DECISION MAKERS

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ABSTRACT

A demand exists for strong, cost-effective, durable, and environmentally benign building materials for weather-exposed marina applications. In particular, the findings from a nationwide survey of decision makers at U.S. marinas indicate a need for waterfront materials and products with superior performance capabilities having a combination of "ideal" attributes that may not be currently available in the marketplace. This study examines the perceptions of decision makers at both large and small U.S. marinas and fixed versus floating dock systems regarding new and established waterfront materials in decking and piling applications. The findings from the survey indicate the most important decking material attribute for U.S. marinas was *resistance to decay*, followed by *reliable strength*, and *low maintenance cost*. The most important piling material attribute was also *resistance to decay* followed by *reliable strength* and *resistance to impact*. The least important attribute for both decking and piling was *use of recycled materials*. Material performance comparisons generally indicated a strong preference for composite decking and steel piling. In terms of cost, wood was perceived as the best (lowest cost); composites were perceived as the worst (highest cost). Knowledge ratings of composite products and the receptivity to new technologies indicated that marina respondents perceived themselves moderately knowledgeable of composite materials and moderately receptive to the adoption of new technologies.

Keywords: Decking, piling, perceptions, product/market development, end-users, specifiers, marinas, marina dock systems, composites.

INTRODUCTION

The word "marina" generally is used to describe a recreational boat facility, commonly referred to as small-craft marina or harbor. The facility may include commercial docking space and services, moorings, boat repair services, new or used boat sales, water transportation components, and other related waterfront activities. There are approximately 12,000 marinas in the Unites States (Lenard 1999).

Marina structures are subject to harsh environmental forces such as waves, tides, currents, extreme water levels, ice, and mechanisms such as corrosion, physical and chemical attacks, and biodegradation, as well as general wear, abrasion, and fatigue and accidental damage such as that caused by vessel impact and overloads. Material selection for marina structures is very important to the cost and durability of the structure. A low initial cost may be offset by high recurring maintenance costs making durability issues of paramount importance to the overall useful life of these structures.

Generally marina structures require the use

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of a variety of construction materials that take advantage of the best properties of each material within individual design configurations. The predominant group of materials most often encountered in marina and small-craft harbor projects are steel, reinforced concrete, prestressed concrete, aluminium, fiberglass, stone, wood, and a variety of composite materials (Tobiasson and Kollmeyer 1991). Marina applications for these materials include fixed and floating dock structures, pilings, dolphins, bulkheads, decking, fendering, building frames, seawalls, and breakwaters (Tobiasson and Kollmeyer 1991). Wood has been the traditional material of choice for many of the individual waterfront components of marinas due to its availability, cost, versatility, and attractive, accepted appearance by the marina community (Tobiasson and Kollmeyer 1991). The introduction of composites to the marine industry has been primarily since the early 90s (March and Colturi 1998).

Materials science advancements related to composite technologies are ongoing, and composite product lines for waterfront applications are evolving. More than 30 U.S. companies manufacture engineered wood products for waterfront applications, and the list of product offerings is growing (Anonymous 1996, 1999a, b; Craigie 2000; Hudson 1999; Kerber 1999; Knights 1996; Lancaster Composites [not dated]; Lewis 1999; Petra 1999; Pianka 1999; Robinson 1999; Schuyler Rubber Co. [not dated]; Seaward International Inc. [not dated]; Toensmeier 1994; Troutman 1998). The Composites Fabricators Association (CFA), projects a 4 percent across the board increase in the pounds of composites to be shipped in the U.S. during 2000 amounting to 3.90 billion pounds of composites (Henriksen 2000). An estimated 5.2 percent increase in millions of pounds of composites shipped in the marine segment for 2001 is forecast (Henriksen 2000), and many wood-based composite materials show promise in these waterfront applications.

BACKGROUND

Increasing marine borer populations, environmental concerns regarding the use and disposal of chemically treated wood in marine environments, and larger service load requirements are factors contributing to an interest in using new engineered materials for marina applications. Over the last two decades, improved water quality has created flourishing marine borer populations resulting in accelerated decay of many shore facilities (Eaton and Hale 1993; Herszenhorn 1999; Kennedy 1999; March and Jarvis 1997; Phair 1997; Rasmussen 1997; Rohde 1998; Tanal and Matlin 1996). Wood pilings are vulnerable to borer attack resulting in costly solutions such as wrapping the pilings or encasing them in concrete (Gaythwaite 1990), the latter method costing as much as $200 per linear foot (Krasner 1998). Other alternatives include using preservative-treated wood; however, negative public perceptions regarding possible leaching of toxic chemicals, and increased state and federal regulations mandating against their use have encouraged the use of other materials (Felton and DeGroot 1996; Hansen and Morrell 1997; Crawford et al. 2000; March and Jarvis 1997; U.S. Dept. of Agriculture 1980).

Larger service load requirements, resulting from larger crafts berthing at facilities, favor steel and concrete, which has created more interest in developing increasingly reliable and strong products (Hoffard and Pendleton 1998). In particular, many marinas have had to accommodate greater numbers of large megayachts (generally considered to start with 80-foot boats) due to an industry trend toward bigger and more expensive vessels that require higher strength materials for greater impact resistance (Petra 2000; Hansen 2000; Mottram 2000).

U.S. naval waterfront facilities and component needs

The U.S. Navy is interested in developing alternative materials for use in their shore facilities (See Acknowledgments). Many of the

Navy's shore facilities, which were constructed during or following WW II using preservative-treated wood, are due for repair and/or replacement (Hoffard and Pendleton 1998; Malvar et al. 1998). The Navy spends approximately $250 million annually on preservative-treated wood for a variety of applications including waterfront facilities, utilities, railroads, and construction (Anonymous 2000; Malvar et al. 1998; Hoffard and Pendleton 1998). The Navy has 118,000 wood piles in service within the 50 states (Hoffard and Pendleton 1998) and an estimated 500 piers and 280 wharves that provide 145 miles of berthing facilities (Scola 1989). It disposes of approximately 20,000 tons of treated wood (Malvar et al. 1998) at an estimated annual cost to the Navy of $667,000 (Pendleton and Hoffard 1998).

This research study is guided by the U.S. Navy's initial interest in developing new engineered composite materials for "drop-in" applications, such as chocks and whales, within existing decking and fendering waterfront systems. Flexible custom design characteristics of composite materials have made them particularly useful in rehabilitation projects (Hastak and Halpin 2000). Additional material and product applications exist for new formulation and design configurations in new waterfront facilities as well (Cofer et al. 1998). Performance attributes such as strength, stiffness, shape, ease of construction, commercial viability, Navy need, and Navy design requirements were considered in the Navy's selection of the two applications of interest: decking and fendering. Because of the additional interest in developing civilian markets for the technology, U.S. marina applications of decking and pilings were included in this study. Decking, the platform or surface attached to the frame, and pilings, used to maintain position/location of floats by resisting applied lateral forces, and to support vertical loads, are components of both fixed and floating dock systems and were identified in preliminary research as most relevant because of material usage and similarity in application to the Navy's interest in decking and fendering systems.

Additional waterfront material markets

Although much of the interest in engineered composite materials is from the U.S. Navy, other potentially high-volume end-uses exist within civilian construction and infrastructure repair (Ashley 1996; Black 1998; Westrup 1992). In the U.S. alone, there are more than 750,000 public and private piers, wharves, and docks. According to the U.S. Army Corp. of Engineers, system deterioration costs total approximately $2 billion annually within marine waterfront communities (March and Colturi 1998). The public port industry is focusing on infrastructure improvements with approximately $180 million (20% of total annual expenditures) directed toward infrastructure investments (United States Port Development Expenditure Report, December 2000). In 1997, U.S. marina planned capital improvements by type indicated that the largest percentage of expenditures (30%, or approximately $34 million) was directed towards infrastructure (International Marina Institute 1998). Additionally, the escalation in boat ownership by larger numbers of Americans has created substantial demand for marina facilities (Tsinker 1995). The U.S. Coast Guard reports there were 12.7 million recreational boats registered with the states in 1999, which is an increase of 180,000 boat registrations from the previous year (Petra 2000).

New product/market development

Businesses and individuals differ in their openness to new ideas and technologies (Mitropoulos and Tatum 2000). The construction industry is generally perceived as conservative in adopting new technologies (Koebel 1999; Mitropoulos and Tatum 1999). The innovation, adoption, and diffusion of new products, defined as the process by which an innovation "is communicated through certain channels over time among the members of a social system", (Rogers 1995) has been the subject of considerable attention since innovation diffusion theory was introduced into marketing in the 1960s (Arndt 1967; Baptista 1999; Bass 1969; Mahajan et al. 1990; Rogers 1995). Much of the empirical research into the adoption and diffusion of building materials has focused on the home building industry (Fell and Hansen 1999; Eastin et al. 1999; Koebel 1999; Mitropoulos and Tatum 1999; NAHB 2000; Shook 1999) as opposed to industrial applications (Smith and Bright 2001; Smith et al. 1999, 2000a). The degree to which target consumers perceive the new product to have a relative advantage compared to the product it supersedes is more important to the actual rate of adoption and new product success than any "objective" advantage the new product may have (Rogers 1995). Understanding the importance of the perceptions on competing materials and attribute importance by target consumers is crucial to developing new products with customer-orientations based on those factors considered most significant to the end-user.

Yet the development of new wood products has not been driven primarily by customer needs, but rather by resource availability, resource cost, and proven technology (Rosenberg et al. 1990; Trinka et al. 1992). There has generally been a resistance to customer-orientation as an organizing principal for new product development and marketing in high technology (Cahill 1994; Trinka et al. 1992). Because a new product's success depends heavily on the relevance of the firm's offerings to the consumers' needs (Busch and Houston 1985), and because typically new products have undeveloped preference structures, the firm must be able to establish the relationship between the capabilities of the new technology and the existing needs of target consumers (Roberts 2000). As shown by Smith et al. (1999, 2000a, b), market research into the perceptions of industrial end-users and specifiers on the relative attribute importance of alternative infrastructure materials can provide valuable information for developing materials and/or product positioning strategies. Understanding how users, specifiers, and influencers perceive a product on important attributes and relative to competing products is referred to as a product's position (Kotler and Armstrong 1996). Products can be positioned on the needs they fill or the benefits they offer to a certain class of users or directly against or away from a competitor (Aaker and Shansby 1982).

STUDY OBJECTIVES

Beyond the Smith et al. (1999, 2000a, b) work, little research on end-users' and specifiers' perceptions of infrastructure materials, and particularly of new products for waterfront applications, is available. The objectives of this study are the following: determine U.S. marina decision makers' overall knowledge (self-rated) of various composite materials and their perceptions of their marinas' receptivity to new technologies; rank for importance the relative perceptual position of twenty key decking and piling attributes; examine the perceptions of material performance of new and existing materials available for waterfront decking and piling of U.S. marina decision makers by comparing among eight select attributes; and examine differences based on size (as determined by the number of wet slips) and type of dock system between marinas for the above constructs.

METHODS

Sample and sampling procedure

Extensive exploratory interviews of personnel at U.S. marinas and web site searches helped identify the National Marine Manufacturers Association, NMMA (Chicago, IL), which is a trade association of more than 1,600 companies that manufacture products used by recreational boaters (Anonymous 2001), and more specifically its affiliated association, the Marina Operators Association of America, MOAA (Washington, D.C.) which represents only marina owners and operators (Wakefield 2001), as the most relevant for the development of the target population.

The 1999 National Marina Directory published by NMMA in conjunction with MOAA was used to identify contact information for 11,045 U.S. marinas (NMMA 1999). The directory is complete, frequently updated, well recognized and was referred to often by those in the industry during preliminary research. The sample frame was designed to include end-users from all 50 states to avoid bias due to geographic considerations and individual state regulatory concerns. In addition, to ensure adequate size diversity (as determined by the number of wet slips), we classified marinas into two groups: those with between 1–300 wet slips and those with >300 wet slips (2,450 marinas were listed as having zero or unknown slips and were not included). Sample size required was based on the following equation given by Ballenger and McCune (1990):

$$n = [(Z/2)^2(\sigma^2)^2]/h^2$$

where

n = required sample size,

$Z/2$ = reliability coefficient,

σ^2 = estimated population standard deviation,

h = tolerance level or precision level which equals the allowable difference between the estimate and population values.

This study used a 95% confidence interval, requiring a sample size of 97 per stratum. Because a high non-response rate from marina respondents was expected (the International Marina Institute 1998 survey mailed to members received only a 7.8% response rate) (International Marina Institute 1998), a random stratified probability sampling technique was employed to select 1,916 marinas for this study.

Research instrument

Mail questionnaires were used for primary data collection, as they are the most effective means to collect data from a geographically dispersed population (Blankenship and Breen 1992; Dillman 1978). To reduce the length of the original questionnaire, maximize response rates, and obtain complete information on both applications, two versions of the mail questionnaire were developed: one for each application (decking and pilings). The questionnaire was thoroughly pre-tested by knowledgeable marina decision makers, university personnel, and civil engineers to test for biased, misleading, or confusing questions and instructions. Refinements were made in the set of material attributes, question wording, and questionnaire length.

Data collection and response rates

To increase response rates, a modified version of Dillman's (1978) Total Design Method was employed as follows: a pre-notification postcard, a cover letter explaining the purpose of the study, and other instructions including descriptions of the two incentives to respond (entry into a prize drawing, and a summary of the findings of the study) were mailed in the spring of 2000; a reminder postcard was sent one week after the initial mailing; three weeks following the initial mailing, a second questionnaire was mailed with a cover letter requesting participation from non-respondents.

The population was reduced for undeliverable surveys resulting in a final population of 1,717 marinas, and an adjusted response rate (ARR) of 27.6% ($n = 474$). Adequate geographic and size diversity ($n = 313$, ARR = 24.7% for marinas with 1–300 wet slips and $n = 161$, ARR = 35.7% for marinas with >300 wet slips) were represented (Fig. 1).

Study bias

To assess non-response bias, those who responded to the initial mailing (early respondents; $n = 300$) were compared to those who responded after follow-up steps were taken (late respondents; $n = 174$) across a number of survey questions using analysis of variance.[1] Later respondents are generally believed to be more like non-respondents (Pearl

[1]Analysis of variance, ANOVA, determines if the mean values of an independent variable are significantly different from each other within each category of independent variable.

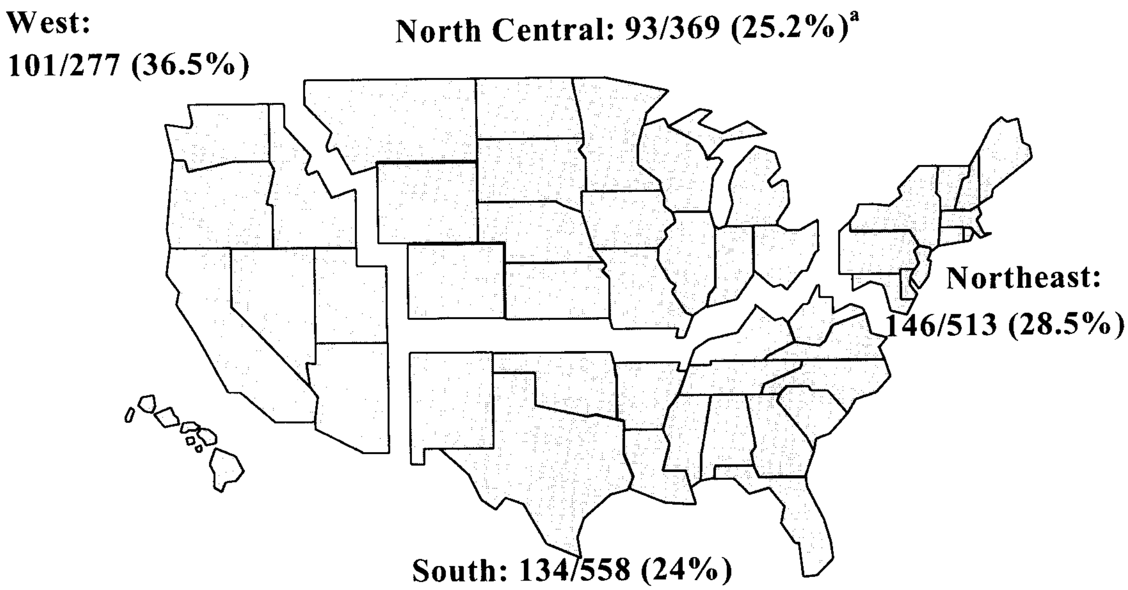

FIG. 1. U.S. Marina (n = 474) response rates by U.S. bureau of census regions.

[a] Interpreted as follows: The North Central U. S. Bureau of Census region had 93 respondents from the adjusted number of 369 marine decision makers contacted, which resulted in an adjusted response rate of 25.2% for this region.

and Fairley 1985). No significant differences (at the $p \leq 0.05$ level) were found between the two groups' mean overall perceptions of attribute importance, their perceptions of overall material performance, their knowledge of composites, and their participation in waterfront construction projects.

Respondent and marina profile

Thirty-two percent of respondents were currently Managers at their marinas, followed by Owners/Operators (27%), Presidents/Directors (18%), "other" (10%) and Harbor Masters (9%). The mean years of service at the respondents' current positions was 14.2 years plus an additional 10.9 years of service in their previous positions, totaling an average of 24+ years of work experience. Nearly all (85%) of respondents had participated in waterfront construction projects within the last five years, with the remaining 15% having participated within the last fifteen years.

Of the 457 responses received concerning the type of dock system used at their marinas, the majority of respondents (n = 207) indicated using a floating dock system (45%), followed by a fixed dock system (29%, n = 134), and lastly a combination of fixed and floating (26%, n = 116) (Fig. 2). Floating docks were more prevalent than fixed docks for larger marinas (n = 153; floating = 64%, fixed = 12%, combination of both types = 24%). Smaller marinas had a more even distribution of fixed and floating docks (n = 304; floating = 36%, fixed = 38%, combination of both types = 26%).

In addition, more than two-thirds of marina decision makers (68%) reported current or planned construction activity. A higher percent of larger marinas (n = 160, 77.5%) than smaller marinas (n = 306, 62.7%) indicated current or planned construction activity.

Construct development

Secondary sources were used to compile an initial list of relevant attributes. Primary sources, including exploratory interviews with vendors of waterfront construction materials,

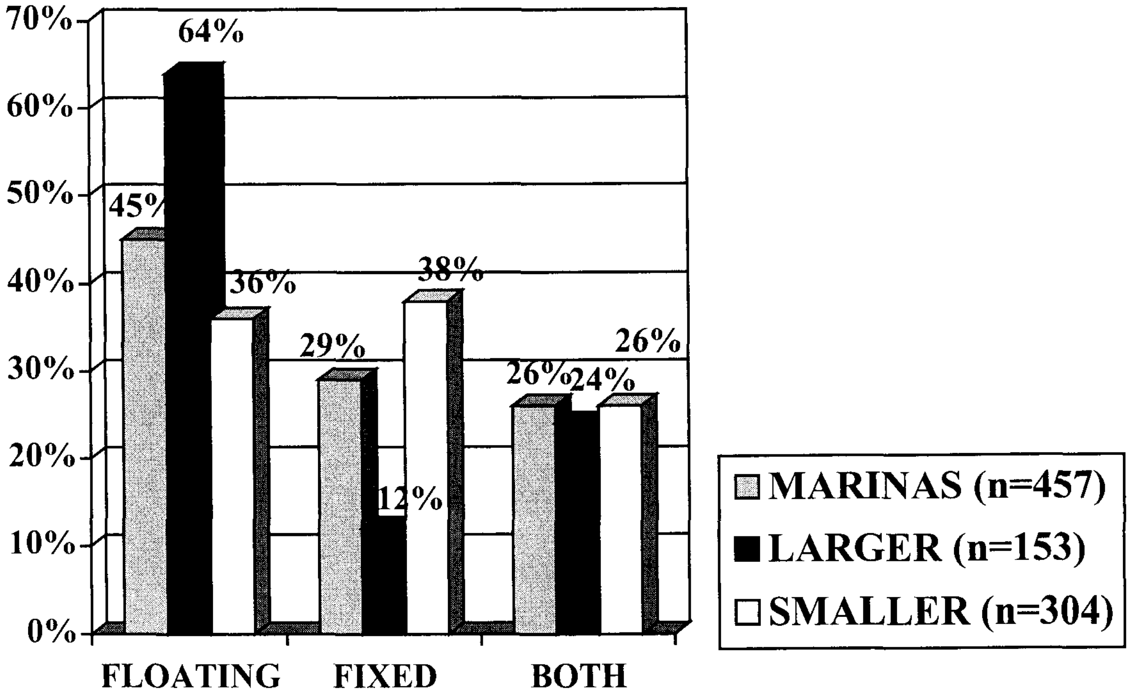

FIG. 2. U.S. Marina dock systems (n = 457): percentage of fixed, floating, and combination of fixed and floating.

discussions with military/civilian structural and material science engineers from the Navy project team, and on-site interviews of engineers from BERGER/ABAM Inc. (Federal Way, WA), General Construction Company (Seattle, WA), and the Port of Tacoma (Tacoma, WA) were used to refine and finalize a list of 20 attributes for both decking and piling materials (Tables 1 and 2).

Respondents were also asked to rank wood, concrete, metals, and composite materials for decking, and wood, concrete, steel, and composite materials for piling on the following eight material attributes: *long life, high strength, low cost, durable, consistent quality of materials delivered to job site, resistant to heat/cold, environmentally safe, and meets environmental regulations.*[2] These eight attributes were selected via interviews with waterfront material suppliers as they were the criteria they emphasized most in their material comparisons.

RESULTS

Analysis of the data began with cross tabulations and range counts to identify coding errors. Analysis of variance (ANOVA) at the alpha levels of 0.05 and 0.10 was used to test for significant differences based on composite knowledge, receptivity to new technologies, attribute importance, and material performance comparisons with respect to large and small marinas and fixed versus floating dock systems.[3] Marinas using a hybrid fixed-floating system were not included in the analyses regarding fixed versus floating dock systems.

[2]Steel is a common material used for marina piling and floating docks; in recent years aluminum has received wide acceptance primarily in the use for floating docks and decking (Tobiasson and Kollmeyer 1991; Tsinker 1995, 1997). The term "metals" was used in the questionnaire to include both steel and aluminum.

[3]Both alpha levels (0.05 and 0.10) were used to test for significant differences using ANOVA to provide complete information; Tables 3 and 4 distinguish between the two levels using one or two asterisks.

TABLE 1. *Decking Material Attributes for Marinas.* "What material attributes do you perceive are the most important for DECKING?"

Decking Material Attributes[1] (Mean ratings)	Total (n = 474)	Larger (n = 161)[a]	Smaller (n = 313)[b]	Sig.[2]	Fixed (n = 133)	Floating (n = 215)	Sig.
Resistance to Decay	4.45	4.48	4.44	.587	4.46	4.42	.591
Reliable Strength	4.35	4.36	4.34	.799	4.38	4.33	.551
Low Maintenance Cost	4.28	**4.40**	**4.22**	**.015**	4.35	4.29	.497
Easy Installation	4.11	4.09	4.13	.679	4.25	4.11	.132
Structural Design Flexibility	4.07	4.09	4.06	.694	4.11	4.06	.558
Resistance to UV	4.03	4.06	4.02	.691	4.02	4.11	.445
Low Life Cycle Cost	4.02	4.03	4.02	.917	4.11	3.97	.223
Resistance to Impact	4.01	3.99	4.02	.719	4.14	3.97	.107
Resistance to Marine Borers	3.98	3.98	3.99	.959	3.94	4.01	.594
Attractive Appearance	3.98	**4.08**	**3.93**	**.084**	3.93	4.03	.270
Low Replacement Cost	3.88	3.82	3.91	.340	**4.09**	**3.75**	**.002**
Low Expansion/Contraction	3.65	3.68	3.63	.643	3.66	3.67	.923
Resistant to Fire	3.65	3.72	3.61	.369	3.58	3.77	.166
Toxic Chemical Free	3.63	3.73	3.58	.254	3.58	3.70	.416
Non-Conductive	3.57	3.58	3.56	.869	3.55	3.58	.794
Low Initial Cost	3.55	3.46	3.60	.166	**3.78**	**3.41**	**.003**
High Energy Absorption	3.52	3.58	3.50	.456	3.55	3.60	.686
Less Aquatic Biofouling	3.38	3.36	3.39	.855	3.35	3.39	.761
Low Disposability Costs	3.26	3.23	3.27	.704	3.19	3.34	.294
Use of Recycled Materials	2.57	**2.77**	**2.47**	**.010**	2.57	2.62	.690

[1] Mean rating on a 5-point scale of 1 = no importance to 3 = somewhat important to 5 = critically important.
[2] Bold print indicates statistically significant at the 0.10 level using ANOVA.
[a] Marinas with >300 wet slips.
[b] Marinas with between 1–300 wet slips.

Composite knowledge and receptivity to new technologies

Respondents were asked to rate their knowledge of composites used in waterfront applications on a ten-point Likert scale from 0 = no knowledge to 10 = much knowledge (Fig. 3a). Overall marina decision makers rated themselves in the middle range for knowledge of composites (mean = 5.10) (Fig. 3a).

Additionally, marina decision makers were asked to rate their perception of how receptive their marinas were regarding the implementation of new technologies on a 10-point Likert scale from 1 = not at all receptive to 10 = very receptive. Overall few respondents rated their firms with a rating of 4 or less (14%), and the mean for marina respondents was 6.68 (Fig. 4a).

Analysis of Variance was used to determine if significant differences existed between respondents from larger marinas (>300 wet slips) as compared to those from smaller marinas (between 1 to 300 wet slips) with respect to knowledge of composites and receptivity to new technologies. Respondents from the 153 large marinas rated themselves significantly higher (mean = 6.16) in knowledge of composite products than respondents from the 301 small marinas (mean = 4.63) at the $P = 0.000$ level (Fig. 3a). In addition, the mean responses for large marinas on receptivity to new technologies were significantly higher (mean = 7.15) as compared to those from small marinas (mean = 6.42) at the $P = 0.003$ level (Fig. 4a).

We also examined significant differences between respondents of fixed versus floating docks with respect to knowledge of composites and receptivity to new technologies. Respondents from the 215 floating docks rated themselves significantly higher (mean = 5.58) in knowledge of composite products than respondents from the 133 fixed dock marinas (mean = 4.54) at the $P = 0.001$ level (Fig.

TABLE 2. *Piling Material Attributes for Marinas.* "What material attributes do you perceive are the most important for PILING?"

Piling Material Attributes[1] (Mean ratings)	Total (n = 474)	Larger (n = 161)[a]	Smaller (n = 313)[b]	Sig.[2]	Fixed (n = 133)	Floating (n = 215)	Sig.
Resistance to Decay	4.45	4.40	4.48	.274	4.41	4.48	.438
Reliable Strength	4.44	4.33	4.44	.908	4.45	4.45	.940
Low Maintenance Cost	4.24	4.21	4.26	.558	4.28	4.26	.843
Easy Installation	4.22	4.28	4.19	.286	4.31	4.22	.422
Structural Design Flexibility	4.12	4.03	4.17	.275	4.06	4.16	.466
Resistance to UV	4.11	4.17	4.08	.330	4.09	4.14	.681
Low Life Cycle Cost	4.08	4.03	4.11	.407	4.11	4.07	.735
Resistance to Impact	4.05	4.03	3.05	.850	4.28	4.26	.843
Resistance to Marine Borers	3.86	**3.68**	**3.94**	**.004**	**4.08**	**3.77**	**.006**
Attractive Appearance	3.83	3.78	3.85	.585	3.89	3.83	.687
Low Replacement Cost	3.81	3.85	3.78	.538	3.84	3.82	.869
Low Expansion/Contraction	3.71	3.70	3.72	.925	3.81	3.70	.352
Resistant to Fire	3.60	3.51	3.64	.227	**3.77**	**3.52**	**.042**
Toxic Chemical Free	3.59	3.66	3.56	.438	3.52	3.67	.302
Non-Conductive	3.57	3.55	3.57	.943	3.52	3.65	.411
Low Initial Cost	3.52	3.60	3.48	.343	3.53	3.59	.666
High Energy Absorption	3.40	3.30	3.45	.264	3.42	3.42	.979
Less Aquatic Biofouling	3.43	3.39	3.45	.691	3.43	3.49	.700
Low Disposability Costs	3.14	3.11	3.16	.714	3.13	3.24	.455
Use of Recycled Materials	2.62	2.67	2.60	.585	2.74	2.58	.255

[1] Mean rating on a 5-point scale of 1 = no importance to 3 = somewhat important to 5 = critically important.
[2] Bold print indicates statistically significant at the 0.10 level using ANOVA.
[a] Marinas with >300 wet slips.
[b] Marinas with between 1–300 wet slips.

3b). In addition, the mean responses for floating dock marina respondents on receptivity to new technologies were significantly higher (mean = 6.92) as compared to marinas with fixed docks (mean = 6.02) at the $P = 0.002$ level (Fig. 4b).

Attribute importance

To determine the relative importance of the 20 decking and piling attributes among marina decision makers, a 5-point Likert scale from 1 = no importance, to 3 = somewhat important, to 5 = critically important was used (Tables 1 and 2).

Decking.—Table 1 shows that *resistance to decay* was rated as the most important decking material attribute for marina decision makers (mean = 4.45). *Reliable strength* (mean = 4.35) *low maintenance cost* (mean = 4.28), and *easy installation* (mean = 4.11) were second through fourth in importance, respectively. The two least important decking material attributes were *low disposability cost* (mean = 3.26) and *use of recycled materials* (mean = 2.57). Moreover, environmental attributes for decking, which included *toxic chemical free, less aquatic biofouling, low disposability cost, and use of recycled materials,* were uniformly rated very low (bottom 7) on attribute importance.

Piling.—As shown in Table 2, the four most important piling material attributes for marinas were *resistance to decay* (mean = 4.45), *reliable strength* (mean = 4.44), *resistance to impact* (mean = 4.24), and *low maintenance cost* (mean = 4.22). The least important piling material attribute was *use of recycled materials* (mean = 2.62). Furthermore, environmental attributes for piling (the same as those for decking) were again uniformly rated near the bottom (lowest 7) in terms of their relative importance in piling applications.

With respect to attribute importance and size of marina, mean responses for the two

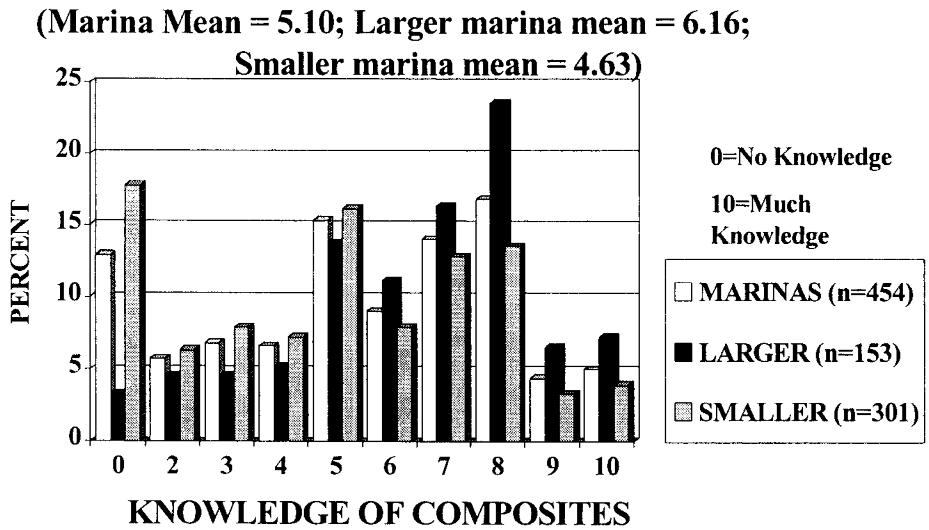

FIG. 3a. Self-rated knowledge of composites by U.S. marinas: larger versus smaller (n = 454).

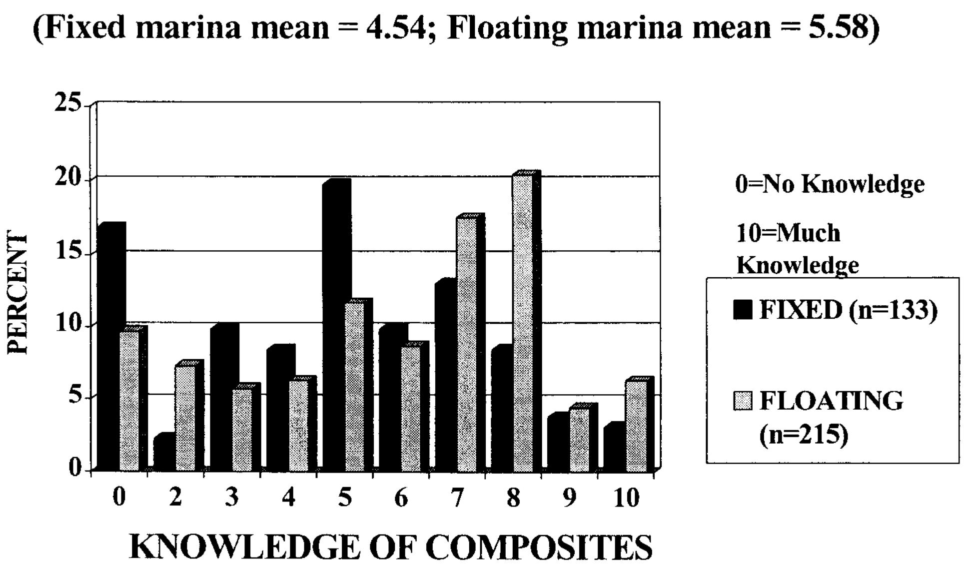

FIG. 3b. Self-rated knowledge of composites by U.S. marinas: fixed versus floating (n = 348).

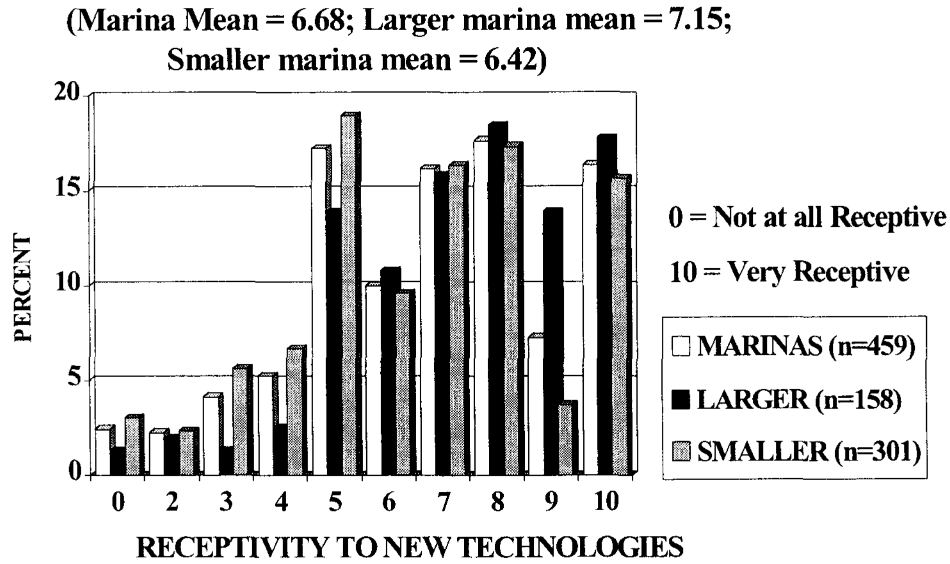

FIG. 4a. Receptivity to new technologies by U.S. marinas: larger versus smaller (n = 459).

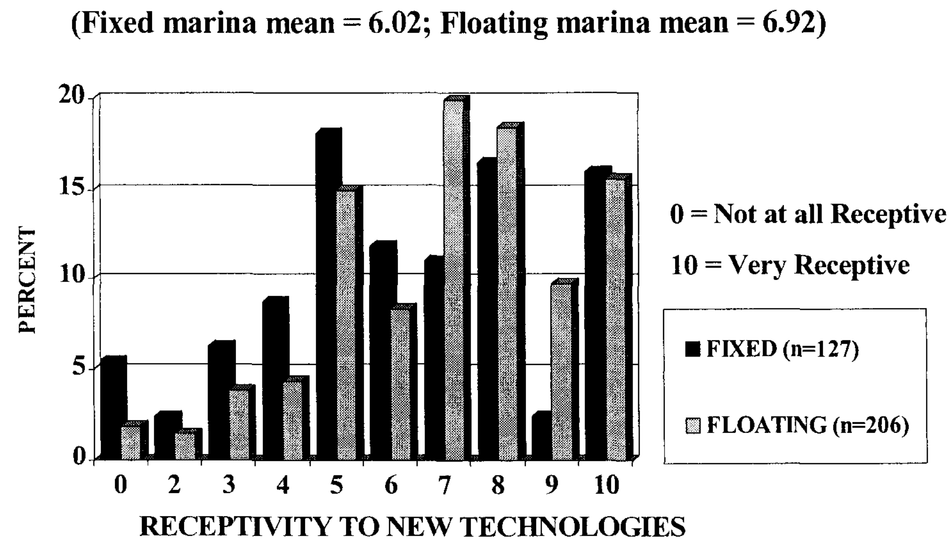

FIG. 4b. Receptivity to new technologies by U.S. marinas: fixed versus floating (n = 333).

groups differed from each other (at the $P \leq 0.10$ level) on the following three decking attributes: *low maintenance cost, attractive appearance,* and *use of recycled materials* (Table 1). Table 2 indicates that marina respondents from larger marinas differed from smaller marinas (at the $P \leq 0.10$ level) in their mean rating of only one piling attribute: *low replacement cost.*

We also compared fixed versus floating dock marina decision makers' perceptions of attribute importance and found two attributes, *low initial cost* and *low replacement cost,* differed significantly (at the $P \leq 0.10$ level), and they differed significantly for both applications (Tables 1 and 2). Respondents from fixed dock marinas rated both *low initial cost* and *low replacement cost* as more important than those from floating dock marinas (Tables 1 and 2).

Material performance

Decking.—Respondents were asked to rank four alternative decking materials (wood, concrete, metals, and composites) on a 4-point scale from 1 = worst performance, to 2 = below average performance, to 3 = above average performance, to 4 = best performance for eight decking material attributes (Table 3). Overall, composites were ranked the highest (highest means for four of the eight attributes); concrete was ranked intermediate (highest means for two and second highest means for four of the eight attributes), followed by wood (highest means for *low cost* and *resistant to heat/cold*), and metals (highest mean for one attribute: *high strength*).

Piling.—Respondents also ranked four alternative piling materials (wood, concrete, steel, and composites) on a 4-point Likert scale from 1 = worst performance, to 2 = below average performance, to 3 = above average performance, to 4 = best performance on the same eight fendering attributes (Table 3). Overall, steel was ranked the highest (highest means for four of the eight attributes), composites were ranked highest on *environmentally safe* and *meets environmental regulations,* concrete was generally ranked intermediate, and wood was ranked the lowest for six of the eight attributes.

A greater number of significant differences existed between large (n = 161) and small (n = 313) and fixed (n = 133) and floating (n = 215) marina decision makers with respect to material performance perceptions than for attribute importance (Tables 3 and 4). For decking and size of marina, the mean rankings between our two groups were statistically different from each other (at the $P \leq 0.10$) on the following decking attributes: *low cost, environmentally safe,* and *meets environmental regulations.* In all three cases, larger marinas rated concrete higher than smaller marinas for these attributes (Table 3). For decking and fixed versus floating dock marinas, the mean rankings between our two groups were statistically different from each other (at the $P \leq 0.10$) on *long life, high strength,* and *durable.* In all three cases, floating dock marinas rated metals higher than fixed dock marinas for these attributes (Table 4).

In piling applications and size of marina, the mean rankings by our two groups differed significantly (at the $P \leq 0.10$) on all eight attributes: *long life, high strength, low cost, durable, consistent quality, resistant to heat/cold,* and *environmentally safe, meets environmental regulations* (Table 3). Respondents from larger marinas rated steel higher for *low cost,* and concrete higher for *long life, high strength, durable* and *resistant to heat/cold* (Table 3).

In piling applications and fixed versus floating dock system, the mean rankings differed significantly (at the $P \leq 0.10$) with those respondents having fixed docks rating wood higher for *long life, high strength, durable, consistent quality, resistant to heat/cold,* and *environmentally safe.* Respondents having fixed docks also rated composites higher; the mean rankings differed significantly (at the $P \leq 0.10$) for seven of the eight attributes (all except *resistant to heat/cold*) (Table 4). Respondents having floating docks rated steel

TABLE 3. *Decking/Piling Material Perceptions for Marinas (Larger and Smaller).*

	DECKING			PILING		
	Total[1&2] n = 474	Larger[3] n = 161	Smaller[4] n = 313	Total n = 474	Larger n = 161	Smaller n = 313
Long Life						
Wood	2.32	2.41	2.27	2.33	**2.13[a]	**2.43
Concrete	3.15	3.24	3.10	2.96	**3.14	**2.87
Composites	3.15	3.11	3.17	2.89	2.81	2.93
Metals (Decking)[5]	2.38	2.39	2.38	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.89	3.02	2.83
High Strength						
Wood	2.35	2.40	2.33	2.31	2.28	2.32
Concrete	3.07	3.07	3.07	2.98	**3.24	**2.85
Composites	2.66	2.65	2.67	2.47	2.41	2.50
Metals (Decking)	3.12	3.18	3.08	NA	NA	NA
Steel (Piling)	NA	NA	NA	3.47	3.39	3.50
Low Cost						
Wood	3.35	3.40	3.32	3.29	3.27	3.30
Concrete	2.31	**2.43	**2.24	2.39	2.47	2.38
Composites	2.00	1.90	2.05	1.99	1.92	2.02
Metals (Decking)	2.20	2.28	2.15	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.40	**2.58	**2.31
Durable						
Wood	2.35	2.44	2.30	2.32	2.22	2.37
Concrete	3.03	3.08	3.00	2.94	**3.11	**2.84
Composites	3.03	2.96	3.07	2.85	2.74	2.90
Metals (Decking)	2.61	2.61	2.60	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.96	3.07	2.91
Consistent Quality						
Wood	2.36	2.43	2.31	2.29	2.29	2.30
Concrete	2.86	2.87	2.86	2.81	2.89	2.76
Composites	3.07	3.00	3.11	2.86	**2.59	**3.00
Metals (Decking)	2.94	2.97	2.93	NA	NA	NA
Steel (Piling)	NA	NA	NA	3.21	3.23	3.20
Resistant to Heat/Cold						
Wood	2.93	2.93	2.94	2.79	**2.61	**2.88
Concrete	2.63	2.76	2.55	2.63	**2.88	**2.49
Composites	2.91	2.92	2.91	2.81	2.68	2.88
Metals (Decking)	2.62	2.59	2.64	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.98	2.98	2.98
Environmentally Safe						
Wood	2.87	2.76	2.93	2.54	*2.38	*2.61
Concrete	2.98	*3.15	*2.88	2.85	2.94	2.80
Composites	3.09	3.15	3.05	3.00	2.99	3.01
Metals (Decking)	2.45	2.51	2.43	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.81	2.92	2.74
Environmental Regulations						
Wood	2.87	2.76	2.92	2.59	**2.42	**2.67
Concrete	3.02	*3.19	*2.93	2.86	2.96	2.80
Composites	3.09	3.07	3.10	2.98	2.93	3.01
Metals (Decking)	2.53	2.66	2.57	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.91	3.00	2.86

[1] Mean based on responses to the following scale: 1 = worst, 2 = below average, 3 = above average, and 4 = best performance.
[2] Using ANOVA, all materials differed on each of the eight material attributes (at the $p \leq 0.05$ level).
[3] Marinas with >300 wet slips.
[4] Marinas with between 1–300 wet slips.
[5] The category "metals" was used for decking to include all metals used for decking (i.e., steel and aluminum).
[a] Bold print indicates statistically significant at the 0.05 level (*); statistically significant at the 0.10 level (**) using ANOVA.

TABLE 4. *Decking/Piling Material Perceptions for Marinas (Fixed and Floating).*

	DECKING			PILING		
	Total[1&2] n = 474	Fixed n = 133	Floating n = 215	Total n = 474	Fixed n = 133	Floating n = 215
Long Life						
Wood	2.32	2.39	2.24	2.33[a]	***2.61**[a]	***2.11**
Concrete	3.15	3.24	3.18	2.96	2.91	3.05
Composites	3.15	3.12	3.10	2.89	***3.04**	***2.73**
Metals (Decking)[3]	2.38	***2.19**	***2.49**	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.89	***2.57**	***3.06**
High Strength						
Wood	2.35	2.48	2.26	2.31	***2.49**	***2.12**
Concrete	3.07	3.15	3.04	2.98	***2.83**	***3.10**
Composites	2.66	2.65	2.64	2.47	***2.70**	***2.32**
Metals (Decking)	3.12	***2.91**	***3.19**	NA	NA	NA
Steel (Piling)	NA	NA	NA	3.47	***3.28**	***3.53**
Low Cost						
Wood	3.35	3.37	3.37	3.29	3.40	3.23
Concrete	2.31	2.26	2.33	2.39	2.28	2.40
Composites	2.00	2.09	2.00	1.99	***2.18**	***1.84**
Metals (Decking)	2.20	2.15	2.25	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.40	***2.23**	***2.51**
Durable						
Wood	2.35	2.40	2.33	2.32	***2.47**	***2.14**
Concrete	3.03	3.06	2.99	2.94	2.87	2.98
Composites	3.03	3.07	3.04	2.85	***3.09**	***2.66**
Metals (Decking)	2.61	***2.38**	***2.63**	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.96	***2.59**	***3.10**
Consistent Quality						
Wood	2.36	2.40	2.38	2.29	***2.47**	***2.09**
Concrete	2.86	2.93	2.79	2.81	2.86	2.81
Composites	3.07	3.14	3.11	2.86	***3.08**	***2.72**
Metals (Decking)	2.94	2.77	2.92	NA	NA	NA
Steel (Piling)	NA	NA	NA	3.21	***2.86**	***3.29**
Resistant to Heat/Cold						
Wood	2.93	2.99	2.92	2.79	***2.95**	***2.57**
Concrete	2.63	2.66	2.70	2.63	2.54	2.70
Composites	2.91	2.91	2.91	2.81	2.89	2.65
Metals (Decking)	2.62	2.55	2.57	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.98	***2.74**	***3.11**
Environmentally Safe						
Wood	2.87	2.69	2.72	2.54	***2.61**	***2.30**
Concrete	2.98	2.85	3.02	2.85	2.78	2.94
Composites	3.09	3.22	3.06	3.00	****3.20**	****2.91**
Metals (Decking)	2.45	2.87	3.01	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.81	2.61	2.84
Environmental Regulations						
Wood	2.87	2.70	2.72	2.59	2.63	2.38
Concrete	3.02	2.88	3.06	2.86	2.79	2.86
Composites	3.09	3.21	3.08	2.98	***3.17**	***2.88**
Metals (Decking)	2.53	2.56	2.55	NA	NA	NA
Steel (Piling)	NA	NA	NA	2.91	****2.68**	****2.94**

[1] Mean based on responses to the following scale: 1 = worst, 2 = below average, 3 = above average, and 4 = best performance.
[2] Using ANOVA, all materials differed on each of the eight material attributes (at the p ≤ 0.05 level).
[3] The category "metals" was used for decking to include all metals used for decking (i.e., steel and aluminum).
[a] Bold print indicates statistically significant at the 0.05 level (*); statistically significant at the 0.10 level (**) using ANOVA.

and concrete higher than those with fixed docks; the mean rankings differed significantly (at the $P \leq 0.10$) for seven of the eight attributes (all except *environmentally safe*) and one attribute for concrete (*high strength*).

DISCUSSION AND CONCLUSIONS

Overall knowledge of composite materials (self-rated) and decision makers' perceptions of their marinas' receptivity to new technologies suggest increased initial use and subsequent diffusion of new materials is most likely to occur with larger marinas and those with floating dock systems. In general, respondents as a whole rated themselves as only moderately knowledgeable about composites (mean = 5.10) and their marinas as only moderately receptive to new technologies (mean = 6.68). Yet respondents from larger marinas and floating dock system marinas differed significantly from smaller and fixed dock marinas for both knowledge and receptivity: those from larger and floating dock system marinas perceived themselves significantly more knowledgeable about composites (at the $P \leq 0.05$) and their marinas as more receptive to adopting new technologies (at the $P \leq 0.05$ level). This outcome is supported in other studies that have indicated early adopters are more likely from larger companies (Rogers 1995; Smith and Vlosky 1997; Vlosky et al. 1994).

In addition, given the increasing popularity and acceptance of floating dock systems, more concentration of design talent and experimental use of new material technology have been directed towards improving floating dock systems (Tobiasson and Kollmeyer 1991; Troutman 1998). Our study indicated that most large marinas employed a floating dock system (64%), and they also are more likely to have current or planned construction as compared to smaller marinas. Therefore well-publicized, highly visible demo or showcase projects targeted towards larger and floating dock system marinas would likely stimulate increased initial use and subsequent diffusion of these composite materials.

However, it is important to bear in mind that 21% of the 80 responses to an open-ended comments section in our questionnaire suggested a general reluctance on the part of respondents from both larger and smaller marinas and fixed versus floating to use new materials due to a lack of experience with the materials. Typical comments we received were, "I have little experience with new materials," "I have never seen composites in use," and, "More information on new materials is needed." Initial use is likely to be undertaken only if the new materials are perceived to have a relative advantage in terms of the benefits and costs resulting from adoption (Rogers 1995).

Rankings of twenty key decking and piling attributes for importance clearly indicated *resistance to decay, reliable strength,* and *low maintenance cost* were perceived as very important and should be among the highest priorities during product development and introduction. Research results from this study strongly suggest that initial marketing communication strategies should focus on these three durability issues.

Earlier studies on the building industry have sought to determine consumers' concerns for environmental issues when making product selections (Gronroos and Bowyer 1999; Ozanne and Smith 1995; Ozanne and Vlosky 1997). This study suggests that environmental concerns are not a high priority among marina decision makers in the selection of new materials. Despite the preponderance of sales literature of new materials emphasizing the "green" image of their products, "green" attributes seem to be of little concern to our study's respondents; the three attributes related to environmental concerns for decking and piling were the least important of the 20 attributes included in our study.

Initial cost comparisons are also emphasized in the sales literature of new materials. Yet attribute comparisons of this study's five cost variables (initial, maintenance, replacement, life-cycle, and disposal) suggest more emphasis should be placed on low maintenance and low life-cycle cost comparisons. Less emphasis should be placed on initial and disposal costs as they were rated the bottom (lowest five) for both applications.

However, limited information on life-cycle costs has been identified as one barrier to the acceptance of new materials, and in particular to composites (Eagar 1995; Hastak and Halpin 2000) because life-cycle benefit cost assessments of new products and materials are inherently based on limited long-term cost and durability information. Product manufactures and the research community may benefit from the initiation of the early life-cycle cost/benefit research for new composite material and product introductions.

Material performance comparisons suggest that composite decking and steel piling products are generally perceived to possess the overall best performance by respondents. Of the four materials rated for decking (wood, concrete, metals, and composites), results indicated a preference for the performance of composites followed by concrete, wood, and lastly metals. Of the four materials rated for piling (wood, concrete, steel, and composites), steel was generally perceived as the best performing material for piling, followed by composites, concrete, and wood.

Uniformly composites were perceived less favorably for cost (highest), and wood was perceived most favorably (lowest). Because marina respondents rated *low initial cost* as a relatively unimportant piling material attribute, effectively communicated differentiation strategies focused on product performance and maintenance/life-cycle costs are suggested.

Generally wood was perceived less favorably for both applications than concrete, composites, metals, and steel. Respondents from smaller marinas generally had a more favorable perception of wood than those from larger marinas in piling applications; respondents from smaller marinas rated wood higher for all eight piling attributes. Fixed dock system marinas have substantially different perceptions of wood and composites for piling attributes; respondents from fixed docks rated wood higher for six and composites higher for seven of the eight piling attributes. Floating dock systems perceived steel more favorably; steel was rated higher for seven of the attributes.

This study adds to the literature addressing infrastructure decision making by addressing product attributes and material comparison in decking and piling waterfront applications by U.S. marina decision makers. Future studies may address perceptions of attribute importance and material performance for additional building material and infrastructure applications and end-user groups. For new materials and products, past diffusion research may serve as a theoretical context. As developments in composite material technology provide a larger and more complicated array of materials, a more challenging selection process by end-users and/or specifiers will result. For increased use of new materials for waterfront and other infrastructure and building material applications, marketing communications efforts should effectively address long-term performance and life cycle cost issues.

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REFERENCES

AAKER, D. A., AND J. G. SHANSBY. 1982. Positioning your product. Bus. Horizons. 25(3):56–72.

ANONYMOUS. 1996. On the waterfront, plastic makes inroads. Engineering News Record. Apr. 8. McGraw-Hill Companies, New York, NY.

———. 1999a. Trex Company, Inc. Prospectus for common stock. Issues by Schroder & Company Inc., and J. C. Bradford & Company, New York, NY (9 March).

———. 1999b. Composites find more support in keeping up piers and bridges. Engineering News Record. Jun. 7. McGraw-Hill Companies, New York, NY.

———. 2000. Engineered wood composites for naval waterfront facilities: Problem statement. 2000. http//

wme132.respark.wsu.edu/problemstatement.html. (28 July 2000).

———. 2001. NMMA mission & structure. http// www.nmma.org/mission.html. (1 Oct. 2001).

ARNDT, J. 1967. Role of product-related conversations in the diffusion of a new product. J. Marketing Res. 4: 291–295.

ASHLEY, S. 1996. Bridging the cost gap with composites. Mech. Eng. 118(2):76–80.

BALLENGER, J., AND S. MCCUNE. 1990. A procedure for determining sample size for multiple population parameter studies. J. Marketing Ed. 12(3):30–33.

BAPTISTA, J. 1999. The diffusion of process innovations: A selective review. Int. J. Economics Bus. 6(1):107–129.

BASS, F. 1969. A new product growth model for consumer durables. Management Science 15 (January):215–27.

BLACK, T. 1998. Salvaging our failing infrastructure: A public works challenge. American City & County 113(10):64–79.

BLANKENSHIP, A. B., AND G. BREEN. 1992. State of the art of marketing research. NTC Publishing Group, Chicago, IL.

BUSCH, P. S., AND M. J. HOUSTON. 1985. Marketing: Strategic foundations. Richard D. Irwin, Inc., Homewood, IL.

CAHILL, D. 1994. The marketing concept and new high-tech products: Is there a fit? J. Product Innovation Mgmt. 11(4):336–343.

COFER, W., K. FRIDLEY, AND D. MCLEAN. 1998. Structural design and analysis progress report first quarter 1998. Washington State University, Pullman WA.

CRAIGIE, LARRY. 2000. Personal Communication. Composites Fabricators Association. Arlington, VA. July 28.

CRAWFORD, D., R. DEGROOT, J. WATKINGS, AND H. GREAVES. 2000. Treatability of U.S. wood species with pigment-emulsified creosote. Forest Prod. J. (50)29–35.

DILLMAN, D. A. 1978. Mail and telephone surveys: The total design method. John Wiley & Sons, Inc., New York, NY.

EAGAR, T. 1995. Bringing new materials to market. Technology Review 98(2):42–50.

EASTIN, I., S. SHOOK, AND D. SIMON. 1999. Softwood lumber substitution in the U.S. residential construction industry in 1994. Forest Prod. J. 49(5):21–27.

EATON, R. A., AND M. D. C. HALE 1993. Wood: Decay, pests and protection. Chapman & Hall, New York, NY.

FELL, D., AND E. HANSEN. 1999. Target engineered products to builders most likely to innovate. Wood Technol. 126(4):22–25.

FELTON, C., AND R. DEGROOT. 1996. The recycling potential of preservative treated wood. Forest Prod. J. (46)7/8:37–47.

GAYTHWAITE, J. 1990. Design of marine facilities for the berthing, mooring, and repair of vessels. Van Nostrand Reinhold, New York, NY.

GRONROSS, J., AND J. BOWYER. 1999. Assessment of the market potential for environmentally certified wood products in new homes in Minneapolis/St. Paul and Chicago. Forest Prod. J. 49(6):28–34.

HANSEN, E., AND J. MORRELL. 1997. Use of anti-stain chemical treatments by western U.S. softwood lumber industry. Forest Prod. J. 47(6):69–73.

HANSEN, L. 2000. More Mega-yachts afloat due to rising economic waters. Virginian Pilot, Norfolk, VA. July 24. B6.

HASTAK, M., AND D. HALPIN. 2000. Assessment of life-cycle benefit-cost of composites in construction. J. Composites for Construction 4(3):103–111.

HENRIKSEN, M. 2000. CFA announces polyester sales to the U.S. fiber-reinforced composites market up 4.9% for 1999. Arlington, VA. http://www.cfa-hq.org/pr061500b.htm. (13 Oct. 2000).

HERSZENHORN, D. 1999. Pest is eating at city's edge: A cleaner harbor gives new life to marine borers. New York Times, NY, July 28. B1.

HOFFARD, T., AND D. PENDLETON. 1998. SP-2042-SHR. Navy wood survey summary. Naval Facilities Engineering Service Center, June, Port Hueneme, CA.

HUDSON, B. 1999. Personal Communication. Sales Representative for Seaward International Inc., Clearbrook, VA. April 16.

INTERNATIONAL MARINA INSTITUTE (IMI). 1998. Financial and operational benchmark study for marina operators. Report prepared by: Moss Adams Advisory Services, Seattle, WA, Report published by IMI, Nokomis, FL.

KENNEDY, R. 1999. A man with a fish's-eye view of the city. New York Times, NY, Feb. 26. B2.

KERBER, D. 1999. Personal Communication. Sales Representative for Schuyler Rubber Co./SSR Marine Fenders, Woodinville, WA. April 16.

KNIGHTS, M. 1996. Plastic lumber: Ready for prime time. Plastics Technology 42(8):34–39.

KOEBEL, T. 1999. Sustaining sustainability: Innovation in housing and built environment. J. Urban Technol. 6(3): 75–94.

KOTLER, P., AND G. ARMSTRONG. 1996. Principles of marketing, 7th ed. Prentice Hall, Englewood Cliffs, NJ.

KRASNER, J. 1998. What's eating Boston harbor? Worm returns. Wall Street Journal, NY, Sept. 23. NE2.

LANCASTER COMPOSITES INC. Columbia, PA. (not dated). Brochure: Composite Post 40: Marine Piling & Structurals.

LENARD, J. 1999. Personal Communication. Association Director of Marine Operators Association of America, Washington, DC. August 27.

LEWIS, R. 1999. Personal Communication. Sales Representative for Schrader Co., Plastic Pilings Inc., Burlington, WA. April 16.

MAHAJAN, V., E. MULLER, AND F. BASS. 1990. New product diffusion models in marketing: A review and direction for research. J. Marketing. 54 (January):1–26.

MALVAR, L. J., T. A. HOFFARD, D. E. PENDLETON, AND D. E. HOY. 1998. SP-2035-SHR: Description and requirements for candidate waterfront engineered wood materials and components. March. Naval Facilities Engineering Service Center, Port Hueneme, CA.

MARCH, F., AND M. COLTURI. 1998. Ports '98: Market advancement for composite marine piling and timber. ASCE. Long Beach, CA. Pp. 824–829.

———, AND W. JARVIS. 1997. Application of large woodfiber-plastic composites for marine structures. The Fourth International Conference on Woodfiber-Plastic Composites. Forest Products Society, Madison, WI.

MITROPOULOS, P., AND C. B. TATUM. 1999. Technology adoption decisions in construction organizations. Journal of Construction Eng. Mgmt. 125(5):330–338.

———, AND ———. 2000. Forces driving adoption of new information technologies. J. Construction Eng. Mgmt. 126(5):340–348.

MOTTRAM, B. 2000. Big boats—Trendy, spendy boaters typically buying larger crafts despite rising costs. The News Tribune, Tacoma, WA. March 29. C4.

NAHB RESEARCH CENTER. 2000. New building materials. http://wwwnahbrc.org/ (29 Sept. 2000)

NATIONAL MARINE MANUFACTURERS ASSOCIATION. (NMMA). 1999. National Marina Directory 1999. Sourcemark Services, Inc., 150 North Wacker Drive, Suite 1345. Chicago, IL, Excel version.

OZANNE, L., AND P. SMITH. 1995. Measuring the market opening for certified forest products. J. Woodworkers, Alliance for Rainforest Protection. 5(4):1–2.

———, AND R. VLOSKY. 1997. Willingness to pay for environmentally certified wood products: A consumer perspective. Forest Prod. J. 47(6):39–47.

PEARL, D., AND D. FAIRLEY. 1985. Testing for the potential for non-response bias in sample surveys. University of Chicago Press. Public Opinion Quart. 49(4):553–560.

PENDLETON, D., AND T. HOFFARD. 1998. SP-2040-SHR. Management of treated wood removed from waterfront service options and costs for Navy activities. Naval Facilities Engineering Service Center, June, Port Hueneme, CA.

PETRA, J. 1999. Personal Communication. Director of Statistical Department of National Marine Manufacturers Association. Chicago, IL. August 20.

———. 2000. 1999 US recreational boat registration statistics. http//www.nmma.org/statistics.html.

PHAIR, M. 1997. Composite piles gaining ground. Engineering News Record. Jan. 6. McGraw-Hill Companies, New York, NY.

PIANKA, R. 1999. Personal Communication. Sales Representative of Lancaster Composites Inc., Columbia, PA. March 12.

RASMUSSEN, E. 1997. Fathoming the strength of structures. Civil Engineering 67(7):58–59.

ROBERTS, J. 2000. Developing new rules for new markets. Academy of Marketing Sci. 28(1):31–44.

ROBINSON, H. 1999. Personal Communication. Sales Representative for Galva-Foam Marine Industries, Camdenton, Missouri. August 16.

ROGERS, E. 1995. Diffusion of innovations, 4th ed. The Free Press, New York, NY.

ROHDE, D. 1998. Burrowing crustaceans cause closing of pier. New York Times, NY, Apr. 28. B3.

ROSENBERG, N., P. INCE, K. SKOG, AND A. PLANTINGA. 1990. Understanding the adoption of new technology in the forest products industry. Forest Prod. J. 40(10):15–22.

SCHUYLER RUBBER CO. Woodinville, WA (not dated). Brochure: Marine fenders offshore and dockside.

SCOLA, P. T. 1989. U.S. Navy underwater inspection of waterfront facilities. Pages 16–34 *in* Proc. Ports' 89. ASCE, New York, NY.

SEAWARD INTERNATIONAL, INC. Clearbrook, VA. (not dated). Brochure: Seapile, Seatimber, Seacamel: Composite marine piling, timber, and camel.

SHOOK, S. 1999. Forecasting adoption and substitution of successive generations of structural wood panel products in the United States. Forest Science 45(2):232–248.

SMITH, P., AND R. VLOSKY. 1997. Electronic Data Interchange (EDI): Implementation Strategies in the Forest Products Industries. *In* Conference Proc. Logistics—for the Forest Industy, Rotorua, New Zealand, November 1997.

———, AND K. D. BRIGHT. 2001. Perceptions of new and established waterfront materials. Wood Fiber Sci. (In Press).

SMITH, R. L., R. BUSH, AND S. BOWE. 1999. A perceptional investigation into the adoption of timber bridges: A national comparative study. Wood Fiber Sci. 31(2):204–216.

———, W. SPRADLIN, D. ALDERMAN, JR., AND E. CESA. 2000a. A perceptional comparison of wood in separate infrastructure markets. Wood Fiber Sci. 32(2):239–255.

———. 2000b. Perceptions of wood in the highway infrastructure market. Forest Prod. J. 50(6):23–31.

TANAL, V., AND A. MATLIN. 1996. Marine borers are back. Civil Engineering 66(10):71–76.

TOBIASSON, B., AND R. KOLLMEYER. 1991. Marinas and small craft harbors. Van Nostrand Reinhold, New York, NY.

TOENSMEIER, P. 1994. Composites industry eyes civil engineering as next big market. Modern Plastics 71(4):18–19.

TRINKA, M., S. SINCLAIR, AND T. MARCIN. 1992. Determinant attribute analysis: A tool for new product development. Wood Fiber Sci. 24(4):385–391.

TROUTMAN, D. 1998. Ports '98: High-strength fiber reinforced polymer composites offer new significance to marine pier design, vol. 2. ASCE, Long Beach, CA.

TSINKER, G. 1995. Marinas. Pages 413–502 *in* Marine structures engineering: Specialized applications. Chapman & Hall, New York, NY.

———. 1997. Handbook of port and harbor engineering. Chapman & Hall, New York, NY.

UNITED STATES PORT DEVELOPMENT EXPENDITURE REPORT. 2000. U.S. Department of Transportation Maritime Administration: Office of Ports and Domestic Shipping. Dec. Washington, DC.

U.S. DEPARTMENT OF AGRICULTURE. 1980. The biological and economic assessment of pentachlorophenol inorganic arsenicals and creosote, vol 1. Wood Preserv. Tech. Bull. 1658-1. Cooperative Impact Assessment Rept. USDA, Washington D.C.

VLOSKY, R., P. SMITH, AND D. WILSON. 1994. Electronic data interchange implementation strategies: A case study. J. Business Ind. Marketing 9(4):5–18.

WAKEFIELD, S. 2001. Personal Communication. Manager of Marketing and Member Services for Marine Operators Association of America, Washington, DC. January 9.

WESTRUP, H. 1992. Patching the nation's crumbling highways. Current Science 77(14):6–7.