FINAL REPORT

Wrack Assessment Using Aerial Photography in Coastal Georgia

Dr. Clark Alexander
Skidaway Institute of Oceanography
10 Ocean Science Circle
Savannah, GA 31411

clark.alexander@skio.usg.edu
912.598.2329

22 April 2008

Abstract

Rafts of dead and decaying *Spartina alterniflora* (i.e., marsh wrack) were mapped from high-resolution aerial photography to determine if docks extending out into the saltmarsh significantly alter the spatial distribution of wrack along the eastern shore of two adjacent islands in coastal Georgia (Wilmington and Skidaway Islands). Both islands exhibit similar physical characteristics, with the exception that Wilmington Island has 101 private recreational docks along the eastern shoreline and Skidaway Island has no docks along the eastern shoreline by homeowner covenant. Each individual wrack raft along the eastern shoreline of both islands was delineated to create polygons representing each wrack raft. Total area, individual area and long-axis orientation of the wrack rafts associated with each island were measured in ARCGIS. On Wilmington Island, wrack polygons were classified as dock-associated or non-dock-associated. Total area of wrack was significantly different between the two islands when examining the dataset, but was not significantly different when the data were normalized to the lengths of the islands' shorelines. Directional orientation of the wrack polygons was found to be significantly different between Skidaway and Wilmington Islands and when comparing Skidaway Island polygons with the dock-associated wrack polygons of Wilmington Island. The Skidaway Island directional data is not significantly different from the non-dock-associated data from Wilmington Island. Based on these results, it is clear that the presence of docks has an effect on the distribution patterns of wrack in the saltmarsh and alters where wrack impacts occur. Data from this study and Alexander and Robinson (2006) demonstrate that dock shading on the east side of Wilmington Island decreases carbon production by 4-7 x 10^5 gC/y. Dock-associated wrack accumulations on the east side of the island have the potential to reduce carbon production by approximately 1-9 x 10^6 gC/accumulation event. These values suggest that the impact of dock-associated wrack accumulation on the marsh may be equal to, if not more, significant than that of private recreational dock shading. We observed several examples on Wilmington Island where derelict, non-servicable structures existed in the marsh which did not provide a public or private benefit, but which still acted to create dock-associated wrack accumulations. Because of the potentially significant negative impacts on marsh productivity created by marsh wrack accumulation, we recommend that no permits for new structures in the marsh be allowed from an individual upland property until all non-servicable structures have been removed.

Introduction

Dead and decaying salt marsh vegetation, commonly referred to as wrack, is the product of a previous growing season's perennial standing crop. The dead stalks of these plants often remain standing in the salt marsh until they break free from the root structure of the plant and are transported through the marsh by tidal action. The interaction of tides, currents and winds combine to aggregate these decaying plant stalks into interwoven rafts which are distributed throughout the low and high salt marsh (Bertness and Ellison 1987). Areas of taller living marsh vegetation often act to structurally control where these rafts accumulate. The physical shape of a shoreline or structure, its directional orientation, or the proximity to a waterway network also play a role in where accumulation of wrack occurs. Wrack rafts which fail to redistribute with the tide and stay in the same area of the marsh may cause local disturbances by compressing vegetation, reducing aboveground biomass, and initiating bare patches within the marsh. The natural processes associated with wrack production, transport, and decay all influence spatial patterns within salt marshes. Residence time of these rafts is of particular importance in determining the impact they have on salt marsh habitat and may directly effect plant mortality. Certain species of plants demonstrate higher tolerances for wrack burial than others and certain species are more efficient at recolonization.

Many studies have investigated wrack deposition as it relates to marsh plant productivity, marsh development and community succession (Niering and Warren 1980; Bertness and Ellison 1987; Anderson, Miller and Neubauer 1997; Brewer, et al. 1998; Pennings and Richards 1998; Hartman 1988; Tolley and Christian 1999; Fisher, et al. 2000; Minchinton 2002, 2006; Bozek and Burdick 2005). Wrack disturbance has also been shown to facilitate migration of nuisance and invasive species (Minchinton, 2002). The majority of these studies however have been conducted in the northeast United States, where the seasonal vegetation and climatic regime is quite different from the southeast (Pennings and Richards 1998). Further, only a few of these studies have examined spatial dynamics of wrack and none have evaluated the role manmade structures may play in altering natural accumulation and removal patterns.

During a study quantifying the impact of private recreational docks on salt marsh productivity in Georgia, several docks were observed with extensive bare patches on the north side and healthy vegetation growing on the south side (Alexander and Robinson 2006). Many other docks were observed with large rafts of wrack piled up against the pilings. In order to fully assess the impact of docks on salt marsh productivity a need exists to determine if and how these structures may be altering natural wrack accumulation and removal processes. Private recreational dock structures in Georgia are regulated by the Georgia Department of Natural Resources through a revocable license agreement. The cumulative effect of these structures on the saltmarsh system is currently unknown, but as we develop methods to conduct this assessment, both the direct footprint impact as well as the potential for interference with natural marsh functions needs to be included.

Large areas of accumulated wrack were observed throughout coastal Georgia during the early spring to late summer of 2007. These large areas of accumulation were distributed throughout the marsh, adjacent to upland shorelines, causeways, bridges and docks. High tides coupled with sustained winds provided the energy to mobilize and consolidate the rafts of wrack. Since no research currently exists quantifying a seasonal range of wrack area or volume, we cannot determine if the observed wrack in 2007 was typical of annual wrack production and retention. The aim of this study is to evaluate if, and in what ways, private recreational docks alter wrack distribution in the saltmarshes of Georgia.

Study Sites

Wilmington Island and Skidaway Island, both located in Chatham County, Georgia, were selected for the analysis. The two back-barrier islands are physically adjacent to one another, in a northeast-southwest orientation, and exhibit similar geographic characteristics. Wilmington Island sits north and east of Skidaway Island; the two islands are separated by the 900-m wide Wilmington River. Both islands have an uninterrupted, linear eastern shoreline with similar northeast orientations and both have a broad, vegetated *Spartina alterniflora* salt marsh between their eastern shores and the major barrier islands farther east (Figure 1). While acknowledging that salt marsh habitats and processes vary spatially, we expect the natural processes associated with wrack accumulation and removal to be similar in the marshes fronting the two islands. Based on high-resolution 2007 imagery, Wilmington Island has 101 private recreational dock structures along the eastern shoreline. Skidaway Island has no private recreational dock structures along the eastern shoreline because of homeowner covenants in The Landings subdivision, which abuts the eastern side of the island. This fortunate situation allows us to compare two similar physical settings, wrack source areas and wrack-raft accumulations in a natural experiment where only the dock and no dock variable is changed.

Analysis

High-resolution aerial photography was acquired on October 12, 2007 for the eastern shoreline of Wilmington and Skidaway Islands. The photography was collected and processed by Kucera International into georeferenced tiles (UTM NAD83 Zone 17N), with a ground resolution cell of 15 cm^2. Using ArcGis 9.2, discrete rafts of wrack were digitized onscreen (Figure 2). One shapefile was created for Skidaway Island and one for Wilmington Island (Figure 3). The area of all polygons in each shapefile was collected in the attribute table and a second shapefile was generated for each island containing only the polygons 400 m^2 and greater. This area was chosen as our minimum raft size for use in our analysis based on the definition of a minor impact in the Coastal Marshlands Protection Act. Using an Arcscript extension (longline.avx) the longest distance between vertices in each polygon was created. A new shapefile representing this distance was generated, which includes the length of the line and the directional azimuth. The azimuth describes the longitudinal axis of each polygon. A dock-related attribute field was placed into the Wilmington Island shapefile to identify if polygons were associated with docks. If rafts of wrack were piled against non-serviceable dock remnants, these polygons were categorized as dock-related (Figure 4). Azimuth data was joined with the polygon attribute table. Azimuths greater than 180 degrees were converted to the reciprocal azimuth so that all data ranged between 0 and 180 degrees. Approximate shoreline lengths were calculated for both islands for comparison with total wrack area.

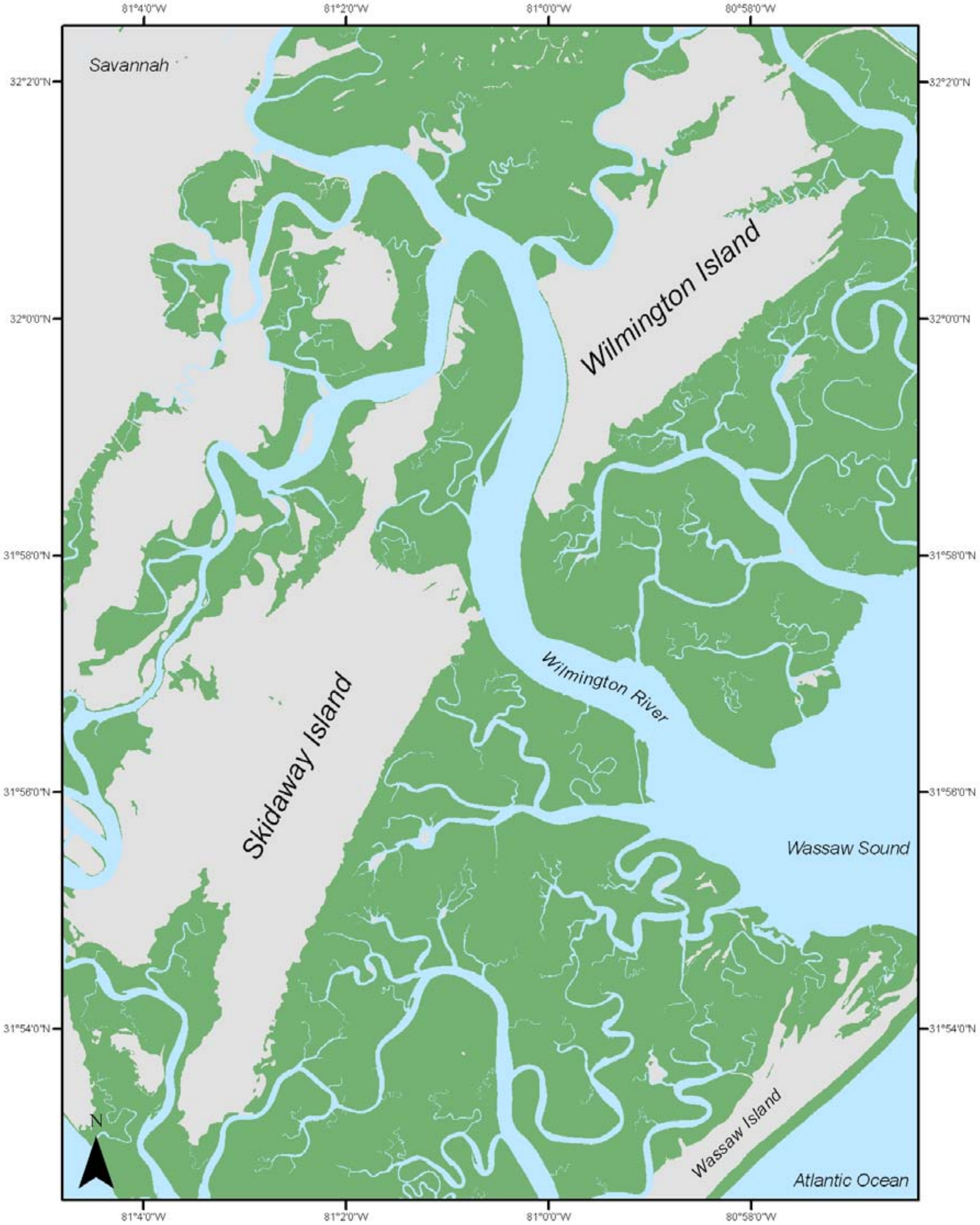

Figure 1. Eastern shorelines of Wilmington and Skidaway Island study locations.

Figure 2. Example of digitized wrack polygons from the Wilmington Island shapefile. Note that some polygons are associated with docks and some are not.

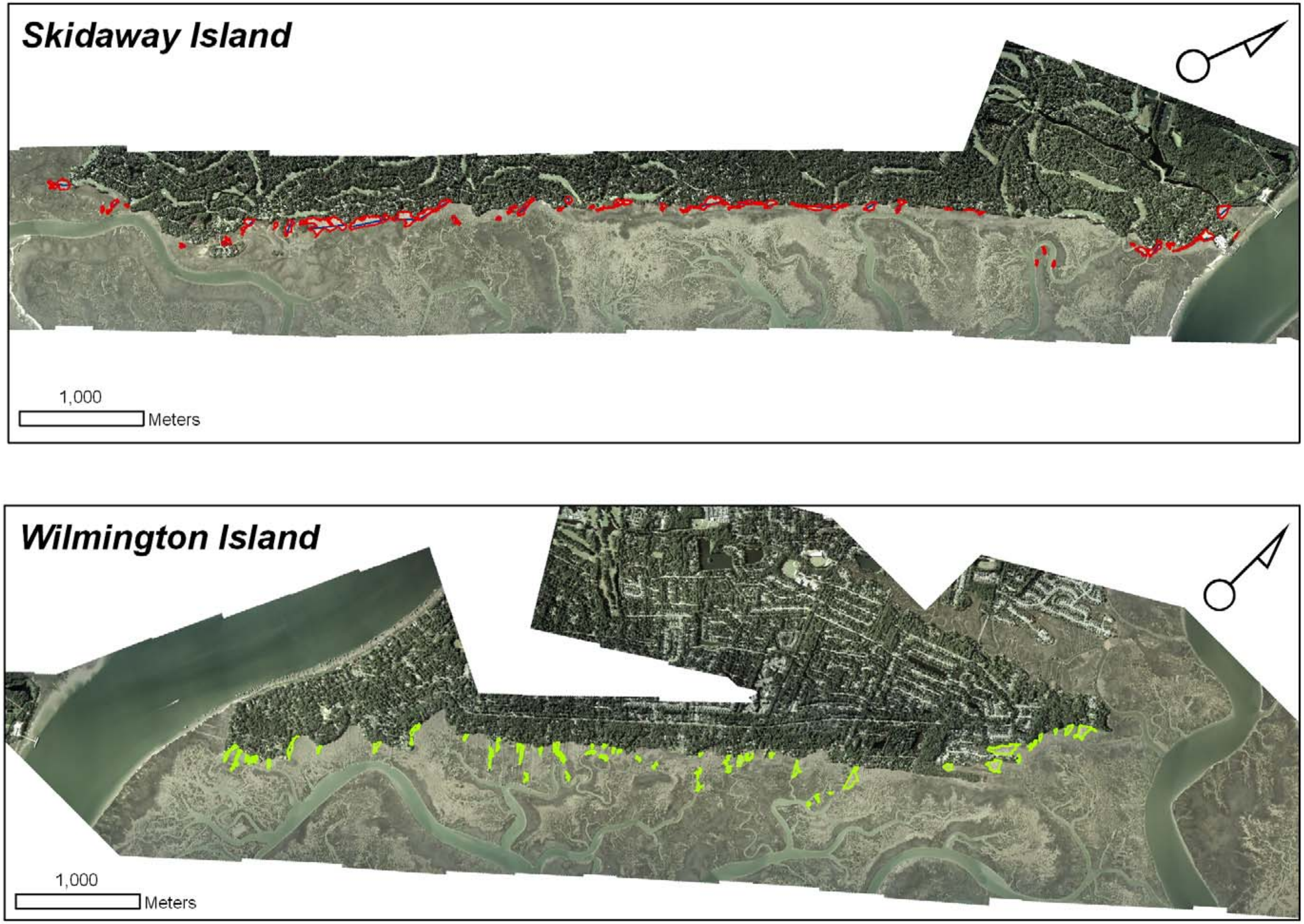

Figure 3. Distribution of wrack polygons greater than 400 m^2 along Wilmington and Skidaway Islands.

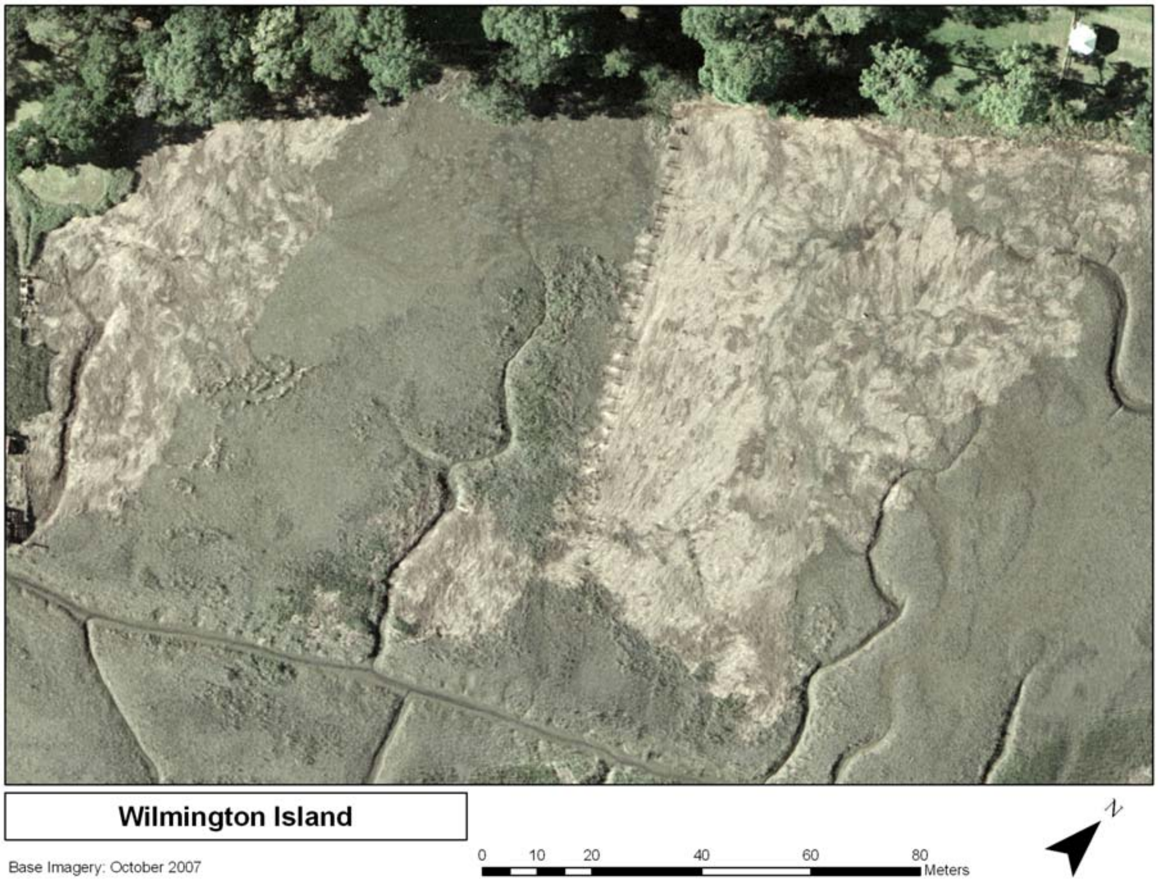

Figure 4. Wrack accumulation associated with non-serviceable dock remnants on Wilmington Island.

Results

The total area of wrack present in 58 polygons on Wilmington Island was 86,842 m^2 with a mean area of 1,497 m^2. The total area of wrack present in 48 polygons on Skidaway Island was 113,194 m^2 with a mean area of 2,358 m^2. Approximate shoreline length of the east side of Wilmington Island is 10.7 km and approximate shoreline length of the east side of Skidaway Island is 14.5 km. The average total area of wrack accumulation per linear shoreline length on Wilmington Island is 8,116 m^2/km and the average area of wrack accumulation per linear shoreline length on Skidaway Island is 7,806 m^2/km (Table 1).

On Wilmington Island, 34 of 58 polygons (59%) are associated with docks (Table 2). On Skidaway Island 0 of 48 polygons are associated with docks. The mean directional orientation of wrack polygons on Skidaway Island is 81°T. The mean directional orientation of all wrack polygons on Wilmington Island is 123°T; the mean directional orientation of dock-associated wrack polygons is 133°T and that of non-dock-associated polygons is 106°T (Figures 5, 6, 7, 8; Appendix 1, 2).

Using a Mann-Whitney Rank Sum Test for non-parametric data, the Wilmington Island and Skidaway Island **wrack polygon areas** were significantly different in size (p = 0.02). Similarly, the Skidaway wrack polygon areas was significantly different from the Wilmington non-dock-associated wrack area (p = 0.03). In contrast, the Skidaway wrack polygon areas is not significantly different from the Wilmington dock-associated wrack polygon areas (p = 0.10). Similarly, the Wilmington dock-associated wrack area versus the non-dock-associated wrack area did not show a statistically significant difference (p = 0.53).

Using the same statistical test for non-parametric data, the difference between the Wilmington Island and Skidaway Island wrack polygon **directional azimuths** is statistically different (p = 0.005). In addition, the difference between Skidaway Island polygons and the Wilmington Island dock-associated wrack polygons is statistically significant (p = 0.004), as is the difference between Wilmington non-dock-associated polygon azimuths when compared to the dock-associated azimuths (p = 0.028). In contrast, when comparing Skidaway Island azimuth data with the Wilmington Island non-dock-associated azimuth data there is no statistically significant difference (p = 0.091).

Table 1. Wrack polygon and island parameters for Wilmington and Skidaway Islands.

Location	Number of Wrack Polygons	Total Wrack Polygon Area (m^2)	Mean Wrack Polygon Area (m^2)	Shoreline Length (km)	Average Wrack Area per Linear km (m^2/km)
Wilmington Island	58	86,842	1,497	10.7	8,116
Skidaway Island	48	113,194	2,358	14.5	7,806

Table 2. Comparison of dock-associated and non-dock-associated wrack polygons on Wilmington Island.

Location and Treatment	Number of Wrack Polygons	Total Wrack Polygon Area (m^2)	Mean Wrack Polygon Area (m^2)	Mean Directional Orientation (°T)
Wilmington Island Dock-Associated	34	55,273	1,625	133
Wilmington Island Non-Dock-Associated	24	31,569	1,315	106

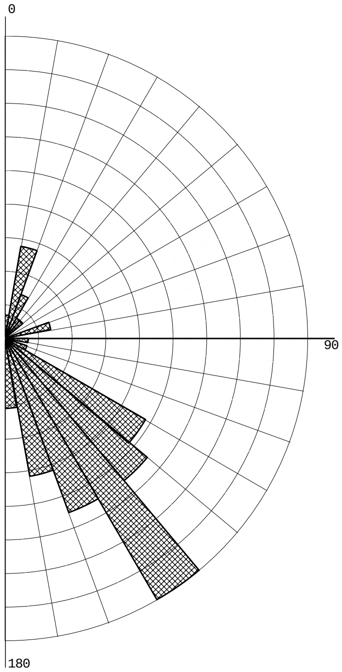

Figure 5. Directional orientation of all Wilmington Island wrack polygons.

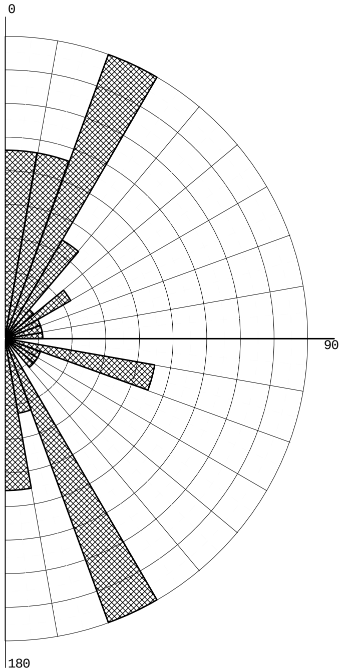

Figure 6. Directional orientation of all Skidaway Island wrack polygons.

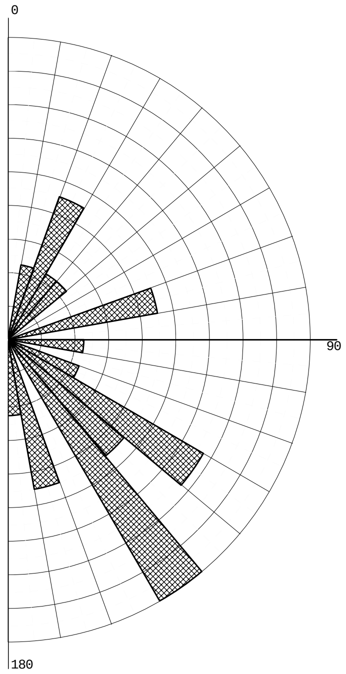

Figure 7. Directional orientation of non-dock-associated Wilmington Island wrack polygons.

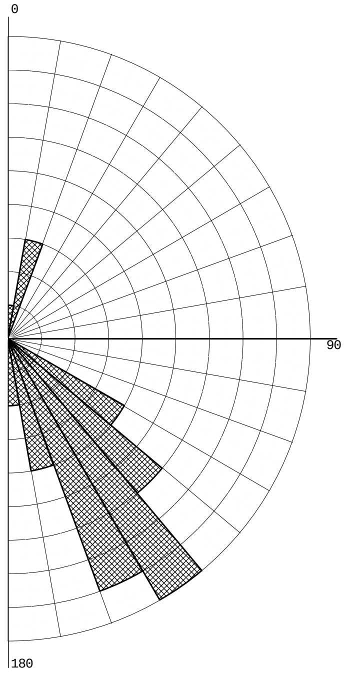

Figure 8. Directional orientation of dock-associated Wilmington Island wrack polygons.

Discussion

The hypothesis for this study was that the presence of docks on Wilmington Island would alter the accumulation patterns of marsh wrack when compared to a shoreline without docks, such as on Skidaway Island. Further, we assumed that naturally formed, free-floating wrack rafts should be randomly distributed in shape and size, when not influenced by structures in the marsh or the marsh-upland interface. As wrack rafts are driven by wind at spring tides onto structures or the marsh-upland interface, they accumulate along these features. From numerous field observations, we know that wrack rafts are driven against the shoreline to form shore-parallel wrack beds in the absence of dock structures. When docks are present, the wrack accumulates against the pilings, with some of the wrack raft reaching to the shore but with some portion of the wrack raft extending channelward across the marsh. Thus two appropriate parameters for study of wrack polygons and comparison between the islands are polygon area and directional orientation.

Wrack polygons associated with Skidaway Island cover more area (by 26,352 m^2) than wrack polygons associated with Wilmington Island (Table 1). However, to compare the total amount of wrack accumulation between islands, the total area of wrack for each island must be normalized to island shoreline length, to assess if wrack input is similar at any shoreline location along the two islands. Skidaway Island is approximately 3.8 km longer than Wilmington Island. When normalized to wrack polygon area per kilometer of shoreline, the average amount of wrack area is only 310 m^2/km greater on Wilmington Island than on Skidaway Island, a value that is smaller than the minimum wrack polygon size we used in this study, indicating that the amount of wrack being supplied to the shoreline of each island is similar on a per kilometer of shoreline basis.

On average, individual Skidaway polygons are approximately 1.5x greater in area than those on Wilmington Island (Table 1). Wrack polygon sizes exhibited a statistically significant difference between the two islands. The number of polygons per kilometer of shoreline is higher on Wilmington Island versus Skidaway Island (5.4 polygons/km and 3.3 polygons/km, respectively) documenting that the Wilmington polygons are smaller in area and suggesting that docks on Wilmington Island may interrupt the development of free-floating rafts of wrack, preventing them from consolidating with other rafts or breaking up larger rafts as they eventually make their way around and through dock structures. If true, then the larger wrack rafts along Skidaway Island are representative of the natural size of accumulated wrack rafts.

The directional orientation of wrack polygons is significantly different on Skidaway Island when compared with those from Wilmington Island. To evaluate if this significant difference could be attributed to the presence docks, Skidaway Island azimuth data were statistically compared with the azimuths of dock-associated rack polygons and non-dock-associated wrack polygons from Wilmington Island. The dock-associated polygons from Wilmington Island were significantly different in their azimuth from those of the polygons from Skidaway Island, whereas the non-dock-associated polygons from Wilmington Island were not significantly different from Skidaway Island polygons. In addition, the orientations of the dock-associated and non-dock-associated wrack polygons on Wilmington Island were significantly different from one another. These observations demonstrate that when not intercepted by structures in the marsh, wrack rafts will have a different set of orientations, similar to those from an area with no docks, than they will when intercepted by structures. Natural accumulations of marsh wrack will form parallel to the shoreline, creating large, quasi-linear bodies that mimic the morphology of the shoreline. These shoreline-associated wrack accumulations, in general, selectively impact the high marsh zone. Wrack accumulations that are kept from their natural distribution by structures impact regions of the marsh that are not adapted ecologically to the shading, compaction and burial impact created by the marsh wrack.

Based on the results of this study, we can say that structures in the marsh do alter the spatial distribution of wrack in the salt marsh. The objective of this study was not to analyze the impact of wrack disturbance to the marsh; that is a much larger (and more expensive) study than that undertaken here. The methodology used in this study provides only a snapshot of conditions present at the time of the photography, during a phase of Fall marsh wrack removal after late Spring and Summer accumulation. This same approach could be successfully used to investigate the larger question of wrack dynamics if aerial photography, spaced closely in time (approximately every 4 weeks), took place over a complete season of wrack accumulation and removal.

Several questions pertinent to potential management of marsh wrack impacts remain. Additional research examining how and when natural wrack accumulations form and are removed is critical to determining if dock structures are altering the natural timing of wrack accumulation, wrack removal or both. Several studies have shown positive relationships between residence time of wrack and plant mortality, with longer residence times acting to shade and eventually denude patches of previously vegetated marsh. The impact of wrack intercepted by docks is spread across open areas of vegetated, *Spartina alterniflora* low marsh and previously impacted, high marsh areas that are more routinely covered by wrack. Thus, the impacts to the marsh from dock-associated marsh wrack may be more significant than from non-dock associated marsh wrack.

Alexander and Robinson (2006) provide data to calculate the relative importance of private recreational dock shading and direct impacts from dock-associated marsh wrack accumulation. From that study, the average carbon production for *Spartina alterniflora* around Wilmington Island is 167 gC/m^2, dock shading reduces carbon production in the marsh between 21% and 37% and docks on the east side of Wilmington Island cover 11,750 m^2 of saltmarsh (Alexander and Robinson, 2006). From the present study, we know that dock-associated wrack on the east side of Wilmington Island covers 55,273 m^2 of saltmarsh.

Using these data, we calculate that dock shading on the east side of Wilmington Island reduces carbon production between 4-7 x 10^5 gC/y [167 gC/m^2 production * 11,750 m^2 saltmarsh * (1-(% biomass reduction under dock)]. If we assume that wrack accumulation reduces aboveground production by 100% (a probable overestimate that will be addressed shortly), then dock-associated wrack accumulations on the east side of the island at the time of our analysis have the potential to reduce carbon production by 9 x 10^6 gC/accumulation event, an order of magnitude greater impact [167 gC/m^2 production * 55,273 m^2 covered by wrack]. This estimate of dock-associated wrack impact on carbon production is a maximum estimate for several reasons: 1) a 100% decrease in carbon production under all dock-associated wrack accumulations is probably not a reasonable assumption; 2) the impact of dock-associated wrack can be a single event, whereas the shading impact from fixed docks is a continuing, annual loss; and 3) some portion of dock-associated wrack resides up against and impacts the shoreline in the high marsh, just as non-dock-associated wrack would. However, even assuming that only 10% of the dock-associated wrack accumulation area is halting production of carbon (equaling 9 x 10^5 gC not produced per wrack accumulation event), the impact of dock-associated wrack is approximately **equal** to the annual reduction caused by private recreational docks. Further understanding of how docks interact with the natural system and quantification of the true impact of dock-associated wrack accumulation is needed to balance public and private resource conservation, protection and utilization.

Finally, one additional management application of our research needs to be highlighted. We observed several examples on Wilmington Island where derelict, non-servicable structures existed in the marsh that still acted to create dock-associated wrack accumulations (Fig. 4). Given the additional impact that dock-associated wrack accumulation creates, if there is no public or private benefit provided by having these structures in the marsh (i.e., where a serviceable dock provides access for water-related activities), there is **no** justification for these derelict structures to remain in the marsh creating this additional impact. We recommend that no permits for new or modified private recreational or community structures in the marsh be allowed from an individual upland property until all non-serviceable structures have been removed, or unless the removal of such materials is a condition of the permit. Acknowledging the damage that complete removal of pilings can cause, we advocate using the least invasive strategies possible for this task, such as cutting pilings cut off at ground level and carrying them out of the marsh, or combining the removal of derelict materials with construction of the new structure.

References

Alexander , C. and M. Robinson. 2006. Quantifying the Ecological Significance of Marsh Shading: The Impact of Private Recreational Docks in Coastal Georgia. Report to the Georgia Coastal Zone Management Program, Georgia Department of Natural Resources, Coastal Resources Division, Brunswick, GA. 47 p. http://www.skio.usg.edu:443/research/sedimentlab/dockprojects.php

Anderson, I.C., Miller, W.D., and S.C. Neubauer. 1997. The Effect of Wrack Deposition and Increased Inundation Frequency on Production and Respiration in a Spartina patens/Distichlis spicata Salt Marsh. Virginia Coast Reserve Long Term Ecological Research All Scientist Meeting June 1997. Available online: http://www.vcrlter.virginia.edu/elecvol/VCRASC97

Bertness, M.D., and A.M. Ellison. 1987. Determinants of Pattern in a New England Salt Marsh Plant Community. Ecological Monographs, 57 (2): 129-147.

Bozek, C.M., and D.M. Burdick. 2005. Impacts of Seawalls on Saltmarsh Plant Communities in the Great Bay Estuary, New Hampshire U.S.A. Wetlands Ecology and Management 13: 553-568.

Brewer, J.S., Levine, J.M., and M.D. Bertness. 1998. Interactive Effects of Elevation and Burial With Wrack on Plant Community Structure in Some Rhode Island Salt Marshes. Journal of Ecology. 86: 125-136.

Fischer, J.M., Reed-Anderson, T., Klug, J.L., and A.G. Chalmers. 2000. Spatial Pattern of Localized Disturbance along a Southeastern Salt Marsh Tidal Creek. Estuaries. 23(4): 565-571.

Hartman, J.M. 1988. Recolonization of Small Disturbance Patches in a New England Salt Marsh. American Journal of Botany, 75(11): 1625-1631.

Lottig, N.R., and J.M. Fox. 2007. A Potential Mechanism for Disturbance-Mediated Channel Migration in a Southeastern United States Salt Marsh. Geomorphology 86: 525-528.

Minchinton, T.E. 2002. Disturbance by Wrack Facilitates spread of Phragmites australis in a coastal marsh. Journal of Experimental Marine Biology and Ecology. 281:89-107.

Minchinton, T.E. 2006. Rafting as a Mode of Dispersal for Plants in Coastal Marshes. Aquatic Botany. 84: 372-376.

Neiring, W.A., and R. S. Warren. 1980. Vegetation Patterns and Processes in New England Salt Marshes. BioScience. 30(5): 301-307.

Pennings, S.C., and C.L. Richards. 1998. Effects of Wrack Burial in Salt-Stressed Habitats: Batis Maritima in a Southwest Atlantic Salt Marsh. Ecography, 21(6): 630-638.

Tolley, P.M., and R.R. Christian. 1999. Effects of Increased Inundation and Wrack Deposition on a High Salt Marsh Plant Community. Estuaries. 22(4): 944-954.

Appendix 1. Parameters for Skidaway Island Wrack Polygons.

Polygon ID	Polygon Area (m^2)	Dock-Associated?	Orientation (°T)
1	6466	no	161
2	411	no	153
3	6515	no	16
4	1261	no	4
5	1057	no	3
6	4882	no	152
7	3613	no	60
8	536	no	49
9	960	no	38
10	412	no	26
11	2585	no	155
12	4057	no	179
13	1100	no	14
14	3033	no	24
15	5516	no	28
16	422	no	33
17	3259	no	7
18	4331	no	24
19	625	no	5
20	1136	no	13
21	1444	no	105
22	1953	no	29
23	3586	no	4
24	419	no	29
25	2099	no	105
26	679	no	178
27	4657	no	158
28	1792	no	164
29	9113	no	174
30	1147	no	27
31	1825	no	12
32	2534	no	18
33	4639	no	138
34	882	no	153
35	4550	no	159
36	2210	no	35
37	7423	no	27
38	805	no	123
39	717	no	109

40	419	no	113
41	810	no	179
42	1766	no	76
43	853	no	53
44	1903	no	160
45	697	no	157
46	412	no	61
47	681	no	104
48	1002	no	85

Appendix 2. Parameters for Wilmington Island Wrack Polygons.

Polygon ID	Polygon Area (m^2)	Dock-Associated?	Orientation (°T)
1	7588	yes	14
2	2704	yes	172
3	565	yes	154
4	913	yes	151
5	1601	yes	19
6	1221	no	36
7	659	no	134
8	7227	no	76
9	2341	no	25
10	8275	yes	167
11	2708	yes	152
12	1053	no	161
13	566	no	163
14	798	no	150
15	2609	no	143
16	622	yes	157
17	426	yes	170
18	497	yes	142
19	507	yes	124
20	1411	yes	140
21	543	yes	0
22	612	yes	141
23	516	yes	11
24	431	yes	134
25	436	yes	137
26	935	yes	124
27	2013	yes	147
28	972	yes	124
29	639	yes	139
30	2536	yes	141
31	694	yes	144
32	1360	yes	144
33	1922	yes	137
34	834	yes	168
35	570	no	139
36	515	no	124
37	1181	no	152
38	605	no	139
39	2249	yes	161
40	684	yes	157

41	3016	no	149
42	1586	yes	150
43	1064	yes	150
44	1208	yes	160
45	505	yes	146
46	2852	yes	158
47	2865	yes	177
48	428	no	41
49	846	no	111
50	648	no	144
51	477	no	128
52	1349	no	172
53	475	no	19
54	576	no	97
55	1486	no	72
56	1349	no	27
57	627	no	124
58	947	no	123