Streambank Erosion in the Pensacola Bay and Perdido Bay Watersheds

by:

Dr. Johan Liebens

and

Kolby Harp

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Introduction

Streambank erosion refers to the removal of materials from the bank of a stream or river and has been found to be a fundamental source of suspended sediments within fluvial systems (Bull, 1997; Evans et al., 2006; Fox et al., 2007; Kronvang et al., 2013). Once suspended within the water column, sediments can cause a multitude of environmental damages, including benthic smothering, increased light attenuation, irritation of fish gills, and the transport of water quality pollutants bound to sediment particles (Davies-Colley and Smith, 2001). Previous studies have shown that streambank erosion can be the source of upwards of ninety percent of the sediments and nutrients within the surface waters of fluvial systems (Fox et al., 2016). Due to the potential magnitude of this contribution, important insights into how to better manage sedimentation issues, water quality reductions, and restoration efforts can be gained by determining the rates at which banks are eroding within watersheds. Bank erosion rates can vary depending on numerous factors related to the composition and contour of the bank, such as the ground cover, bank height, bank slope, and bank material (Daly et al., 2015). Identifying the relationship between erosion rates and bank types allows for management and restoration efforts to be concentrated on streambanks with the highest potential for erosion and can be used to inform predictions of the impacts of future land use modifications. Existing research within the Pensacola Bay and Perdido Bay (PPB) watersheds has created a baseline for streambank erosion rates (Finch, 2020; McMillan et al., 2017), allowing efforts of the current project to expand the timeframe of observations and produce average annual erosion rates over a multi-year scale. In areas where baseline data did not exist, the establishment of new sites by the current project makes future long-term monitoring possible with only minimal additional effort required. By expanding existing measurements and establishing new monitoring sites, the current project will determine the magnitude of streambank erosion and the relationship between erosion rates and various bank characteristics, thereby providing a comprehensive collection of data that can be used to inform effective decision-making within the Pensacola Bay and Perdido Bay watersheds.

Methods

Streambank erosion rates in the Pensacola Bay and Perdido Bay watersheds were determined by repeat measurements of streambank profiles at a total of thirty sites. Twenty of these sites were previously established and surveyed within the last decade, and ten additional new sites were established in the Perdido Bay watershed, where baseline data did not exist. Locations for the ten new sites were selected based on the distribution of the existing survey sites, permission to access sites, and their potential for providing a variation in bank characteristics and conditions. The selected sites and their distribution within the PPB watersheds are shown in Figure 1.

Bank profiles were measured by installing a vertical toe pin (1.5m long section of rebar) in the stream at the toe of the bank. A surveying rod with a rod level was held vertically atop the toe pin, serving as the y-axis for the profile. Horizontal distances, the x-values, were measured between the vertical surveying rod and the face of the bank using a ruler and line level to ensure horizontal alignment (Figure 2). Measurements were taken at varying intervals along the vertical surveying rod depending on the contour of the bank. At the twenty existing sites, streambank profiles were measured once and compared to initial profiles of the bank, which were originally surveyed using this same method, to determine the average annual erosion rate over an extended period of time. At the ten newly established sites, bank profiles were surveyed at the beginning and end of the six-month project period, with the exception of one site (PB09) due to a loss of accessibility (Figure 3). Local land use and site characteristics, including bank height, bank vegetation cover, and stream order, were also recorded at each site. The height of the study bank was determined by subtracting the height of the foot of the study bank from the height of the top of the study bank. The percentage of the bank covered by vegetation was approximated by averaging the visual estimations provided by two or three independent observers. Stream order was determined by reviewing topographic maps of each site and evaluating their positions within their respective river systems.

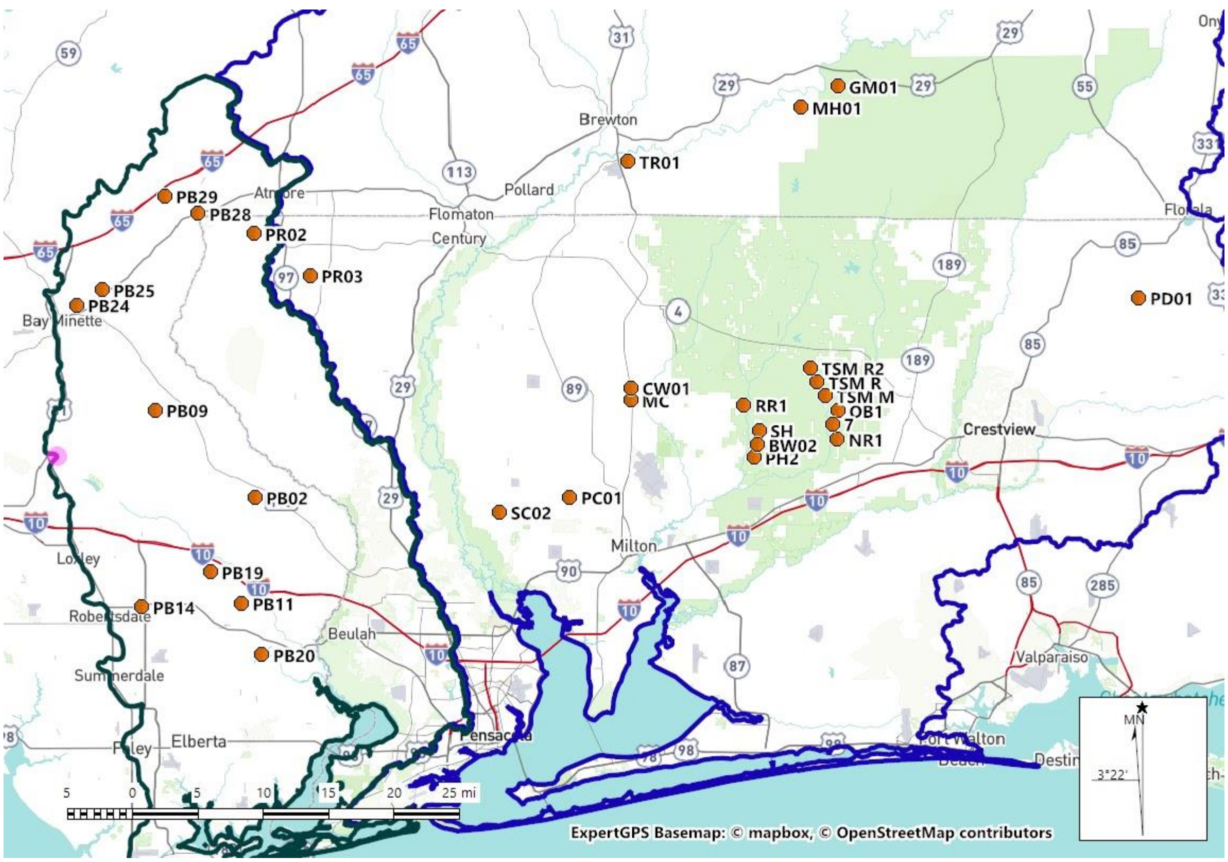

Figure 1: Sampling points within the Pensacola Bay (blue border) and Perdido Bay (green border) watersheds.

Figure 2: The horizontal distance between the vertical surveying rod and the face of the bank being measured using a ruler and line level.

Figure 3: Inaccessible roads leading to site PB09, where a repeat bank profile measurement was unable to be collected.

The magnitude of bank erosion between visits was calculated by subtracting the area-under-the-curve of the two profiles recorded at each site and dividing the difference by the bank height. The resulting bank erosion was converted to an annual rate [cm/yr]. In addition to the rate of bank erosion, the bank erosion hazard index (BEHI) of each site was calculated. The BEHI rating evaluates the potential erodibility of a site based on the numerical rating of numerous site indicators: study bank height divided by bankfull height (study bank-height ratio), root depth divided by bank height (root depth ratio), weighted root density, bank angle, surface protection, and the type and stratification of bank material (Rosgen, 2006). The root depth, root density, surface protection, and stratification of the bank were estimated visually by two or three independent observers. Bank material was classified using the standard feel method for identifying soil texture in the field. The bank angle and bank heights were determined using an Abney level and surveying rod. Once measured, each variable was converted to a rating ranging from zero (Very Low) to ten (Very High) (Rosgen, 2006). The sum of the numerical ratings of the indicators is used to obtain an adjective rating that classifies the bank's susceptibility to erosion on a scale from Very Low to Extreme. Additionally, potential relationships between rates of bank erosion and site characteristics (bank height, bank vegetation cover, stream order, and BEHI rating) were investigated using the Pearson correlation coefficient (r) and evaluations of the coefficients of determination (R^2) from linear regression models of the data.

Results and Discussion

The annual erosion rate and site characteristics of each of the studied sites are listed in Table 1. The majority of the studied sites (~ 70%) were found to be experiencing a net loss of bank material each year. At the twenty revisited sites, where longer observation periods exist, bank erosion rates ranged from -1.4 cm/yr (SH1) to 5.1 cm/yr (PH2). Negative erosion rates indicate deposition, which occurred at six of these sites. Due to the short study period at the new sites (approximately six months), erosion rates had to be extrapolated to produce an annual erosion rate. The short study period and the extrapolation at these new sites produced a wider spread of erosion rates, ranging between -8.0 cm/yr (PB14) to 13.5 cm/yr (PB11). Deposition occurred at three of the nine sites. In subsequent years, follow-up surveys can produce a more robust annual rate that will likely be more indicative of the true rate of erosion at these newly established sites. No specific areas with high rates of erosion or deposition within the PPB watersheds were identified, suggesting a spatial trend does not exist. Determinations of the BEHI score of each of the thirty sites identified one Extreme, two Very High, eight High, thirteen Moderate, and six Low ratings of potential erodibility. The land use in all local watersheds of the study sites was forest, which prevented us from examining any potential effect of the land use on bank erosion.

Due to the dissimilar lengths of the study periods between the existing sites and the new sites, statistical analyses of these sets of sites were conducted independently of one another, rather than averaged across all sites. Analysis of the relationships between the erosion rate and varying site characteristics (bank height, bank vegetation cover, stream order, and BEHI rating) using Pearson correlation coefficients at the existing sites revealed negative relationships between erosion rates and bank cover, bank height, and stream order, albeit to a small degree. The negative relationships between these three variables indicates that erosion rates decrease when bank cover, bank height, stream order increase. In addition to the negative relationships, a positive relationship was observed between bank erosion rates at the existing sites and their corresponding BEHI rating. Such a correlation was expected to exist due to the fact that the

BEHI rating is intended to serve as a predictor for bank erosion rates and has been identified as a strong predictor of bank erosion in previous studies (McMillan et al, 2017). A multiple linear regression with all of the above parameters did not show a strong control over bank erosion (R^2=0.16, not significant at p=5%). A potential reason for the weak explanatory value of the parameters, offered by Mc Millan et al. (2017), is that stochastic toppling of trees on the stream banks is an important control over bank erosion in the study area but quantifying this process is very challenging. Statistical analysis of the data collected from the new study sites identified a similar, but much stronger relationship between erosion rates and bank cover. As aforementioned, the strong negative relationship between these two variables indicates that when the percentage of the bank covered by vegetation increases, the erosion rate decreases. The presence of such a strong relationship has implications for the future management of streambanks within the PPB watersheds. By encouraging the growth of vegetation along streams, bank erosion could be reduced and the amount of downstream sediment loading could be minimized, alleviating some of the environmental issues associated with this process. If future land use changes within the PPB watersheds result in losses of bank vegetation, however, an increase in bank erosion may occur, worsening the associated issues.

Table 1: Annual erosion rates and various site characteristics.

Site ID	Erosion Rate [cm/yr]	Bank Height [cm)]	Bank Cover (%)	Stream Order	BEHI Score	BEHI Rating
MC7	1.8	90	25	3	41.6	Very High
NR1	1.1	175	10	2	48.5	Extreme
OB1	2.2	164	90	3	27.8	Moderate
PH2	5.1	90	40	3	27.8	Moderate
RR1	1.8	113	40	3	42.8	Very High
SH1	-1.4	132	80	3	25.2	Moderate
TSMM	1.7	77	10	3	38.7	High
TSMR2	0.9	77	80	3	25.2	Moderate
TSMR	0.7	47	60	3	14.8	Low
MC	-0.2	151	80	3	31.9	High
PR02	1.4	160	12	4	22.1	Moderate
PR03	-0.2	140	93	3	15.1	Low
BW02	1.0	200	86	3	34.3	High
TR01	1.8	150	30	2	19.0	Low
MH01	-0.5	250	15	4	30.7	High
GM01	-0.9	190	63	3	23.9	Moderate
CW01	2.6	130	40	3	37	High
PD01	1.8	230	40	4	23.4	Moderate
PC01	-0.7	110	30	3	24.6	Moderate
SC02	1.2	80	40	2	17.2	Low
PB02	-1.6	157	70	2	16.5	Low
PB09	–	147	25	3	32.8	High
PB11	13.5	169	35	3	17.5	Low
PB14	-8.0	155	80	4	21.1	Moderate
PB19	-1.1	173	60	3	28.3	Moderate
PB20	4.0	327	5	4	38.3	High
PB24	0.8	150	88	2	25.4	Moderate
PB25	1.2	157	35	3	23.8	Moderate
PB28	2.2	158	58	4	25.5	Moderate
PB29	0.7	112	90	3	30.4	High

Table 2: Pearson correlation coefficients between site characteristics and streambank erosion rates. Value in bold signifies strong statistical significance.

	Erosion Rate (Revisited sites)	Erosion Rate (New sites)
Bank Height	-0.255	0.229
Bank Cover	-0.262	**-0.546**
Stream Order	-0.097	-0.062
BEHI	0.232	-0.017

Conclusions

Eroded material from streambanks can be an important source of sediment and nutrients in fluvial systems and can subsequently cause numerous environmental issues, such as the smothering of aquatic vegetation and the transportation of water quality pollutants. To evaluate the degree to which bank material is being eroded within the Pensacola Bay and Perdido Bay watersheds, repeat surveys of streambank profiles were carried out at thirty sites. Twenty of the selected sites had pre-existing measurements from previous years of research and were revisited in this study to extend the period of observations. Ten new sites were established to create baseline data in under-represented areas. Quantifications of the changes between bank profile measurements showed evidence of erosion at twenty of the twenty-nine study sites, with rates as high as 13.5 cm/yr (PB11). Net deposition was found to be occurring at nine of the sites at relatively small magnitudes. Bank characteristics and stream order were also recorded at each site and used to investigate potential relationships between these variables and bank erosion rates. Analyses revealed a strong negative relationship between bank erosion and bank vegetation cover at the newly established sites, but this observation has to be interpreted cautiously because of the short observation period for the new sites. Correlations between other environmental parameters and erosion rate were weak, indicating that other factors are the main control over bank erosion in the area. In addition to showing the ways in which remediation efforts can be implemented, this data also shows where these efforts should be prioritized. Streams within the PPB watersheds that are experiencing the largest rates of erosion can be expected to be the main sources of sediment loading within Pensacola Bay and Perdido Bay. To relieve and prevent further sedimentation issues in these fluvial systems, efforts should be focused at the sources of sediment that this research has identified. Continued monitoring in subsequent years can expand upon this research and be used to refine the understanding of streambank erosion within the PPB watersheds, providing a source of continually improving data that can inform future management decisions in this region for years to come.

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