Characterization of Impacts of Waves and Boat Wakes on Marsh Spits in the Transitional Zone of Fowl River

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Boat Wake Characteristics

The boat wake magnitudes in Fowl River are typically small and well below the often-cited Roland and Douglass (2005) threshold for wave tolerance of saltmarsh vegetation (i.e., $H_s < 0.3$ m). However, this is only strictly true for the more extreme conditions and our measurements show that the frequency of boat wakes may play an important role in the ongoing degradation of marshes and land spits in Fowl River.

Overview

Fowl River experiences substantial pressure from recreational boating (i.e., fishing, tow watersports, personal watercraft, pleasure boaters). The wakes generated by these recreational boats have been cited as a factor contributing to the degradation of marshes and spits within the study area. To that end, boat wake characteristics were sampled at a number of locations, nearly continuously, from May through October 2018. These measurements allow us to characterize the magnitude and frequency of boat wakes impinging on shorelines. The results of these analyses provide some of the information needed to develop appropriate strategies for shoreline stabilization. A brief summary of the gage deployments, results, and conclusions follow.

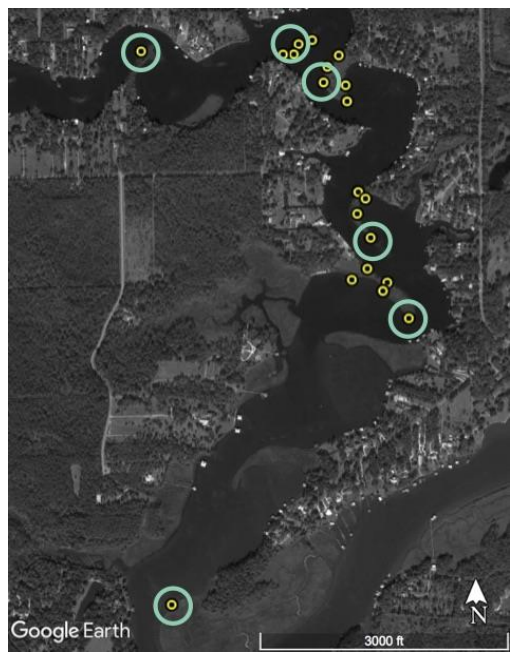

Figure 1. Wave Gage Deployment Location Map

Deployment Information

Boat wakes in Fowl River were measured using pressure gages manufactured by RBR Global. Six RBR Solo and four RBR Virtuoso gages were utilized in the study. The six RBR Solo gages sampled pressure at a frequency of 8 Hz. The four RBR Virtuoso sampled pressure at a frequency of 6 Hz (maximum possible). The six RBR Solo gages were deployed at long-term locations for the duration of the study period: one at each target location, one at a reference marsh in the "coastal" zone, and one at a reference marsh in the "freshwater" zone. The four RBR Virtuoso gages were deployed for shorter durations at each of the target spits. This deployment strategy resulted in both long-term, longitudinal measurements throughout the study area, and shorter-term but higher resolution measurements at the spits targeted for restoration. The deployment locations are shown in *Figure 1*. In that figure, each yellow "bullseye" symbol denotes a deployment location during the study period. The bullseye symbols encircled by the larger hollow circle represent the long-term deployment locations of the six RBR Solo gages.

The deployment dates, corresponding data durations, and target (short-term deployment) spit locations are summarized in *Table 1*. All ten gages were used in Deployments 1 and 2. Only nine gages were used in Deployments 3 and 4 due to mount failure in the field. For the duration of the study, the six RBR Solo gages remained at their respective locations. Only the four RBR Virtuoso gages were relocated during the study period. The "target spit" location identified in *Table 1* denotes the location of those four (or three) RBR Virtuoso gages during each deployment.

Table 1. Wave Gage Deployment Dates and Durations

Deployment	Dates	No. Days	No. Gages	Target Spit
1	5/24/18-6/13/18	20	10	Closing Hole
2	6/14/18-7/11/18	27	10	Tapia
3	7/17/18-8/24/18	31	9	Lightcap
4	8/30/18-10/19/18	34	9	Strout

Each gage was deployed vertically on its own mount fabricated using PVC pipe. The pressure sensor was oriented downward, facing toward the bed, for every deployment. With few exceptions, the gages were deployed such that their pressure sensors were within 20 cm of the bed. Gages were typically deployed in water depths of approximately 1 meter. A number of ancillary measurements were taken during each gage deployment and recovery, including:

- Sensor geographic location;
- Sensor elevation (relative to NAVD88);
- Water depth;
- Water temperature;
- Water salinity; and
- Water density.

Methods

The RBR gages measure absolute pressure, which is the sum of atmospheric and gage pressure. Gage pressure is the sum of the hydrostatic (tide) pressure and the hydrodynamic (wave) pressure. Atmospheric pressure was removed from the absolute pressure measurements to yield a more accurate measurement of gage pressure, and subsequently more accurate estimates of boat wake characteristics. For the purposes of this study, atmospheric pressure in Fowl River was assumed to be equal to that measured by the NOAA/CO-OPS station on the east

end of Dauphin Island (Station 8735180). The NOAA/CO-OPS meteorological data were resampled from their native frequency of once every six minutes to 8 Hz or 6 Hz as appropriate.

Boat wake characteristics were estimated from the pressure measurements using linear wave theory and standard time-domain analysis techniques. These analyses resulted in estimates of individual wave height and period for each boat wake event. The records of wave height and period were further processed to yield statistical representations that are often used in coastal engineering design (e.g., significant wave height, average wave period, etc.). Statistical quantities representing the entire study period were coalesced from each deployment using a weighting equation based on the number of waves measured.

Results & Discussion

Selected statistical quantities for wave height and wave period are listed for each of the six long-term deployment locations in *Table 2*. The wave height and wave period quantities derived from the short-term deployments at Tapia, Lightcap, Closing Hole, and Strout were not substantially different from those listed in *Table 2*. However, there was a fairly clear pattern at most spit locations where wave heights were larger on the upstream sides of spits than on their downstream sides. The exception to this statement was Closing Hole, which exhibited larger wave heights on the downstream side of the spit.

Table 2. Summary of Boat Wake Height and Period Results

Location	No. Waves > 5 cm	H_s (cm)	H_{max} (cm)	T_{avg} (s)
Bellingrath	162168	11.8	65.0	1.68
Tapia	76881	11.3	39.8	1.49
Lightcap	57478	10.5	33.9	1.67
Closing Hole	84671	12.8	43.3	1.61
Strout	122087	12.2	62.0	1.50
Harrison Pt.	157098	14.6	88.0	1.45

The significant wave height (H_s)—the average of the largest one-third of the waves measured—at each location is well below the often-cited vegetation tolerance threshold of 33 cm (Roland and Douglass 2005). However, that tolerance threshold is a function of both wave height and frequency of occurrence as shown in *Figure 2*. Our measurements indicate that the tolerance threshold is exceeded at least 20% of the time at almost every deployment location, and up to 80% of the time at some of the deployment locations. So, while no location exhibits large significant wave heights, every site exhibits measurable wave action for long periods of time. A summary of the tolerance exceedance percentage values in the study area is provided in *Figure 3*.

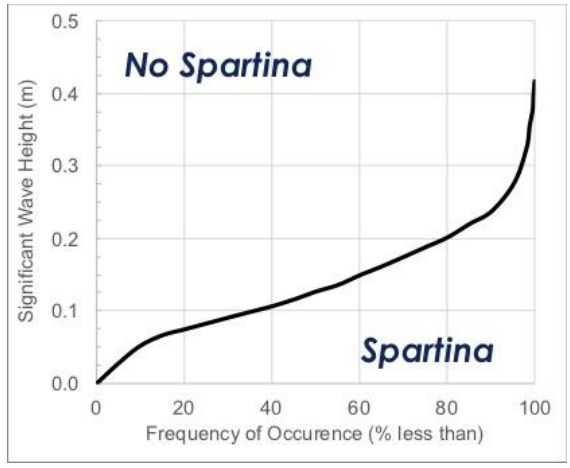

Figure 2. Simplified Wave Tolerance Curve

Conclusions

The deployment of pressure gages in Fowl River during the period May – October 2018 provides the measurements necessary to characterize boat wakes in the study area during high-traffic periods. Recreational boating in the winter months tends to be less frequent. It is reasonable to assume that the potential for boats to generate wave heights and periods in the study area remains constant regardless of the season, but the frequency of boat wake events will generally be higher in the more temperate months of the year.

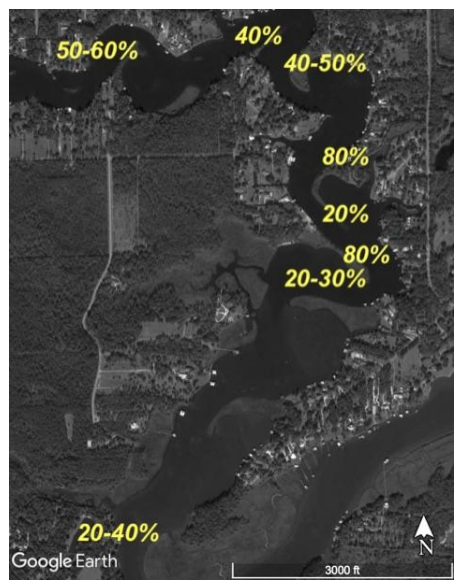

Figure 3. Summary of Tolerance Exceedance Values

The analysis of boat wake characteristics has yielded a number of substantial conclusions:

- Almost 100% of the wave energy in the study area is attributed to boat wakes;
- Almost 100% of the boat wake events occur during the period 7:00 am to 7:00 pm;
- Significant wave heights are small and range from 8 cm to 18 cm;
- Average wave periods range from 1.4 to 2.5 s;
- Wave heights are generally larger on the upstream sides of spits; and

- Significant wave heights routinely exceed the threshold for vegetation tolerance.

The boat wake measurements, particularly when combined with other data collected during the study period, provide important context that may inform restoration design in the future. For example, the relatively small but frequent wave heights suggest that the spits may require persistent wave attenuation in the form of edge protection. This edge protection could be achieved using appropriately designed sills or wave screens. Since the wave heights are typically small, the required stone size for a rock sill may be of a moderate size. Confined oyster shell could likely be incorporated into edge protection strategies. While many sills are low in elevation, an effective sill design in Fowl River may require a crest elevation above or close to mean high water. In the summer months, high tide occurs during the daylight hours when boat traffic is heaviest. Therefore, much of the frequent wave action occurs at high tide and the edge protection should continue to provide an appropriate amount of wave attenuation during those times.

Literature cited

Roland, R. M. and Douglass, S. L. 2005. Estimating wave tolerance of Spartina alterniflora in coastal Alabama. Journal of Coastal Research: Volume 21, Issue 3: pp453-463.