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Feature Article

Evaluation of interventions focused on reducing propeller scarring by recreational boaters in Florida, USA

Savanna C. Barry [a,b,c,*], Karissa N. Raskin [d], Joy E. Hazell [b,c], Maria C. Morera [d], Paul F. Monaghan [d]

[a] Nature Coast Biological Station, University of Florida, 552 1st Street, Cedar Key, FL, 32625, USA
[b] Florida Sea Grant, University of Florida IFAS Extension, PO Box 110400, Gainesville, FL, 32611, USA
[c] School of Forest Resources and Conservation, University of Florida, PO Box 110410, Gainesville, FL, 32611, USA
[d] Department of Agricultural Educational and Communication, University of Florida, PO Box 110540, Gainesville, FL, USA

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ABSTRACT

Propeller scarring by recreational vessels is a known threat to seagrass meadows in Florida. Despite decades of awareness about the problem, there has been little meaningful progress in addressing this largely preventable stressor. We consider it preventable because it rests on human behaviors, which can be changed by education, technology, social norms, and policy. However, past attempts to address seagrass scarring have rarely been evaluated for effectiveness. Thus, very little guidance exists for natural resource managers, educators, and policy makers responsible for allocating limited resources toward effective interventions. Using a social marketing approach, we deployed two separate interventions, one education-based and the other cue-based (navigational aids) in Florida, USA. We measured boater behavior and attitudes before and after the interventions to assess the relative effectiveness of each. Navigational aids elicited a clear behavioral improvement across a broad cross-section of boaters, while minimal effects were observed for the educational intervention. However, analyses suggest the recreational boating audience can be segmented by factors such as experience level to better target educational messages in future seagrass protection efforts. These results will assist seagrass managers, educators, advocates, policy makers, and boating industry stakeholders in deploying an efficient combination of approaches to better address propeller scarring in Florida's seagrass meadows.

1. Introduction

Among the multiple stressors contributing to the decline of seagrass meadows in Florida, including non-point source pollution and elevated sea surface temperatures, boat-generated scarring represents a direct and largely preventable threat (Sargent et al., 1995; Hallac et al., 2012; Carlson et al., 2018). Seagrass scarring can be reduced when boaters are educated about the risks, aware of the conditions, experienced in operating a boat, and reminded of the dangers and penalties for this behavior. Management programs designed to educate the public and prevent physical perturbations in seagrass beds have been in effect for more than two decades (Sargent et al., 1995). Yet, propeller scarring of seagrass associated with recreational factors has worsened in some areas, such as Florida Bay (NPS, 2008; Atkins, 2011; Kruer, 2017), and remains a significant source of seagrass disruption (Hallac et al., 2012). At issue is an ongoing disconnect between boating behaviors and preventative management efforts. Herein, we present the results of a social marketing campaign aimed at recreational boater behavioral change.

Seagrass scarring is physical damage caused when the hulls, propellers, motors, or anchors of vessels come into contact with shallow seagrass beds. While water quality issues pose the greatest threat to seagrass health in Florida (FWC, 2012), seagrass scarring has several long-term negative impacts in seagrass ecosystems (Zieman, 1976; Lewis and Estevez, 1988; Durako et al., 1992; Dawes et al., 1997; Kenworthy et al., 2002, 2006; Whitfield et al., 2002; Larkin et al., 2010; Uhrin et al., 2011; Orth et al., 2017; Furman et al., 2018). Over time, erosion and scouring from waves and currents in scarred areas, especially those dominated by fine sediments, can result in expansion of scars, causing additional loss of seagrass and declines in the functional habitat value (Bell et al., 2001; Whitfield et al., 2002; Uhrin and Holmquist, 2003; Bourque et al., 2015; Sweatman et al., 2017).

* Corresponding author. UF/IFAS Nature Coast Biological Station, PO Box 878, Cedar Key, FL, 32625, USA.
E-mail address: savanna.barry@ufl.edu (S.C. Barry).

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Boat damage to seagrass beds in Florida Bay has been a recognized problem since the early 1950s (NPS, 2008) and continues to be a problem in coastal waters of Florida (Sargent et al., 1995; Durako et al., 1992; Kenworthy et al., 2002, 2006; Geselbracht et al., 2011; FWC, 2012). Although large commercial vessels are responsible for significant propeller scarring at a number of locations along the Atlantic and Gulf Coasts of the United States, in Florida, most seagrass disruption results from widespread scarring by smaller boats (Sargent et al., 1995; Orth et al., 2017) where a lack of experience, knowledge, and skills are important drivers (Sargent et al., 1995).

Management strategies implemented at federal and state levels to prevent seagrass scarring have consisted of multifaceted approaches that include education, signage, no-motor areas, and restricted entry zones (Sargent, 1995; FDEP, 2004; Atkins, 2011; Lathrop et al., 2017; Orth et al., 2017). Regulatory interventions such as the creation of no-motor zones or slow speed zones have been widely applied and generally show mixed results (Gorzelany, 1996, 2008, 2004; 2006; Scheidt and Garreau, 2007; Sorice et al., 2007; Schaub et al., 2009; Jett and Thapa, 2010; Atkins, 2011; Lathrop et al., 2017). Many of these studies report either no significant change in boater behavior or even a negative boater behavior response to new regulatory zones, perhaps given the unpopularity of such approaches among some boater groups (Chipman and Helfrich, 1988; Salz et al., 2001; Salz and Loomis, 2005). Findings also indicate that environmental education approaches have been frequently applied with mixed results in attempts to influence boater behaviors (Morris, 2004; FDEP, 2004) because educational programs must contend with a variety of user groups and limited public awareness (Hallac et al., 2012). Nonetheless, in the Chesapeake Bay, aerial monitoring has shown that regulations have been effective and that open discussions between scientists, natural resource managers, and the public have resulted in increased understanding of the impact of boating activities (Orth et al., 2017). Furthermore, a major pole and troll zone was established in Everglades National Park with public support in 2011 (Atkins, 2011) and while monitoring of this effort is ongoing, early reports suggest positive results (Atkins, 2017). These examples suggest a role for community-based strategies that involve cooperation with the public.

Community-based social marketing (CBSM) blends community organization techniques with commercial marketing research principles, including audience analysis, plans to reduce the barriers to change, and targeted communication to promote socially beneficial action (Andreasen, 1995; Bryant et al., 2007; Geller, 1989; Kotler and Zaltman, 1971). A key component of CBSM interventions that address gaps between education and behavior, is the targeting of specific audience segments with behavioral choices that compete with comfortable—yet potentially harmful—alternatives (Andreasen, 1995, 2005). For example, not all boaters are the same and a social marketing approach may choose to focus on new boaters, or those who engage in specific activities such as fishing or diving, if research shows those characteristics present different constraints to adopting a new behavior. Over the longer term, CBSM efforts seek to facilitate the adoption of positive practices and attitudes by a broad cross-section of the target population by identifying and lowering barriers to behavior change. A CBSM approach to environmental behaviors stands in contrast to traditional environmental education approaches that assume a lack of knowledge is the primary barrier to change or the adoption of innovations. While knowledge and awareness of new ideas and behaviors is often a prerequisite to change, it is rarely enough to produce results. CBSM boosts the likelihood of behavior change through audience segmentation, focusing campaigns on the benefits valued by the target audience. CBSM has been applied in nutrition, conservation, public health, and social justice issues but has rarely been applied to address problems in coastal systems related to recreational boater behavior (Bowerman and DeLorme, 2014; DeLorme et al., 2015).

We used CBSM to better understand our audience and to develop and evaluate an education-based (a media campaign) intervention. We compared it with a more traditional, cue-based intervention (installing warning buoys near shallow seagrass beds) to compare effectiveness and results. Both approaches are based on the needs of the target audience (awareness and guidance) and each provides lessons for natural resource managers, educators, and policy makers. Similar interventions have been widely applied in Florida but the scarcity of information on the outcomes precludes critical evaluation and improvement to future efforts. Interventions were applied to address two potential barriers to change: lack of knowledge about seagrass scarring and lack of adequate navigational skill/navigational markers. We also sought to better define different audiences among recreational boaters as well as identify boater values and motivators in order to craft messages that would increase the likelihood of adopting seagrass-friendly boating practices (i.e., slowing down near seagrass, trimming up motor near seagrass). We hypothesized that two of the main barriers to achieving seagrass-safe boating were:

1) Boaters' lack of knowledge about seagrass and seagrass scarring as a problem. Knowledge and communications about coastal ecosystems are not widespread, especially for submerged habitats like seagrass that are harder to access and view (Duarte et al., 2008; Hallac et al., 2012; Lloret et al., 2008). In addition, knowledge about the extent of damage that can be done by propeller scarring is not well known (Hallac et al., 2012; Orth et al., 2017).
2) Boaters' lack of navigational skill and the low number of aids to navigation along Florida's very shallow waters are also problems. There are many visitors and non-local boaters attempting to navigate in poorly marked and challengingly shallow waters (Sargent et al., 1995; Hallac et al., 2012).

We further hypothesized that lack of navigational skill/aids to navigation was the more significant barrier and would respond more strongly to an intervention. We tested our hypotheses by deploying an intervention to address each barrier and using pre-/post-observations (either intercept surveys or behavioral observation) to determine which intervention resulted in a more significant adoption of desired behaviors.

2. Materials and methods

2.1. Educational campaign

The educational campaign was developed by a community advisory committee composed of university faculty, Florida Sea Grant Extension, commercial fishermen, professional guides, sport fishermen, recreational boaters, and a marketing firm. We conducted market research that included boat ramp surveys, key informant interviews, stakeholder focus groups, and message testing. Over 75 local boaters, of all types, from rental boat clients to marina owners, dedicated anglers, commercial guides, seasonal scallop enthusiasts, and long term residents of the targeted areas, were asked for their opinions about seagrass health, good boater stewardship and ways to improve the natural resources of a popular boating and fishing area in southwest Florida. The advisory committee looked at propeller scarring from an individual boater behavior perspective as well as a community-wide issue of stewardship among county boaters and natural resources stakeholder groups. The committee suggested that communications focus on new boaters and those with little experience who rent boats and show them the consequences of behaviors that cause unsafe conditions such as grounding and scarring. The impact to fishing and wildlife habitat was highlighted.

We piloted the Be Seagrass Safe campaign (including the Scars Hurt signage and webpage) in the Naples, Florida area. Educational messages were directed at boaters, especially those who lacked experience in the shallow waters of the region. Graphics and messages developed during the focus group and pilot testing phase were adapted into a series of educational campaign materials, including boat ramp signage, social media graphics, a website with YouTube videos, slides for public lectures, online fact sheets, stickers, phone cases, and flyers (Fig. 1, also see:

http://beseagrasssafe.com/).

These materials were distributed through a variety of methods in Florida's north-central Gulf coast, including direct contact at boat ramps, providing flyers and stickers to hotels and boat rental locations, public presentations, social media and website promotion, and publishing online blogs and magazine articles. The campaign was deployed beginning in Oct 2016 and continued through July 2017, with the majority of the effort from May to July 2017.

2.2. Navigational aids

We installed six seagrass warning buoys around the most heavily scarred area of a shallow seagrass bank adjacent to a sandbar in Crystal River, Florida that receives frequent boat traffic. Buoys were placed approximately 100 m apart along the contour of the shallow seagrass bank adjacent to the sandbar in May 2017. Buoys were 23 cm in diameter and 155 cm tall, with approximately 91 cm of the buoy visible above the water. They were white with orange reflective tape and a diamond symbol, the standard maritime symbol for a hazard warning. The buoys bore the message "CAUTION SEAGRASS AREA" in black lettering (Fig. 2). The area remained open to boat traffic and there were no speed restrictions or other regulatory meaning associated with these informational warning buoys.

2.3. Pre- and post-intervention surveys

We conducted pre- and post-intervention surveys (Appendix) to determine the effectiveness of the educational campaign and navigational aid approaches. For both interventions, pre-surveys were conducted in the summer (Jun–Sep) of 2016 and post-surveys were conducted in the summer (Jun–Sep) of 2017. Data for the educational campaign intervention were collected in person via intercept surveys with recreational boaters at popular boat launch points in Crystal River, Cedar Key, and Steinhatchee, Florida. Researchers approached boaters and invited them to participate in the survey by reading an informed consent statement. If the boater agreed to participate, the researcher read survey questions aloud to participants and recorded answers on their behalf. At the conclusion of the survey, boaters were asked to sign a voluntary seagrass safe boating pledge.

Data for the navigational aid intervention were collected by observing boater behavior at the location of the buoy placement. Observers were stationed on an unmarked vessel in a location with a good vantage of the target location and used binoculars to ensure optimal visual accuracy. Researchers worked in teams of at least three (two observers and one data recorder) to record information about boater behavior for every boat that approached the area during the observation event. All data collection events (intercept surveys and boater observations) occurred on calm days in the absence of thunderstorms or rain, to ensure observer safety and avoid interruption of observational events.

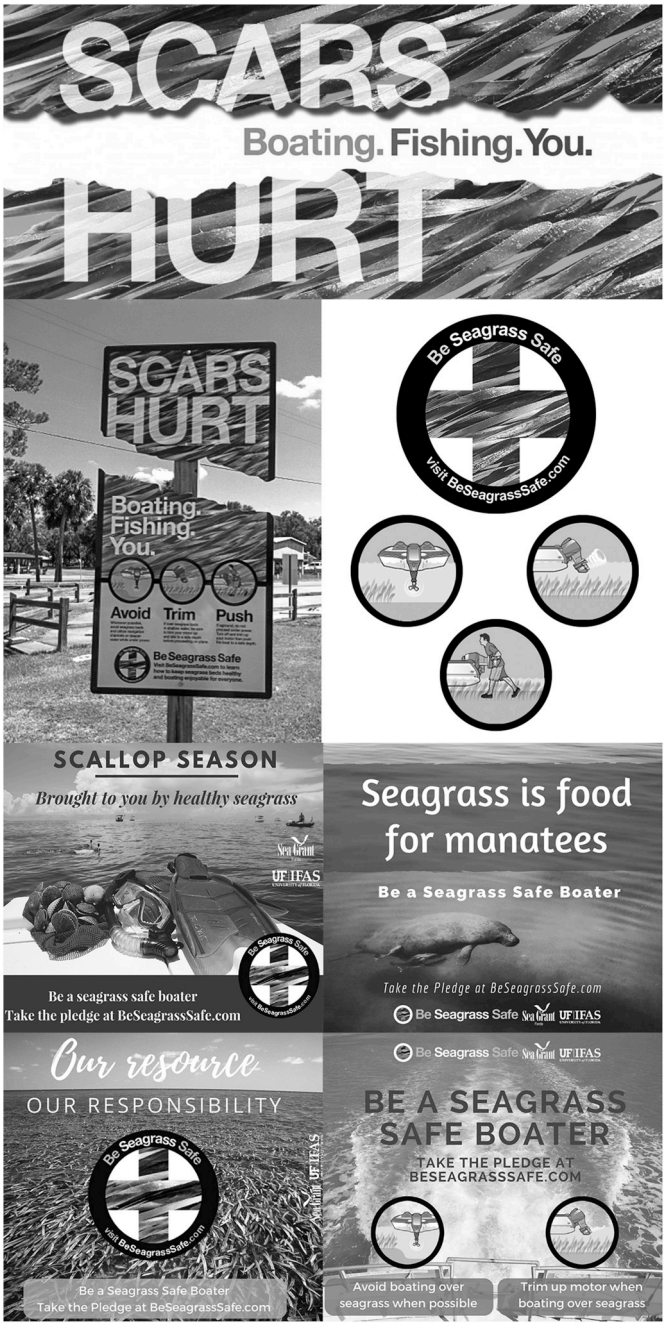

Fig. 1. Examples of materials used in the educational intervention. From top to bottom, left to right: Scars Hurt website header, boat ramp sign, Be Seagrass Safe emblem, boater behavior icons (avoid, trim, push), social media post images (four examples).

Fig. 2. Photograph of a shallow seagrass warning buoy placed for the cue-based intervention.

2.4. Data analysis

For each intervention, we applied regression tree analysis to parse significant driving factors of the target attitude or behavior and identify thresholds for target audiences. The dependent variable was the rating of scarring as a problem for the educational campaign and the distance away from the area that boaters slowed down for the navigational aid intervention. We used the ANOVA method of recursive partitioning and pruned over-fitted trees using k-fold cross-validation procedures available in the R package 'rpart' in R version 3.3.0 (Therneau et al., 2018). See Table 1 for a list of variables entered into the regression tree and the final variables included in the tree after pruning for each analysis. Levene's (1960) test, based on the median (Brown and Forsythe, 1974), was used as a diagnostic tool to assess whether the assumption of homogeneity of variance was tenable. The test indicated that variances were not significantly different between the pre and post samples for all but one variable (accidental cutting of seagrass beds within last 12 months). In that case, we also double-checked the variance ratio. However, the ratio was less than 2, suggesting it was safe to assume homogeneity of variance (Kirk, 2013). We also conducted independent means t-tests and bivariate correlation analysis using SPSS (version 25.0; IBM, Armonk, NY) to provide further insight into specific variables of interest. Finally, we summarized answers to open-ended survey questions to enrich understanding of audience segments and educational messages that may resonate with boaters in future campaigns.

Table 1
Variables included in regression tree models for each intervention. Bold independent variables indicate those included in the final regression tree after pruning to minimize over-fitting.

Intervention	Dependent variable	Independent variables
Educational campaign	Rating of seagrass scarring as a problem (Likert scale: 1 to 5)	- Intervention status (pre or post) - Survey location (Crystal River, Cedar Key, Steinhatchee) - **Years of boating experience** (numerical) - Primary purpose for boating (fishing, scalloping, or pleasure boating) - Number of times boated in the last year (numerical) - Churned mud and grass in the last year (yes or no) - Scarred seagrass in the last year (yes or no) - Rating of the importance of seagrass (Likert scale: 1 to 5) - **Recall seeing information about preventing seagrass scarring** (yes or no) - **Pledge signed** (yes or no)
Navigational aids	Distance away from the seagrass bank the boater slowed down (ordinal scale: 1 to 4) 1 = did not slow down until right next to sandbar 2 = slowed down less than 100 m away 3 = slowed down 100–200 m away 4 = slowed down more than 200 m away	- **Intervention status** (pre or post) - Tide stage (falling, rising, slack) - Type of boat (deck/pontoon, open fisher, airboat, skiff/utility, flats, personal watercraft, john boat, other) - Size of boat (less than 21 feet or 21 feet or more) - Operator gender (male or female) - Direction of approach (cardinal directions) - Speed of approach (idle, fast idle, on plane) - Rental boat (yes or no)

3. Results

3.1. Educational campaign

A total of 449 boaters participated in the intercept survey, 148 in the pre-campaign surveys and 301 in the post-campaign surveys. There were almost no significant differences in the audience composition, attitudes, or behaviors of recreational boaters between the pre- and post-campaign time periods (Table 2). However, there was a small but significant decline in the percentage of boaters who reported cutting a scar in seagrass between the pre- (17%) and post- (9%) campaign surveys ($t = -2.31$, $df = 205.8$, $p = 0.02$). Across both time periods, respondents who reported accidentally cutting a scar in the last 12 months also tended to be more frequent boaters (pre: $r = 0.26$, $p < 0.001$; post: $r = 0.13$, $p = 0.03$).

Boaters generally indicated that seagrass scarring was not a serious issue to them. Overall, average ratings barely approached neutral (pre: 2.56; post: 2.18), but the distribution of responses was bimodal, indicating that there are two main segments of boaters. Regression tree analysis showed that boater experience (number of years boating in Florida, Table 1) was the main factor that predicted that rating a boater would assign to seagrass scarring as an issue, with the major division in the target population occurring at 4.5 years of boating experience (Fig. 3a). More experienced boaters (those with at least 4.5 years of experience) tended to rate seagrass scarring as more of an issue (mean rating = 2.46) than boaters with less experience (mean rating = 1.52). Within the more experienced boater group, there was a further division in the audience where boaters who signed the optional pledge were also more likely to rate seagrass scarring as more of an issue (mean rating = 2.57) in comparison to those who did not sign the pledge (mean rating = 1.70). Of the less experienced boaters, the audience was further divided by those who recalled seeing information about propeller scar prevention vs. those who did not recall any information (Table 1). There was a small but significant subset of inexperienced boaters who recalled seeing information about preventing propeller scarring. These boaters rated seagrass scarring as a much more severe issue, with a mean rating of 4.00 for this subgroup (Fig. 3a). Inexperienced boaters who did not recall seeing any information had the lowest average rating of any other subgroup (1.21). Bivariate correlation analysis revealed that, across both sampling periods, boaters who recalled seeing information about preventing propeller scarring were more likely to rate scarring a problem (pre: $r = 0.22$, $p = 0.01$; post: $r = 0.15$, $p = 0.01$). However, the overall number of boaters who recalled seeing information was relatively low (18–22%) and did not increase significantly after the educational campaign. Interestingly, 41% of boaters who recalled information in the post-intervention surveys specifically recalled campaign materials such as boat ramp signs, social media, or stickers as the information source.

Almost all boaters surveyed, regardless of experience level or other factors, rated seagrass meadows as important or extremely important, and these sentiments were not significantly different across the two sampling periods. Mean rating of seagrass importance changed minutely from 4.78 to 4.71 and 96% of respondents felt they were important across both time periods. There was a weak positive correlation between the rating boaters assigned to the importance of seagrass and the issue of seagrass scarring in the post-campaign period ($r = 0.14$, $p = 0.02$). Responses to the open-ended survey question asking boaters about the most important reasons for protecting seagrass revealed several common themes. Overall, the most common theme was that seagrass provides habitat for fish and wildlife (55.2% of responses), followed by the themes that seagrasses were a natural part of the estuarine ecosystem (10.5% of responses) and that conserving nature is the right thing to do (5.6% of responses). There were several other themes that were mentioned very infrequently (ranging from 0.5 to 5.5% of responses). These included themes of water quality improvement, food web relationships, erosion prevention, aesthetics/beauty, support for young or

Table 2
Survey audience characteristics, self-reported behavior, and overall ratings of seagrass scarring and the importance of seagrass in the pre- and post-phases of the educational campaign intervention.

	Pre-campaign (n = 148)	Post-campaign (n = 301)	
	Survey participants (%)		
Purpose for boating today			
Fishing	42	44	
Scalloping	57	51	
Other	9	13	
	Years (mean)		
Boating experience	20.6	21.6	ns
	Count (mean)		
Boating frequency in the past 12 months	26.6	24.1	ns
	Survey participants (%)		
Boating behavior			
Churned grass and mud	44	35	ns
Cut a scar in seagrass	17	9	$p = 0.02$
Ran aground	19	18	ns
	Survey participants (%)		
Recalled information about preventing scarring	18	22	ns
Views	Rating on 5-point scale (mean)		
Problem of seagrass scarring	2.59	2.18	ns
Importance of healthy seagrass beds	4.78	4.71	ns

small organisms (nursery function), and protection for future generations.

3.2. Navigational aids

Regression tree analysis indicated that the only significant factor for predicting the distance away that boaters slowed down was the observation time period (pre-buoy vs. post-buoy; Fig. 3b). Independent means t-tests verified that, overall, the distances at which boaters slowed down before reaching the sandbar increased significantly after the placement of the seagrass warning buoys ($t = 3.69$, $df = 122$, $p < 0.001$). The percentage of boaters who slowed down more than 200 m out increased significantly after the buoy intervention (pre: mean = 26%, post: mean = 41%; $t = 2.31$, $df = 183$, $p = 0.02$). Furthermore, the percentage of boaters who slowed down less than 100 m out or did not slow down until reaching the sandbar decreased significantly (<100m: pre-buoy mean = 20%, post-buoy mean = 8%; $t = -2.28$; $df = 147$, $p = 0.02$; did not slow: pre-buoy mean = 9%, post-buoy mean = 2%; $t = -2.11$, $df = 119$, $p = 0.04$). For the post-buoy observation period only, bivariate correlation analysis revealed that both larger boats (>21 ft) and deck/pontoon boats were more likely to slow down at greater distances (>21 ft: $r = 0.23$, $p = 0.02$; deck/pontoon: $r = 0.23$, $p = 0.02$).

Independent means t-tests did not show any significant differences, overall, for the speed of approach or the percentage of boaters who trimmed up their motors between the pre- and post-buoy observation periods. However, bivariate correlation analysis showed that for both observational periods deck/pontoon boats were more likely to approach at slower overall speeds (pre: $r = -0.30$, $p < 0.001$; post: $r = -0.31$, $p < 0.001$) and boaters who slowed down at greater distances were more likely to trim up their motors (pre: $r = 0.35$, $p = 0.01$; post: $r = 26$, $p = 0.03$).

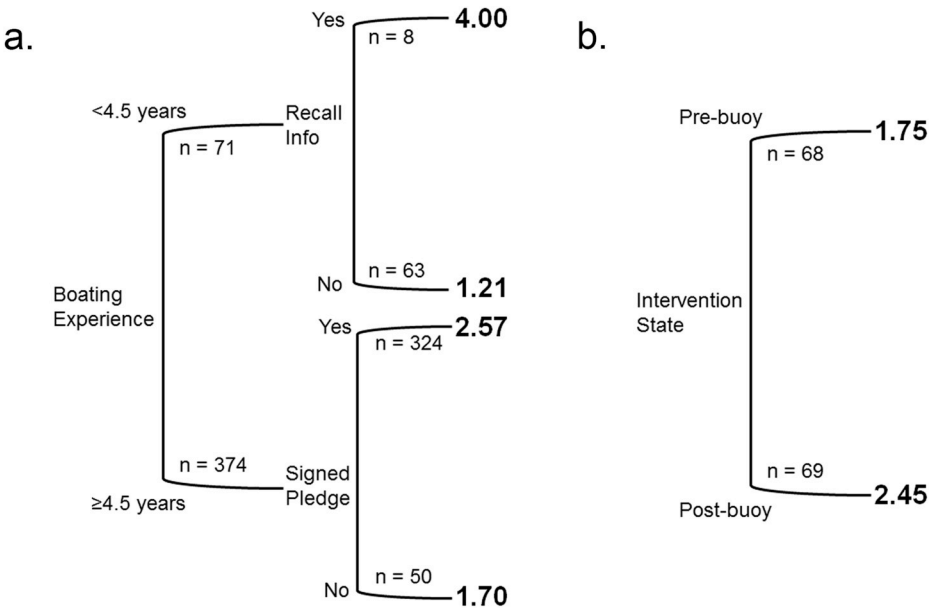

Fig. 3. Regression tree results for a. the educational intervention and b. the buoy intervention. Large bold numbers represent the mean for each subgroup of the dependent variable for analysis (see Table 1).

4. Discussion

Overall, the navigational aids appeared to result in a more immediate and direct increase in seagrass-friendly boating behavior across a wider cross-section of boaters. This is evidenced by the apparently small percentage of boaters reached by campaign materials (4 percentage point increase in boaters who recalled information) and the lack of widespread significant changes in boater attitudes and behavior across sampling periods. In contrast, we documented a higher percentage of boaters positively altering their behavior in response to buoys (e.g., 15 percentage point increase in boaters slowing down far away). Results from the educational campaign also indicated that the vast majority of boaters already assigned high importance to seagrass (96%) and that most could correctly identify at least one correct shallow water boating behavior (97%) before the campaign. These results support our hypothesis that lack of aids to navigation was the more significant barrier to seagrass-friendly boating behavior in this region of Florida. The apparently more immediate benefits of buoys for seagrass protection could be explained by the fact that the buoy intervention occurred close to the location where behavior should be applied. This follows the social marketing practice of placing behavioral reinforcement cues close to where the consumer makes the decision to adopt the behavior (Lee and Kotler, 2016), in this case, slowing the boat and trimming the motor. Prior research has shown that such interventions are typically more effective than those that occur farther away (Lee and Kotler, 2016). While our boat ramp intercept interviews had a low chance of detecting change (original participants were not re-surveyed at a later date), we were encouraged that those who took the pledge later self-reported that they applied the recommended behaviors, shared information with other boaters, and had a more positive attitude towards the importance of seagrass.

Even though lack of knowledge about seagrass or shallow water boating did not appear to be a major barrier, there are several areas for improvement in boater knowledge about seagrass and seagrass scarring. Overall, boaters largely seemed to understand only the habitat function of seagrasses, with many of the other benefits of seagrass ecosystems understood by only a small percentage of boaters. This finding confirmed what was originally reported in the focus groups conducted prior to the development of the Be Seagrass Safe campaign. Therefore, future education and outreach could aim to increase knowledge about the multiple benefits provided by seagrass ecosystems. This result is also important for informing future CBSM campaigns on seagrass because it shows that fish and wildlife habitat is a critical target for future messaging, as habitat benefits seem to resonate with a majority of boaters.

In general, there appears to be a disconnect between the high value boaters assign to seagrass and the low level of concern that most boaters reported about seagrass scarring. A relatively high percentage of boaters in the survey population self-reported that they had personally churned grass and mud (35–44%), scarred seagrass (9–17%), or run aground (18–19%) in the last year (Table 2). These results, as well as aerial imagery and statewide reports (Sargent et al., 1995; FWC, 2012), indicate that seagrass scarring is a significant and growing issue across Florida. Yet boaters we surveyed, even those who had personal experience with their boat hitting the bottom in some way, did not generally report that seagrass scarring was an important issue to them. Addressing this disconnect is another potential target for improved messaging in future CBSM campaigns. We found evidence that boaters who had accessed information about preventing seagrass scarring were more likely to rate scarring as a bigger issue. However, we hypothesize that showing boaters the problem in a more concrete manner through aerial imagery or reporting the percentage of boaters who have scarred seagrass might result in a more significant change in the level of concern boaters report about seagrass scarring.

Even though the navigational aids seemed to be more effective in the short-term, long-term behavior change is often more sustainable if there is a rationale or explanation provided to the audience (Geller, 2002). Boaters may be more likely to apply seagrass safe boating principles over the long-term when educational messages are deployed in tandem with cues (buoys) in areas the behaviors should be applied (Cottrell, 2003). We found evidence of small changes in attitudes and behaviors of certain subsets of boaters in our surveys, paired with evidence of larger improvement in behavior around buoys. Each intervention showed some level of positive outcome and each addressed different points along the spectrum of behavior change (awareness, concern, intention, action), with different audience segments perhaps being more responsive to different interventions at different points on the spectrum. We found evidence to suggest that the recreational boating audience can be segmented by experience level and boating frequency in terms of attitudes and behaviors. More experienced boaters tended to better understand that seagrass scarring was a problem but less experienced boaters were much more likely to rate scarring as an important issue if they had also recently viewed educational materials. However, more frequent boaters were more likely to have scarred seagrass in the last year, regardless of experience level. Therefore, the effectiveness and efficiency of educational campaigns could be increased by targeting these different audiences with messages suited to them and via informational pathways they are most likely to access (Hendee et al., 1990). For example, newer boaters or visitors to an area might be more likely to come into contact with educational messages delivered via boater safety classes, handouts at visitor's centers or hotels, and information at boat rental points. These introductory-level educational messages could be focused on the habitat benefits of seagrass that seemed to resonate universally with boaters. In contrast, experienced or resident boaters that frequently boat an area may respond better to more advanced messaging that includes elements such as aerial imagery or local information about the loss of services due to scarring in their own estuary. Interestingly, we did not find any evidence that activity type (e.g., scalloping, fishing, other activities like pleasure boating) should be considered a significant audience segmentation factor, though other studies have suggested primary activity on the water can be important in other regions (Lloret et al., 2008).

5. Conclusion

This study employed several behavior change methodologies in order to understand and influence boater behaviors related to seagrass scarring. Using a social marketing approach, we designed an educational campaign with the help of target audience members that addressed priority concerns for raising awareness about the damage caused by propeller scarring, and providing clear action items for all boaters in shallow areas. By offering boaters the chance to take a pledge to protect seagrass, we incorporated the power of commitments to influence change. We compared this with a more direct appeal to the navigational needs of boaters by installing warning buoys near shallow seagrass areas. The buoys had a measurable impact on boater behavior as they slowed their approach and trimmed their motors. Our research showed that many boaters admitted to causing seagrass scarring but few reported that seagrass scarring was a concern, demonstrating that we urgently need to make progress on this issue. Changing boater behavior to prevent damage to seagrass can be complex, involving knowledge, efficacy, concern for natural resources, and boating skills in shallow areas. We recommend that a variety of methods be used to raise awareness about propeller scarring (which was low but increased with the level of boater experience), reinforce the already accepted viewpoints about seagrass importance as habitat, and provide visible aids such as buoys in scarring hotspots. A variety of approaches are needed because in vast, remote areas, buoys cannot cover all of the potential areas needing protection. Education and raising awareness are also limited in their reach and effectiveness, pointing to the need to employ audience targeting to increase efficiency. Overall, the modest to minimal improvements in boater attitudes and behavior we report for these two non-

regulatory interventions point to the likelihood that a comprehensive solution to the seagrass scarring problem in Florida will require regulatory interventions such as special boating zones (e.g., troll and pole or slow speed areas), stricter penalties for boaters who cause seagrass damage, and enforcement of seagrass protection laws.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2019.105089.

References

Andreasen, A.R., 1995. Marketing Social Change: Changing Behavior to Promote Health, Social Development, and the Environment. Jossey-Bass, San Francisco, CA, USA, p. 368.

Andreasen, A.R., 2005. Social Marketing in the 21st Century. SAGE Publications, Inc., Thousand Oaks, CA, USA, p. 280.

Atkins, 2011. Snake Bight Pole and Troll Zone, Everglades National Park: Year 1 Monitoring Report. Technical Report. National Parks Service, Homestead, FL, USA, p. 58.

Atkins, 2017. Snake Bight Pole Troll Zone: Revegetation Monitoring and Analysis. Final Report, Everglades National Park, National Parks Service Contract P11PC21000. Homestead, FL, USA, p. 67.

Bell, S.S., Brooks, R.A., Robbins, B.D., Fonseca, M.F., Hall, M.O., 2001. Faunal response to fragmentation in seagrass habitats: implications for seagrass conservation. Biol. Conserv. 100, 115–123. https://doi.org/10.1016/S0006-3207(00)00212-3.

Bourque, A.S., Kenworthy, W.J., Fourqurean, J.W., 2015. Impacts of physical disturbance on ecosystem structure in subtropical seagrass meadows. Mar. Ecol. Prog. Ser. 540, 27–41. https://doi.org/10.3354/meps11505.

Bowerman, K., DeLorme, D.E., 2014. Boaters' perceptions of a mobile app for a marine conservation social marketing campaign. Soc. Mark. Q. 20, 47–65. https://doi.org/10.1177/1524500413515448.

Brown, M.B., Forsythe, A.B., 1974. Robust tests for the equality of variances. J. Am. Stat. Assoc. 69, 364–367. https://doi.org/10.2307/2285659.

Bryant, C.A., Brown, K.R., McDermott, R.J., Forthofer, M.S., Bumpus, E.C., Calkins, S.A., Zapata, L.B., 2007. Community-based prevention marketing. Health Promot. Pract. 8, 154–163. https://doi.org/10.1177/1524839906290089.

Carlson, D.F., Yarbro, L.A., Scolaro, S., Poniatowski, M., McGee-Absten, V., Carlson, P.R., 2018. Sea surface temperatures and seagrass mortality in Florida Bay: spatial and temporal patterns discerned from MODIS and AVHRR data. Remote Sens. Environ. 208, 171–188. https://doi.org/10.1016/j.rse.2018.02.014.

Chipman, B.D., Helfirch, L.A., 1988. Recreational specialization and motivations of Virginia river anglers. N. Am. J. Fish. Manag. 8, 390–398. https://doi.org/10.1577/1548-8675(1988)008<0390:RSAMOV>2.3.CO;2.

Cottrell, S.P., 2003. Influence of sociodemographics and environmental attitudes on general responsible environmental behavior among recreational boaters. Environ. Behav. 35, 347–375. https://doi.org/10.1177/0013916503035003003.

Dawes, C.J., Andorfer, J., Rose, C., Uranowski, C., Ehringer, N., 1997. Regrowth of the seagrass *Thalassia testudinum* into propeller scars. Aquat. Bot. 59, 139–155. https://doi.org/10.1016/S0304-3770(97)00021-1.

DeLorme, D., Neuberger, L., Wright, J., 2015. Exploring boaters' environmental views for a marine conservation campaign. Appl. Environ. Educ. Commun. Int. J. 14, 33–42. https://doi.org/10.1080/1533015X.2015.1008655.

Duarte, C.M., Dennison, W.C., Orth, R.J.W., Carruthers, T.J.B., 2008. The charisma of coastal ecosystems: addressing the imbalance. Estuar. Coasts 31, 233–238. https://doi.org/10.1007/s12237-008-9038-7.

Durako, M.J., Hall, M.O., Sargent, F., Peck, S., 1992. Propeller scars in seagrass beds: an assessment and experimental study of recolonization in Weedon Island State Reserve, Florida. In: Webb Jr., F.J. (Ed.), Proceedings of the 19th Annual Conference Wetlands Restoration and Creation. Hillsborough Community College, Plant City, FL, pp. 42–53.

Florida Department of Environmental Protection, 2004. John Pennekamp Coral Reef State Park Management Plan. Florida Department of Environmental Protection Division of Recreation and Parks, Tallahassee, FL, USA, p. 138.

Florida Fish and Wildlife Conservation Commission, 2012. Florida's Wildlife Legacy Initiative: Florida's State Wildlife Action Plan. Tallahassee, Florida, USA, p. 665.

Furman, B.T., Merello, M., Shea, C.P., Kenworthy, W.J., Hall, M.O., 2018. Monitoring of physically restored seagrass meadows reveals a slow rate of recovery for *Thalassia testudinum*. Restor. Ecol. 27, 421–430. https://doi.org/10.1111/rec.12877.

Geller, E.S., 1989. Applied behavior analysis and social marketing: an integration for environmental preservation. J. Soc. Issues 45, 17–36. https://doi.org/10.1111/j.1540-4560.1989.tb01531.x.

Geller, S.E., 2002. The challenge of increasing pro-environment behavior. In: Bechtel, R. B., Churchman, A. (Eds.), Handbook of Environmental Psychology. John Wiley & Sons, New York, NY, USA, pp. 525–540, 736 pages.

Geselbracht, L., Jones, T., Charbonneau, M., Brucker, J., 2011. Seagrass Restoration and Protection in the St. Martins Marsh Aquatic Preserve. Final Report. Florida Department of Environmental Protection St. Martins Marsh and Big Bend Seagrasses Aquatic Preserves, Crystal River, FL, USA, p. 20.

Gorzelany, J.F., 1996. Evaluation of Boater Compliance with Speed Regulations in Sarasota County, Florida. Florida Department of Environmental Protection. West Coast Inland Navigation District. Sarasota County Natural Resources Department. Mote Marine Laboratory Technical Report No 465, p. 112.

Gorzelany, J.F., 2004. Evaluation of boater compliance with manatee speed zones along the Gulf Coast of Florida. Coast. Manag. 32, 215–226. https://doi.org/10.1080/08920750490448514.

Gorzelany, J.F., 2006. An assessment of changes in recreational boat traffic resulting from the placement of new speed zones in Lemon Bay, Florida. Mote Marine Lab Technical Report No 1118, 56.

Gorzelany, J.F., 2008. An Assessment of Changes in Recreational Boating Activity Resulting from the Addition of New Regulatory Zones in Terra Ceia Bay, Florida. Mote Marine Lab Technical Report No. 1282, p. 56.

Hallac, D.E., Sadle, J., Pearlstine, L., Herling, F., Shinde, D., 2012. Boating impacts to seagrass in Florida Bay, Everglades National Park, Florida, USA: links with physical and visitor-use factors and implications for management. Mar. Freshw. Res. 63, 1117–1128. https://doi.org/10.1071/MF12025.

Hendee, J.C., Stankey, G.H., Lucas, R.C., 1990. Wilderness Management, second ed. North American Press, Golden, CO, USA, p. 546.

Jett, J.S., Thapa, B., 2010. Manatee zone compliance among boaters in Florida. Coast. Manag. 38, 165–185. https://doi.org/10.1080/08920751003668454.

Kenworthy, W.J., Fonseca, M.S., Whitfield, P.E., Hammerstrom, K.K., 2002. Analysis of seagrass recovery in experimental excavations and propeller-scar disturbances in the Florida Keys National Marine Sanctuary. J. Coast. Res. 37, 75–85.

Kenworthy, W.J., Hammerstrom, K.K., Fonseca, M.S., 2006. Scientific Evaluation of a Sediment Fill Technique for the Restoration of Motor Vessel Injuries in Seagrass Beds of the Florida Keys National Marine Sanctuary. Final Report. National Oceanic and Atmospheric Administration Center for Coastal Fisheries and Habitat Research. Beaufort, NC, USA, p. 18.

Kirk, R.E., 2013. Experimental Design: Procedures for the Behavioral Sciences, fourth ed. SAGE Publications, Inc., Thousand Oaks, CA, USA, p. 1072.

Kotler, P., Zaltman, G., 1971. Social marketing: an approach to planned social change. J. Mark. 35, 3–12. https://doi.org/10.2307/1249783.

Kruer, C.R., 2017. Florida Keys Shallow Water Boating Impact Analysis and Trends Assessment Mapping Summary Report. Technical Report, Florida Keys National Marine Sanctuary. Key West, FL, USA, p. 7.

Larkin, P.D., Heideman, K.L., Burfeind, D.D., Stunz, G.W., 2010. The effect of boat propeller scarring intensity on genetic variation in a subtropical seagrass species. Bot. Mar. 53, 99–102. https://doi.org/10.1515/BOT.2010.004.

Lathrop, R.G., Bognar, J., Buenaventura, E., Ciappi, M., Green, E., Belton, T.J., 2017. Establishment of marine protected areas to reduce watercraft impacts in Barnegat Bay, New Jersey. J. Coast. Res. 78, 277–286. https://doi.org/10.2112/SI78-019.1.

Lee, N.R., Kotler, P., 2016. Social Marketing: Changing Behaviors for Good. SAGE Publications, Inc., Thousand Oaks, CA, USA, p. 567.

Levene, H., 1960. Robust tests for equality of variances. In: Olkin, I. (Ed.), Contributions to Probability and Statistics. Stanford University Press, Palo Alto, CA, pp. 278–292.

Lewis III, R.R., Estevez, E.D., 1988. The Ecology of Tampa Bay, Florida: an Estuarine Profile. US Fish Wildlife Service Biological Report 85(7.18). National Wetlands Research Center. US Department of the Interior, Washington, DC, USA, p. 132.

Lloret, J., Zaragoza, N., Caballero, D., Riera, V., 2008. Impacts of recreational boating on the marine environment of Cap de Creus (Mediterranean Sea). Ocean Coast Manag. 51, 749–754. https://doi.org/10.1016/j.ocecoaman.2008.07.001.

Morris, J., 2004. A Quantitative Evaluation of a Boater Education Program for Manatee Protection. Master's Thesis. University of Florida, Gainesville, FL, USA, p. 95.

National Park Service, 2008. Patterns of Propeller Scarring of Seagrass in Florida Bay: Associations with Physical and Visitor Use Factors and Implications for Natural Resource Management. Resource Evaluation Report: South Florida Natural Resources Center Technical Series 2008:1. US Department of the Interior, Washington, DC, USA, p. 39.

Orth, R.J., Lefcheck, J.S., Wilcox, D.J., 2017. Boat propeller scarring of seagrass beds in Lower Chesapeake Bay, USA: patterns, causes, recovery, and management. Estuar. Coasts 40, 1666–1676. https://doi.org/10.1007/s12237-017-0239-9.

Salz, R.J., Loomis, D.K., 2005. Recreation specialization and anglers' attitudes towards restricted fishing areas. Hum. Dimens. Wildl. 10, 187–199. https://doi.org/10.1080/10871200591003436.

Salz, R.J., Loomis, D.K., Finn, K.L., 2001. Development and validation of a specialization index and testing of specialization theory. Hum. Dimens. Wildl. 6, 239–258. https://doi.org/10.1080/108712001753473939.

Sargent, F.J., Leary, T.J., Crewz, D.W., Cruer, C.R., 1995. Scarring of Florida's Seagrasses: Assessment and Management Options. Florida Marine Research Institute Technical Report TR-1. Florida Department of Environmental Protection, St. Petersburg, FL, USA, p. 66.

Schaub, R., Scheidt, D., Garreau, C., Hall, C., 2009. Quantitative Assessment of Seagrass Scarring in the Southern Mosquito Lagoon and Northern Indian River of Brevard and Volusia Counties, FL. Final Report. US Fish and Wildlife Service Project #GS10F0237R. US Department of the Interior, Washington, DC, USA.

Scheidt, D., Garreau, C., 2007. Identification of Watercraft Use Patterns in Canaveral National Seashore. US Department of the Interior, Washington, DC, USA. Final Report. National Park Service Project #1021131.

Sorice, M.G., Flamm, R.O., McDonald, S., 2007. Factors influencing behavior in a boating speed zone. Coast. Manag. 35, 357–374. https://doi.org/10.1080/08920750601169642.

Sweatman, J.L., Layman, C.A., Fourqurean, J.W., 2017. Habitat fragmentation has some impacts on aspects of ecosystem functioning in a sub-tropical seagrass bed. Mar. Environ. Res. 126, 95–108. https://doi.org/10.1016/j.marenvres.2017.02.003.

Therneau, T., Atkinson, B., Ripley, B., 2018. Recursive Partitioning and Regression Trees. Package 'rpart', Version 4.1-13. https://cran.r-project.org/package=rpart.

Uhrin, A.V., Holmquist, J.G., 2003. Effects of propeller scarring on macrofaunal use of the seagrass *Thalassia testudinum*. Mar. Ecol. Prog. Ser. 250, 61–70. https://doi.org/10.3354/meps250061.

Uhrin, A.V., Kenworthy, W.J., Fonseca, M.S., 2011. Understanding uncertainty in seagrass injury recovery: an information-theoretic approach. Ecol. Appl. 21, 1365–1379. https://doi.org/10.2307/23023002.

Whitfield, P.E., Kenworthy, W.J., Fonseca, M.S., Hammerstrom, K.K., 2002. The role of a hurricane in expansion of disturbances initiated by motor vessels on subtropical seagrass banks. J. Coast. Res. 37, 86–99.

Zieman, J.C., 1976. The ecological effects of physical damage from motor boats on turtle grass beds in southern Florida. Aquat. Bot. 2, 127–139. https://doi.org/10.1016/0304-3770(76)90015-2.