The Maryland Department of the Environment's Historical Trends for Shoreline Erosion Control Activities from January 2015 to August 2020

Prepared for the Maryland Department of the Environment
Wetlands and Waterways Program

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Executive Summary

Living shorelines are a natural way to protect coastal shorelines from erosion and are recognized as an adaptation strategy for developing coastal resilience in the face of climate change. This report was prepared by James Beauregard for the Maryland Department of the Environment (MDE) Tidal Wetlands Division as one of his projects during his year with the Department as a Chesapeake Bay Trust Chesapeake Conservation Corps Member. The purpose of this document is 1) to establish baseline statistics of historic patterns and trends seen in the implementation of different shoreline erosion control projects in Maryland and 2) to discuss ways the state could increase the installation of living shorelines.

Data on shoreline erosion control activities from MDE's Environmental Tracking System (ETS) was pulled from January 2015 to August 2020 and was checked/updated for quality assurance and quality control. Statistics of structural erosion methods and living shorelines are reported on the number of authorizations, percentages of total authorizations, annual averages, and project dimensions across different counties. Below are the key findings from the report:

- Out of the total erosion control activities (on developed and undeveloped shorelines) authorized, bulkheads made up most of the activities at 42%, followed by revetments at 34.1%, then living shorelines at 17.9%. Groins, beach nourishment, and breakwater projects together make up a small percentage of total shoreline activities. Similarly, the annual averages of each shoreline erosion control project follow the same order.
- When comparing only new structural control projects on undeveloped shorelines, structural methods only made up 68.03% of all activities, while living shorelines made up 31.97%.
- Shoreline control methods vary greatly across different counties in the number of authorizations and marsh areas created. Anne Arundel, Talbot, and St. Mary's counties have the greatest number of living shoreline authorizations, but in terms of the most marsh being created, Somerset, Charles, and Anne Arundel counties ranked the highest. Due to the presence of existing functional shoreline structures, Baltimore, Cecil, and Harford counties, and Baltimore City and Ocean City are the most likely to waive living shoreline projects in favor of structural controls.
- Less than 1% of the total living shoreline projects were maintenance/replacement activities whereas 54% of the total structural control projects were for maintenance/replacement.

This report demonstrates that property owners prefer structural methods over living shorelines. Structural methods are viewed to be more effective at controlling erosion, despite studies stating otherwise. To increase the adoption of living shorelines, it's recommended that erosion control projects emphasize site-specific approaches and structural resiliency. Additional studies and public education highlighting the long-term economic and ecological benefits of living shorelines will assist with further public acceptance and understanding. Continuing to emphasize living shorelines as the preferred shoreline erosion control practice will facilitate the transition to more living shoreline projects and allow Maryland's coastal communities to adapt and fight against climate change.

Abstract

In accordance with State law, the Tidal Wetlands Division of the Maryland Department of the Environment (MDE) aims to promote Living Shoreline (LS) projects as the primary means of shoreline erosion control. Living Shoreline projects are an adaptation strategy for coastal communities vulnerable to sea-level rise and other effects of anthropogenic climate change. Along with shoreline erosion control, LS projects can provide critical habitat for a variety of estuarine organisms, and aim to be less detrimental to adjacent natural wetlands than armored structural controls. This project involved conducting statistical analyses on the historical LS projects and structural controls data within the Environmental Tracking System (ETS) database from January 2015 to August 2020. Structural controls (new and maintenance/replacement activities) had a greater total and annual average than LS projects (new and maintenance/replacement activities) on a State and County level. Only Kent, St. Mary's, and Talbot Counties had a LS projects percentage greater than structural controls. Structural controls were also significantly greater than LS projects in terms of linear feet total, annual average, and percentage. The three Counties where the linear feet total percentage of LS projects was greater than structural controls were Charles, Somerset, and Talbot County. When comparing the annual trends, the number of structural controls were more consistent each year than the LS projects. To increase the installation of LS projects throughout the Chesapeake Bay portion of Maryland, there needs to be an emphasis on site specific designs and approaches, and a further understanding of their ecological and economic benefits.

Introduction

The world's tidal estuaries, including the Chesapeake Bay, are major centers of human activity, experiencing continuous growth and development (Bosch et al. 2006, Bilkovic et al. 2016). Although tidal estuaries and wetlands are crucial to coastal human populations for ecological and economic purposes, they are also some of the most vulnerable ecosystems affected by anthropogenic climate change (Day et al. 2008, Baustian et al. 2012, Kirwan and Megonigal 2013). Along with sea-level rise, anthropogenic climate change is increasing the frequency and magnitude of storms and excessive erosion around coastal human populations near tidal estuaries (Day et al. 2008, Kirwan and Megonigal 2013). While erosion is a natural process in coastal tidal wetlands, anthropogenic activities such as improper land development and cultivation practices, ranging from lack of buffers to not using cover crops, can cause excessive erosion rates on the Bay's shorelines of over four feet per year (Bosch et al. 2006, MDE 2008). Between 25-50% of the planet's coastal tidal wetlands have been lost and converted to land for agricultural and aquacultural purposes, which interrupts sediment delivery to stabilize shorelines (Kirwan and Megonigal 2013). The increasing intensity in storms due to climate change further contributes to the deterioration of coastal tidal wetlands through massive amounts of rainfall and wave energy (MDE 2008, Kirwan and Megonigal 2013). If not addressed properly, coastal communities will continue to face certain ecological and economic impacts from excessive erosion rates. Such impacts include homes and businesses lost to storm damage, diminishing water quality, and increasing pressure on various native plants and animals from habitat degradation (Bosch et al. 2006, Day et al. 2008, MDE 2008). To counter these effects, people on the Bay and other coastal communities are searching for effective mitigation and adaptation strategies for shoreline stabilization.

When it comes to shoreline stabilization, methods are often categorized as structural or nonstructural. A structural method refers to any shoreline stabilization technique that incorporates timber, stone, or concrete and is designed to armor shorelines from storms and high wave energy (Bosch et al. 2006, MDE 2008). By 2013, around 18% of the Chesapeake Bay's tidal shorelines were composed of armored structural controls (Bilkovic et al. 2016). Although armored structural control methods, such as bulkheads, revetments, groins, and breakwaters can effectively protect human infrastructure, they can diminish wetlands and their ecological services through habitat fragmentation, chemical runoff, and decreasing accretion rates (MDE 2008, Bilkovic et al. 2013, Gittman et al. 2014). Structural shoreline methods also redirect storm and wave energy which can induce excessive erosion toward any nearby tidal wetlands (Bosch et al. 2006, Gittman et al. 2016). Thus, many Federal, State, and community organizations are attempting to focus more on hybrid erosion protection which involve native vegetation plantings reinforced by a multitude of structural components that prevent erosion (Bosch et al. 2006).

In terms of nonstructural methods, slope grading has been used throughout the Bay, though the one with the most potential are LS projects (Bosch et al. 2006). An LS project is a shoreline stabilization adaptation technique that incorporates adjacent coastal habitat primarily composed of native vegetation and other natural materials (Bilkovic et al. 2016). In numerous designs, LS projects have a hybrid design that includes stones as structural components in the form of low-profile sills or breakwaters (Duhring 2006, Smith 2006, Bilkovic et al. 2013). The structural components of LS projects are approved if they can protect and be dominated by marsh vegetation, and have minimal impact on adjacent natural wetlands (Duhring 2006, Bilkovic et al. 2013). Furthermore, properly implemented structural components of hybrid LS projects can promote secondary productivity in areas where loss of biogenic habitat, such as oyster reefs and submerged aquatic vegetation (SAV) beds, have occurred (Bilkovic et al. 2013).

The Tidal Wetlands Division of MDE is responsible for providing authorizations to alter tidal wetlands throughout the Maryland portion of the Chesapeake Bay and its tidal tributaries (MDE 2008). When it comes to the selection of an erosion control measure, the Maryland State law has a specific order of preference (MDE 2008). The first measure is “no action” or relocation, which is a determination that no erosion control method is required and thus the State will not issue an authorization for a proposed shoreline erosion control project (MDE 2008). If a waterfront property owner proves to MDE with satisfying evidence that “no action” or relocation methods can be implemented at their property, then by State statute, the property owner shall follow the second erosion control measure and incorporate a nonstructural shoreline erosion control method i.e. a LS project (MDE 2008). Many LS projects can include structural controls as long as the project is dominated by tidal wetlands vegetation. Based on the Code of Maryland Regulations (COMAR), if a structural component is necessary in order to preserve the natural shore, minimize erosion, and establish aquatic habitat, a nonstructural shoreline stabilization measure may include the use of:

1. A breakwater, sand containment structure, or sill that is acceptable to the Department; or
2. A beach that is acceptable to the Department, when used for the purpose of habitat enhancement.

However, waivers can be granted to properties in areas that MDE has considered impractical for LS projects, and property owners would follow the third erosion control measure, structural controls (MDE 2008). For a property owner to have structural erosion controls, proof of consideration for each alternative must be provided, including an analysis of habitat impact for each alternative (MDE 2008). The following order of preference for structural controls are:

1. Beach Nourishment;
2. Breakwater;
3. Groin, Jetty, or a similar structure;
4. Revetment; and
5. Bulkhead.

Furthermore, the MDE’s 2008 Shoreline Erosion Control Guidelines states that the other factors besides the attributes found on the waiver worksheet that may allow MDE to grant a waiver to LS projects include:

A. Properties lacking adjacent natural shorelines;
B. Properties being located in major navigation channels;
C. Areas having high-wave energy or severely eroded shorelines;
D. Properties having infrastructure (ex. septic systems) close to shorelines;
E. Shorelines being inaccessible to implement LS projects; and
F. Commercial vessel berthing, which requires a bulkhead.

If MDE determines that the applicant has proven that a LS is not practical due to the site conditions documented in the waiver worksheet and/or the conditions above, the Department will issue a waiver from a LS, and the applicant may apply for structural erosion controls (MDE 2008). In order to increase the use of LS projects, there should be thorough coordination among regulatory and advisory agencies, and public acceptance of LS projects must be expanded upon (Bilkovic et al. 2016). Therefore, the Tidal Wetlands Division of MDE collaborated with an intern from the Chesapeake Conservation Corps (CCC) of the Chesapeake Bay Trust to evaluate trends in the MDE's historical shoreline erosion control data. This project aims to compare and contrast the averages and percentages of LS approvals (in terms of LS projects) and waivers (in terms of structural controls) on a County and State level. Additionally, the results of this project can indicate where in Maryland LS projects require further promotion and where future LS waivers can be expected.

Methods

Project Design

This project was conducted by the CCC intern from September 2020 to August 2021. The historical shoreline erosion control data used in this project was provided by the MDE Tidal Wetlands Division staff. The following tasks were identified in a Work Plan between the CCC intern and the Chief of the Tidal Wetlands Division:

- Task 1. Provide quality assurance and quality control on historical LS projects and armored structural erosion control activities.
- Task 2. Consolidate similar shoreline activities for each tidal wetlands license.
- Task 3. Fully update 01/2015-08/2020 historical LS data into the MDE ETS database.
- Task 4. Analyze the 01/2015-08/2020 historical LS data for significant trends, and report them.

Task 1 was conducted from September 2020 to October 2020. For effective quality assurance and quality control, several Tidal Wetlands licenses were pulled from each year of the data's time range (January 2015 to August 2020) to determine if listed shoreline erosion control activities matched their license description. Task 2 occurred from September 2020 to November 2020. This task involved combining similar shoreline erosion control activities on each Tidal Wetlands license. For example, if a Tidal Wetlands license had two new revetments, then the measurements of these same activities would be consolidated to avoid potential error in the statistical analyses. Task 3 lasted from October 2020 to December 2020. This task required uploading any missing values from certain Tidal Wetlands licenses into the MDE ETS database. Additionally, all listed zero values were reviewed to determine if they were genuine. Tasks 1-3 have been completed, and this report provides the summary and associated graphs of theTask 4 statistical trends for the historical LS data.

Statistical Analyses

All values in the statistical analyses are based on the number of shoreline erosion control activities in the Tidal Wetlands licenses from MDE's Environmental Tracking System (ETS) database ranging from January 2015 to August 2020. This decision was made due to some Tidal Wetlands licenses containing both LS projects and structural controls. Furthermore, all beach nourishment activities were classified under structural controls since they are not considered by statute or regulations as an action for LS projects. Living Shoreline projects and structural controls were compared on a county and State level in terms of their calculated totals, percentages, and annual averages, with standard error taken into account. In terms of the annual averages, the time range is approximately 5.67 years due to the 2020 year not being complete at the time of this study.

The LS projects were also compared on a county level in terms of marsh establishment acreage. The next phase of statistical analyses involved assessing the LS projects and armored structural controls by their amounts in linear feet, and their annual trends from January 2015 to December 2019. An Analysis of Variance (ANOVA) test was conducted among the county, State, and linear feet comparisons between LS projects and structural controls to see if the results were statistically significant. An ANOVA test was also used in the marsh establishment acreage assessment among the LS projects. If there was statistical significance, a Tukey Post-hoc test was performed to find where the statistical significance was among the groups of data if there were more than two variables.

Results

In the MDE ETS database, there were a total of 3,009 documented shoreline erosion control activities from January 2015 to August 2020 in all of Maryland (Fig. 1). This assessment of total shoreline erosion controls took into account both new and maintenance/replacement activities. Bulkheads had the most prevalent total (1,262 activities, 42.0%), and was followed by revetments (1,027 activities, 34.1%). The LS projects had the third largest total (539 activities, 17.9%).

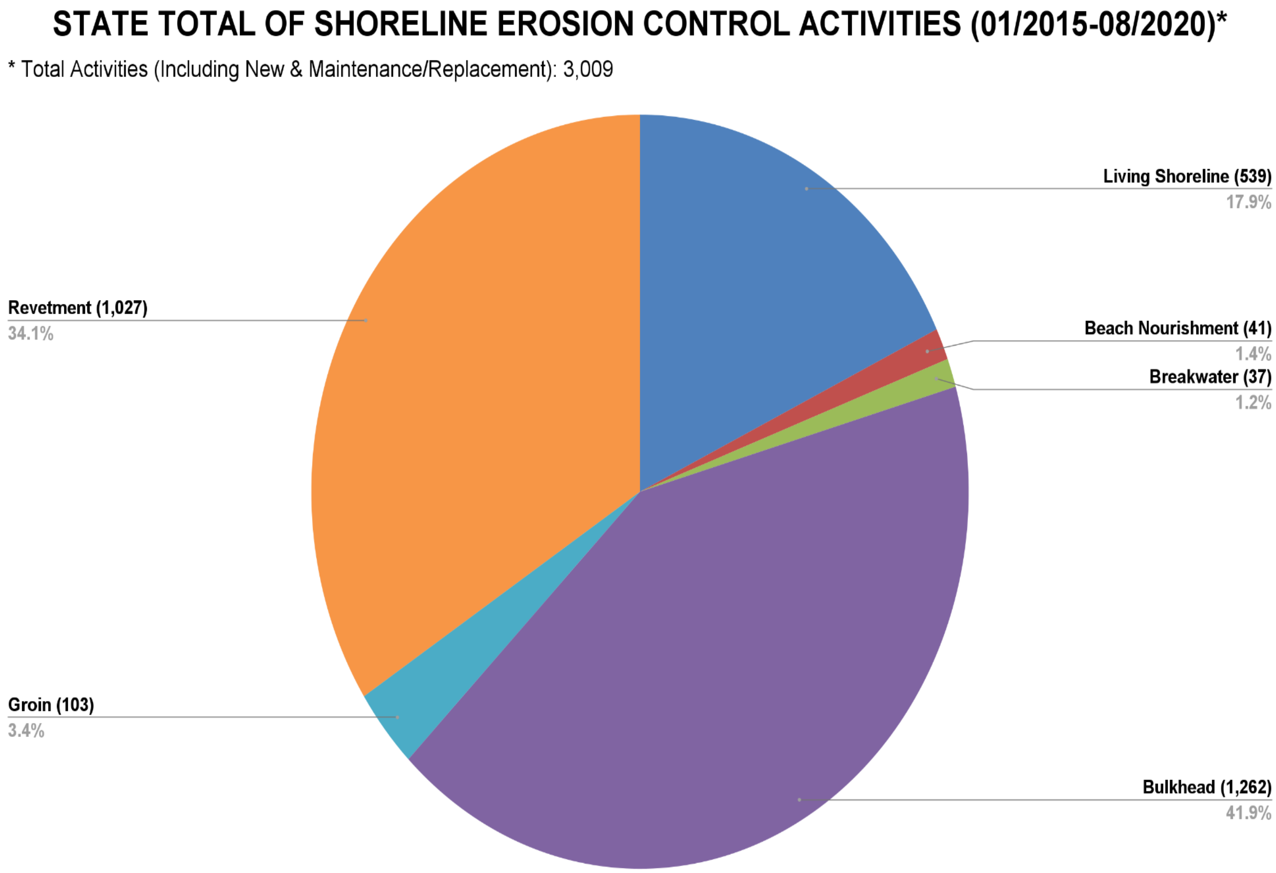

Figure 1. The total of all shoreline erosion control activities, with percentages, that included both new and maintenance/replacement activities in the State of Maryland from January 2015 to August 2020 (n = 3,009).

The annual averages of all the shoreline erosion control activities reflected the results of their totals (Fig. 2). Bulkheads had the highest annual average (223 activities), with revetments being second (181 activities), and LS projects being third (95 activities). Significant differences were found among the shoreline erosion control activity averages, except between beach nourishment, breakwaters, and groins (Tukey Post-hoc: $P<0.05$).

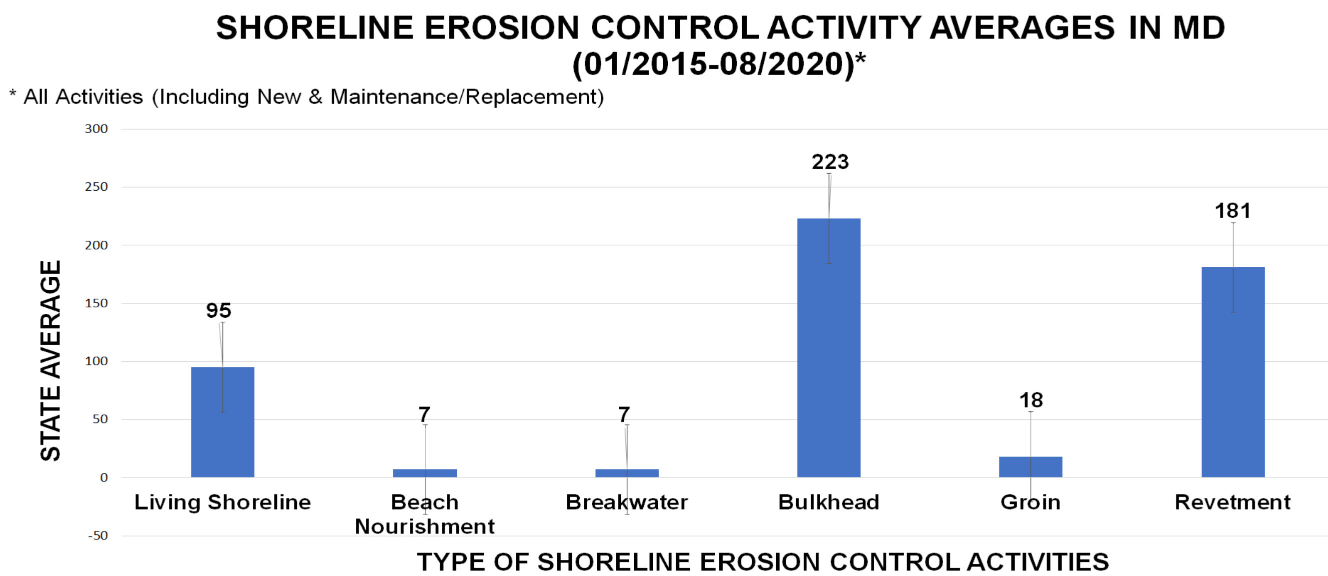

Figure 2. Shoreline erosion control averages (±SE) including new and maintenance/replacement activities in the State of Maryland from January 2015 to August 2020 (n = 3,009, Tukey Post-hoc: $P<0.05$).

The total number of shoreline erosion control activities was later compared in terms of all structural controls (bulkhead, revetment, groin, breakwater, and beach nourishment) in Maryland per county (Fig. 3). In the MDE ETS database there are a total of 2,470 structural control activities from January 2015 to August 2020 throughout Maryland. In terms of total structural controls that included both new and maintenance/replacement activities, the top five Counties were: 1. Anne Arundel (759, 30.8%), 2. St. Mary's (254, 10.3%), 3. Baltimore (242, 9.8%), 4. Ocean City (241, 9.8%), and 5. Talbot (153, 6.2%).

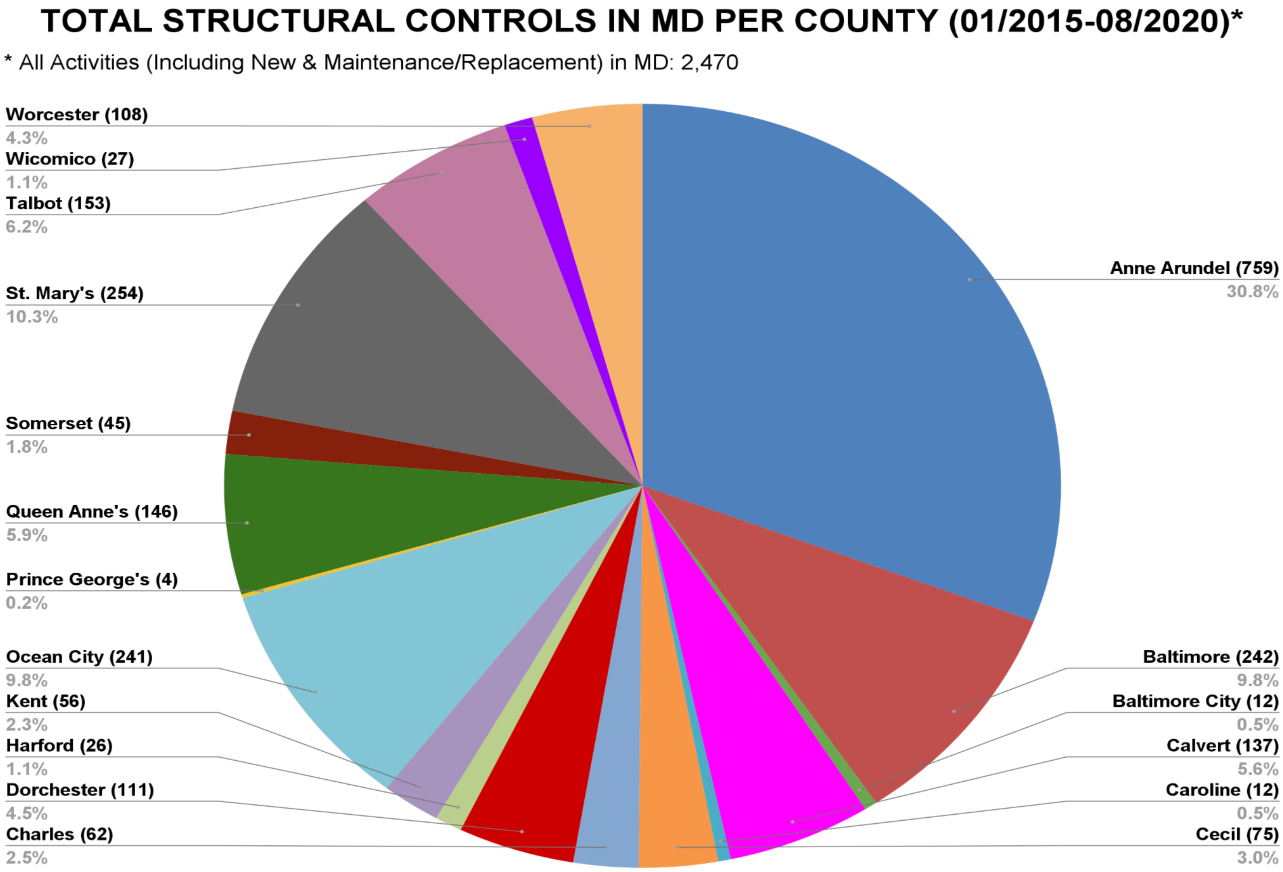

Figure 3. The total of all structural controls, with percentages, that included new and maintenance/replacement activities in Maryland Counties on the Chesapeake Bay and its tidal tributaries from January 2015 to August 2020 (n = 2,470).

The total number of LS projects in Maryland per County were also compared (Fig. 4). In the MDE ETS database there are a total of 539 LS projects from January 2015 to August 2020 throughout Maryland. In terms of total LS projects per County that included both new and maintenance/replacement, the top five Counties were: 1. Anne Arundel (140, 26.0%), 2. Talbot (117, 21.7%), 3. St. Mary's (90, 16.7%), 4. Queen Anne's (31, 5.8%), and 5. Worcester (28, 5.2%).

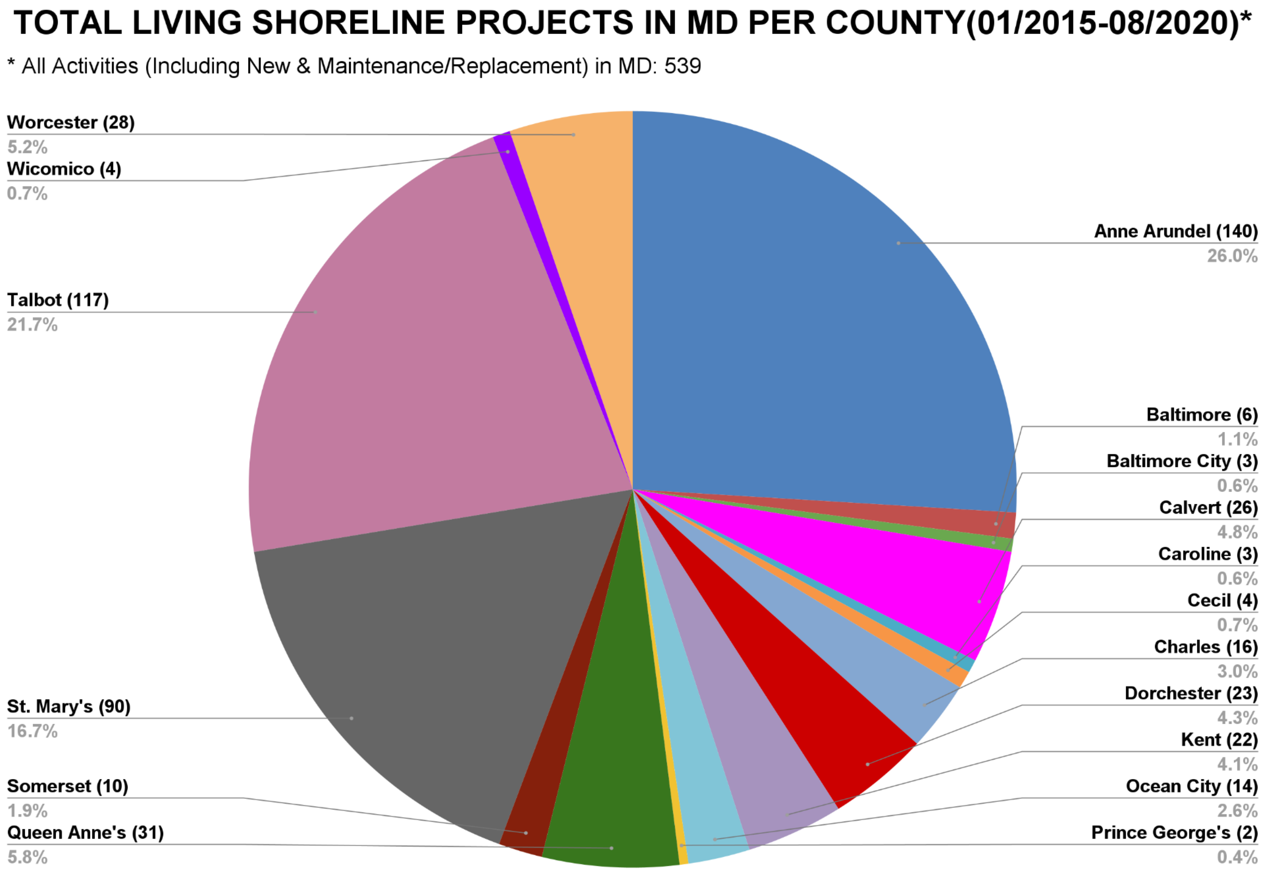

Figure 4. The total of all Living Shoreline projects, with percentages, that included both new and maintenance/replacement activities in Maryland Counties from January 2015 to August 2020 (n = 539).

The annual averages of the structural controls and LS projects were compared among the Maryland Counties (Fig. 5). Structural controls were broken down by focusing on projects that are new separately from maintenance/replacement projects. The LS projects had their new and maintenance/replacement grouped together due to having only five maintenance/replacement activities listed from January 2015 to August 2020. The majority of the Maryland Counties had annual averages of structural controls (new or maintenance/replacement activities) that were greater than their LS projects (new and maintenance/replacement activities) annual averages. The notable exceptions were Prince George's and Talbot County, where structural controls (new and maintenance/replacement activities) and LS projects (new and maintenance/replacement activities) were almost equivalent. Significant difference was found between the LS projects and structural controls among the counties, with Anne Arundel being the prime example.

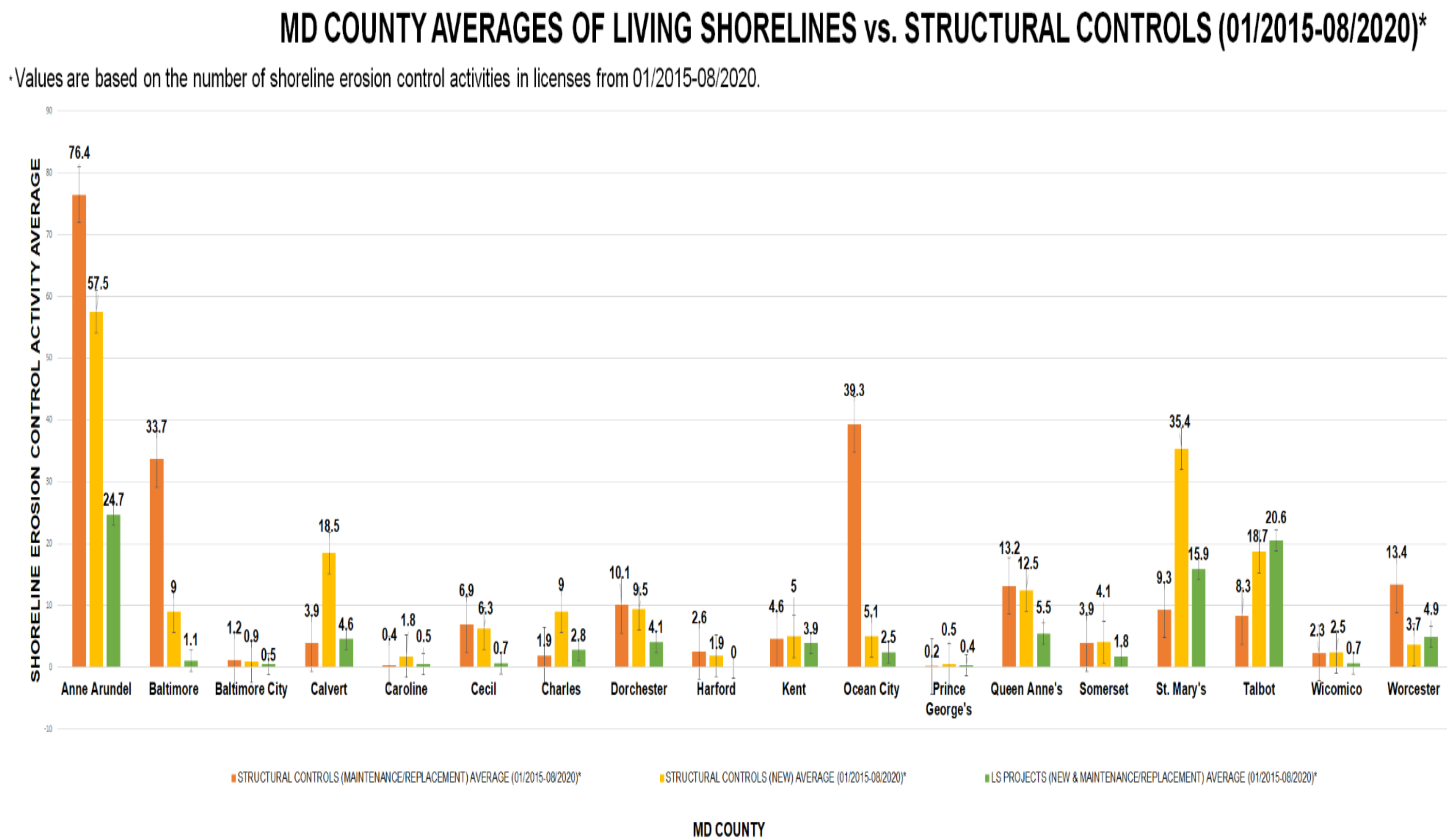

Figure 5. The averages of LS projects and structural controls (±SE) in Maryland counties on the Chesapeake Bay and its tidal tributaries from January 2015 to August 2020 (n = 3,009, Tukey Post-hoc: $P<0.05$).

The total number of all structural controls and LS projects, new and maintenance/replacement activities, were then compared based on the entire State of Maryland (Fig. 6). Significant differences were found between the LS projects and structural controls. Here, the State totals of all structural controls, both new and maintenance/replacement activities combined are roughly five times greater than the total of LS projects (new and maintenance/replacement activities). When comparing LS projects to only new structural controls, the overall total of structural controls is two times greater than LS projects. The results were similar when comparing the annual averages of all structural controls and all LS projects (Fig. 7).

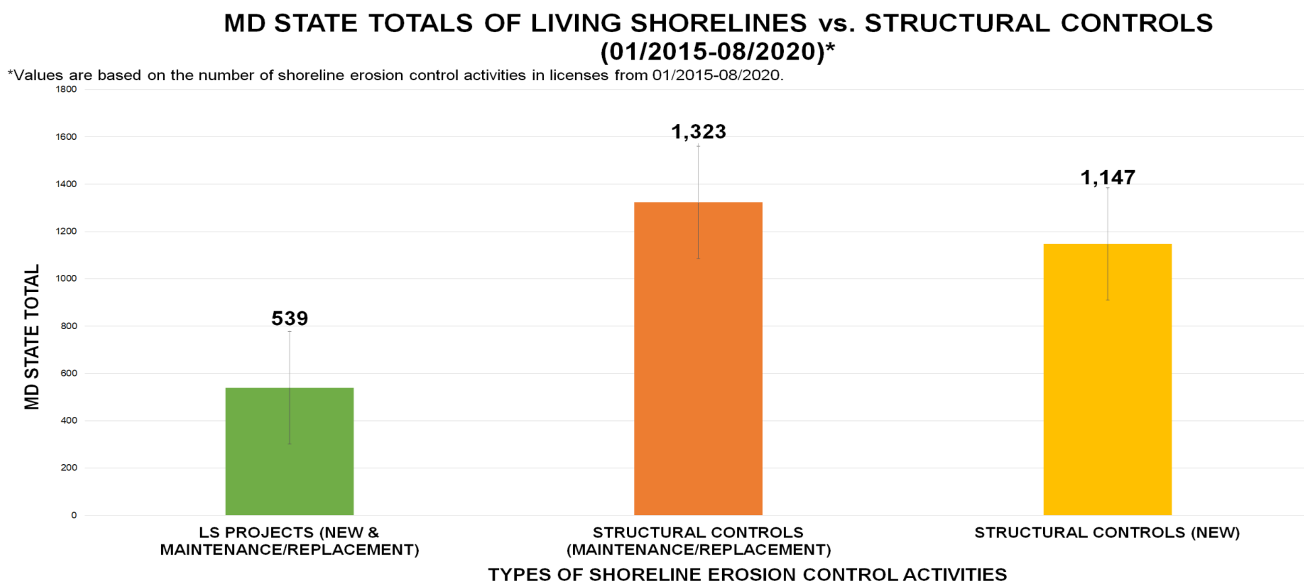

Figure 6. The total of all LS projects and structural controls (±SE), including new and maintenance/replacement activities, in the State of Maryland from January 2015 to August 2020 (n = 3,009, Tukey Post-hoc: P<0.05).

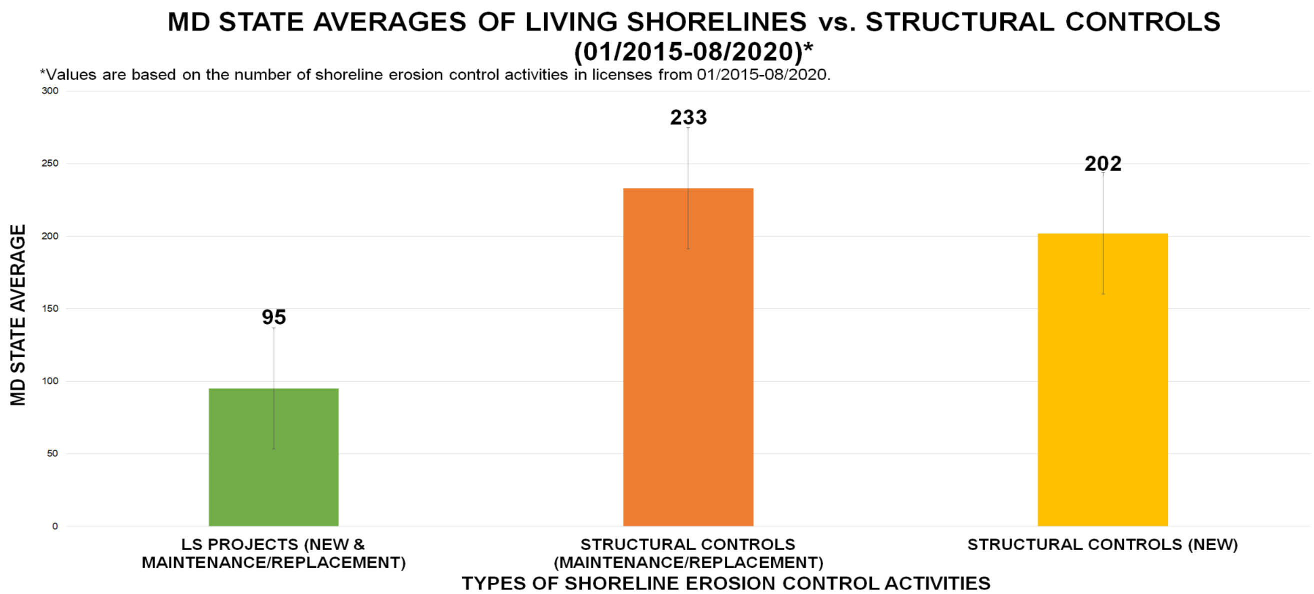

Figure 7. The averages of LS projects and structural controls (±SE), including new and maintenance/replacement activities in the State of Maryland from January 2015 to August 2020 (n = 3,009, Tukey Post-hoc: $P<0.05$).

The next comparison between structural controls and LS projects on a State level were percentages (Fig. 8). Significant difference was found between the LS projects and structural controls. Out of the 3,009 shoreline erosion control activities in Maryland, 57% were structural controls (new), 25% were structural controls (maintenance/replacement), and LS projects made up 18%.

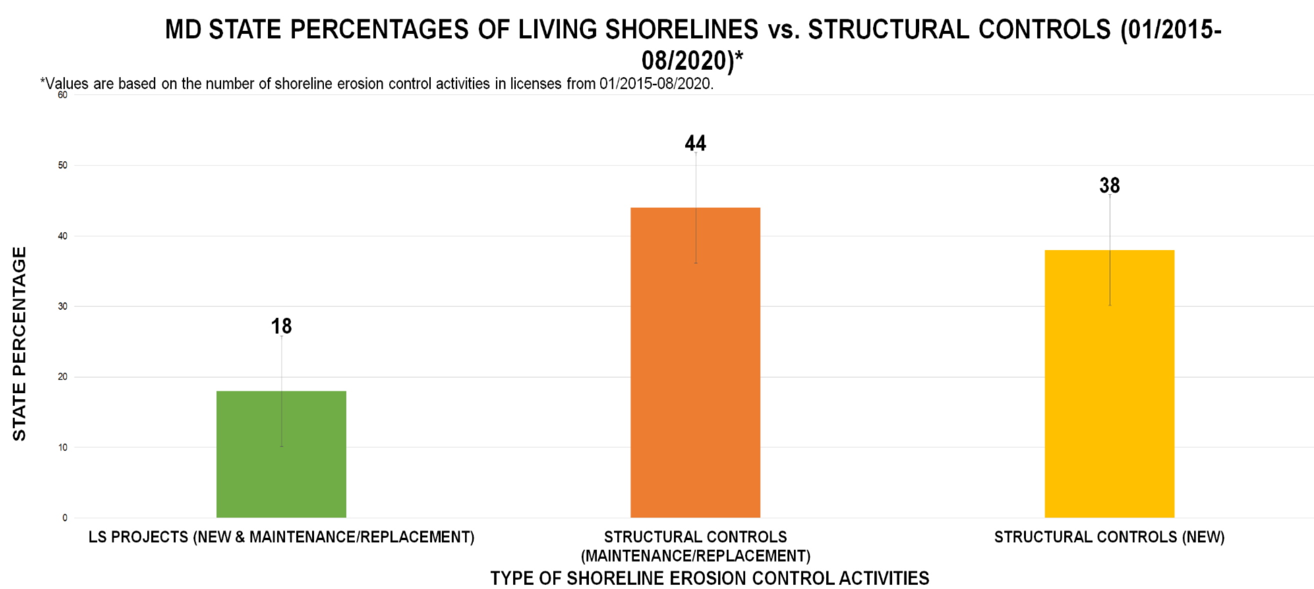

Figure 8. The percentages of LS projects and structural controls (±SE), including new and maintenance/ replacement activities, in the State of Maryland from January 2015 to August 2020 (n = 3,009, Tukey Post-hoc: $P<0.05$).

The final step of comparing the LS projects and structural controls on a State level was assessing the percentage of LS projects (new and maintenance/replacement) and only new structural controls (Fig. 9). This comparison was pursued since the structural maintenance/replacement activities are automatic waivers. By evaluating only new structural controls next to LS projects, there was a better chance of understanding the frequency of new LS waivers from January 2015 to August 2020. Out of this new total, 1,686 shoreline erosion control activities, 31.97% was LS projects (all sub-work types), and new structural controls made up 68.03%. Significant difference was found between the percentages, with the percentage of new structural controls being over twice as much as LS projects (all sub-work types).

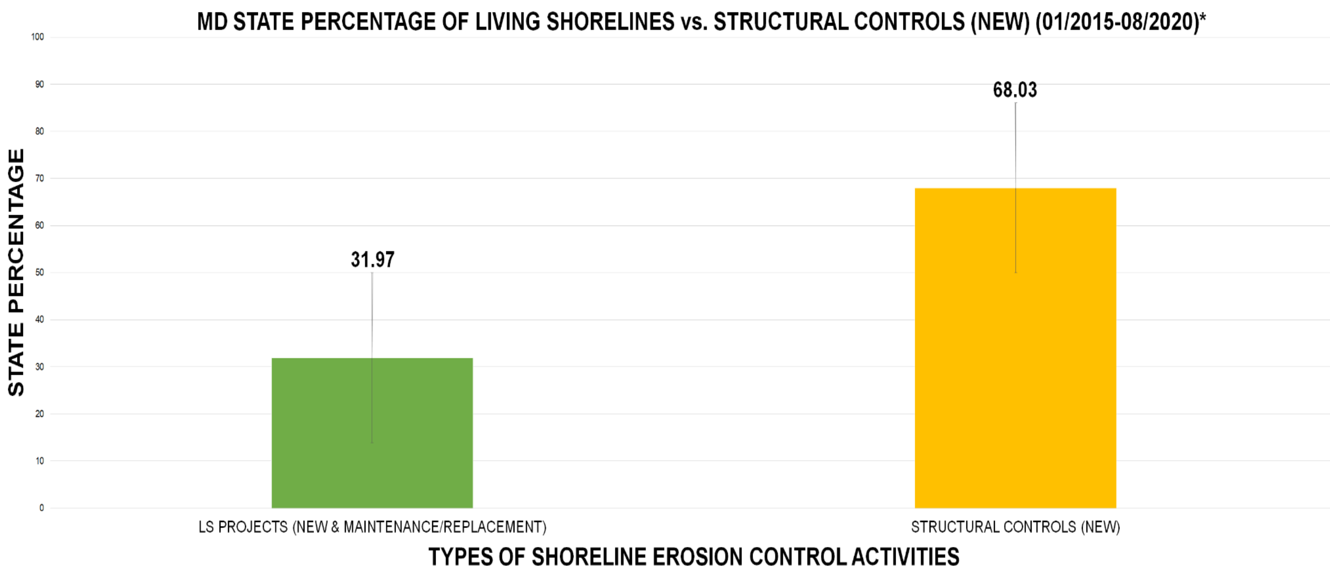

Figure 9. The percentages of LS projects (new and maintenance/replacement) and new structural controls (±SE) in the State of Maryland from January 2015 to August 2020 (n = 1,686, ANOVA: $P<0.05$).

An additional layer to the historical LS data analysis was assessing the amount of marsh establishment acreage in LS projects throughout Maryland on a county level. The total amount of marsh establishment (135.92 Acres) was first compared between all of the Maryland counties from January 2015 to August 2020 (Fig. 10). The five counties with the greatest amount of marsh establishment were: 1. Somerset (40.03 Acres, 29.5%), 2. Charles (17.24 Acres, 12.7%), 3. Anne Arundel (16.29 Acres, 12.0%), 4. St. Mary's (14.68 Acres, 10.8%), and 5. Baltimore (14.13 Acres, 10.4%).

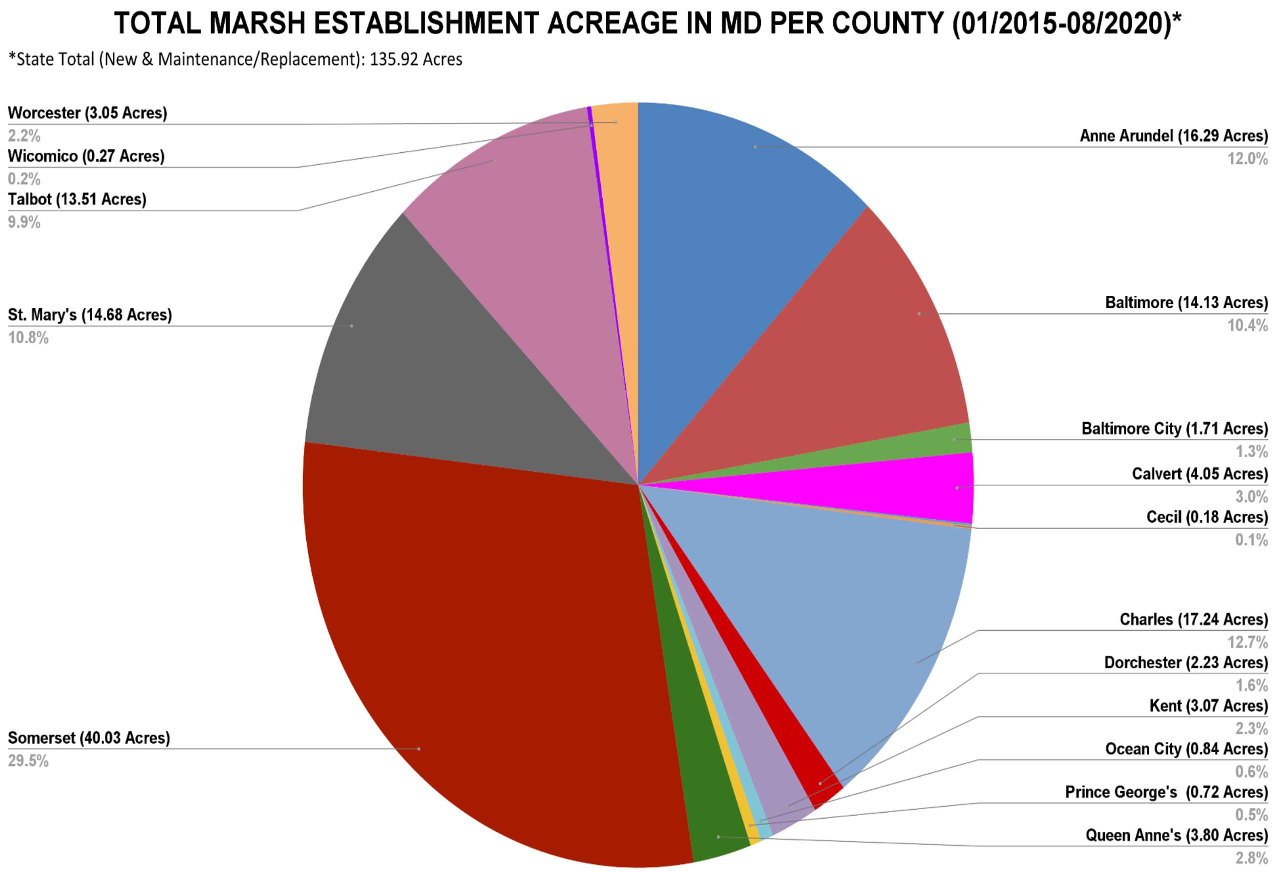

Figure 10. The total acreage of marsh establishment (135.92 Acres) with percentages, including new and maintenance/replacement activities, in Maryland Counties from January 2015 to August 2020 (n = 480).

The annual averages of the marsh establishment acreage had a similar outcome to their totals (Fig. 11). The five counties with the highest marsh establishment acreage annual averages were: 1. Somerset (7.06 Acres), 2. Charles (3.04 Acres), 3. Anne Arundel (2.87 Acres), 4. St. Mary's (2.59 Acres), and 5. Baltimore (2.4913 Acres). However, no significant differences were found between the marsh establishment acreage averages.

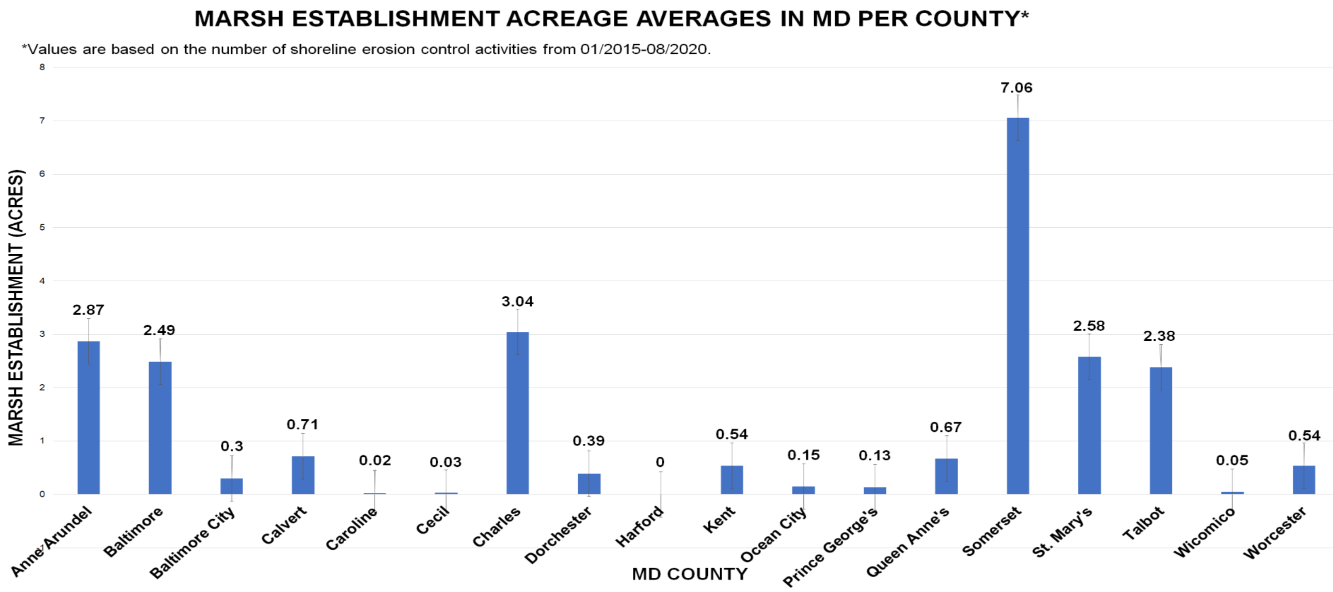

Figure 11. The averages of marsh establishment acreage (±SE), including all new and maintenance/ replacement activities, in Maryland Counties on the Chesapeake Bay from January 2015 to August 2020 (n = 480, ANOVA: P>0.05).

The next layer of comparing the structural controls and LS projects was assessing the amount of linear feet from each category of shoreline erosion control that existed among the Maryland counties from January 2015 to August 2020. In this assessment, only new structural controls were compared to the LS projects, since maintenance/replacement structural control activities were automatic waivers. The total amount of linear feet of new structural controls in Maryland per county (238,698.4 ft.) was assessed first (Fig. 12). The top five counties for total linear feet of new structural controls were: St. Mary's (47,768.5 ft., 20.0%), 2. Anne Arundel (46,157.4 ft., 19.3%), 3. Talbot (43,704.5 ft., 18.3%), 4. Calvert (20,177.0 ft., 8.5%), and 5. Somerset (11,285.0 ft., 4.7%).

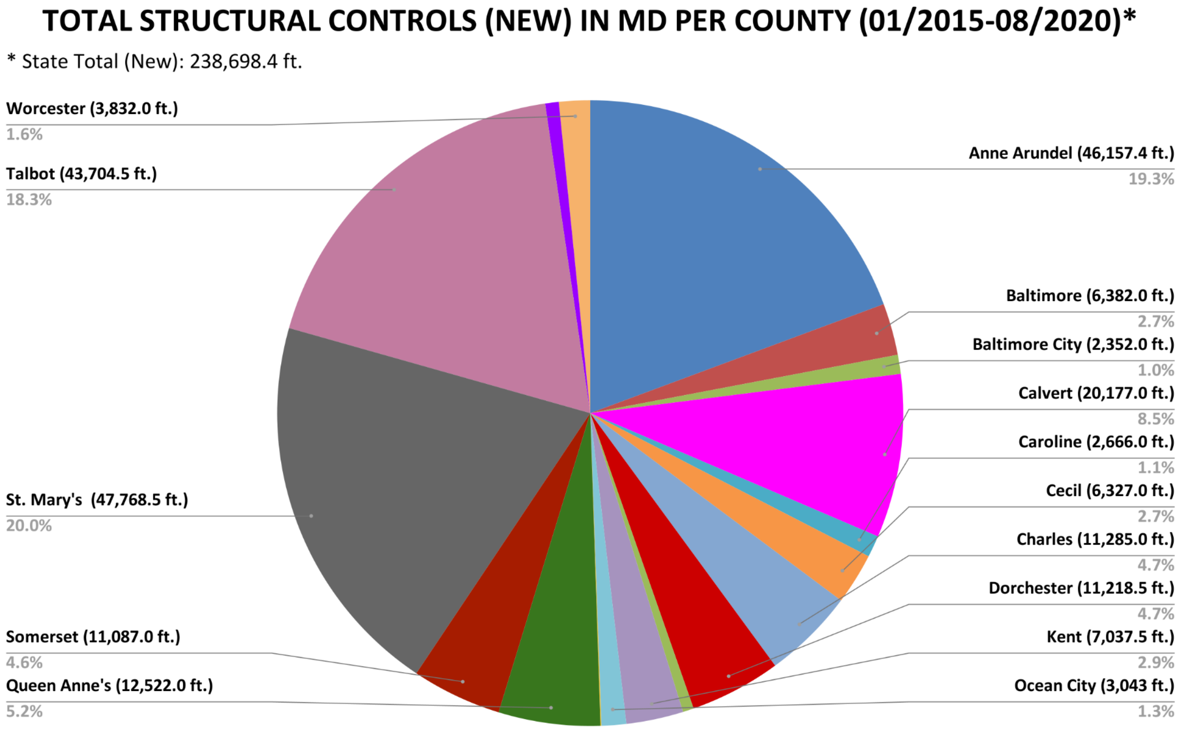

Figure 12. Total linear feet of new structural controls (238,698.4 ft.) with percentages, in Maryland Counties on the Chesapeake Bay from January 2015 to August 2020 (n = 1,147).

The total amount of linear feet of all LS projects in Maryland per County (169,313.5 ft.) was later assessed (Fig. 13). The top five counties for total linear feet of LS projects (new and maintenance/replacement) were: 1. Talbot (33,959.0 ft., 20.1%), 2. Anne Arundel (26,034.1 ft., 15.4%), 3. St. Mary's (24,852.0 ft., 14.7%), 4. Charles (21,844.0 ft., 12.9%), and 5. Somerset (18,863.0 ft., 11.1%).

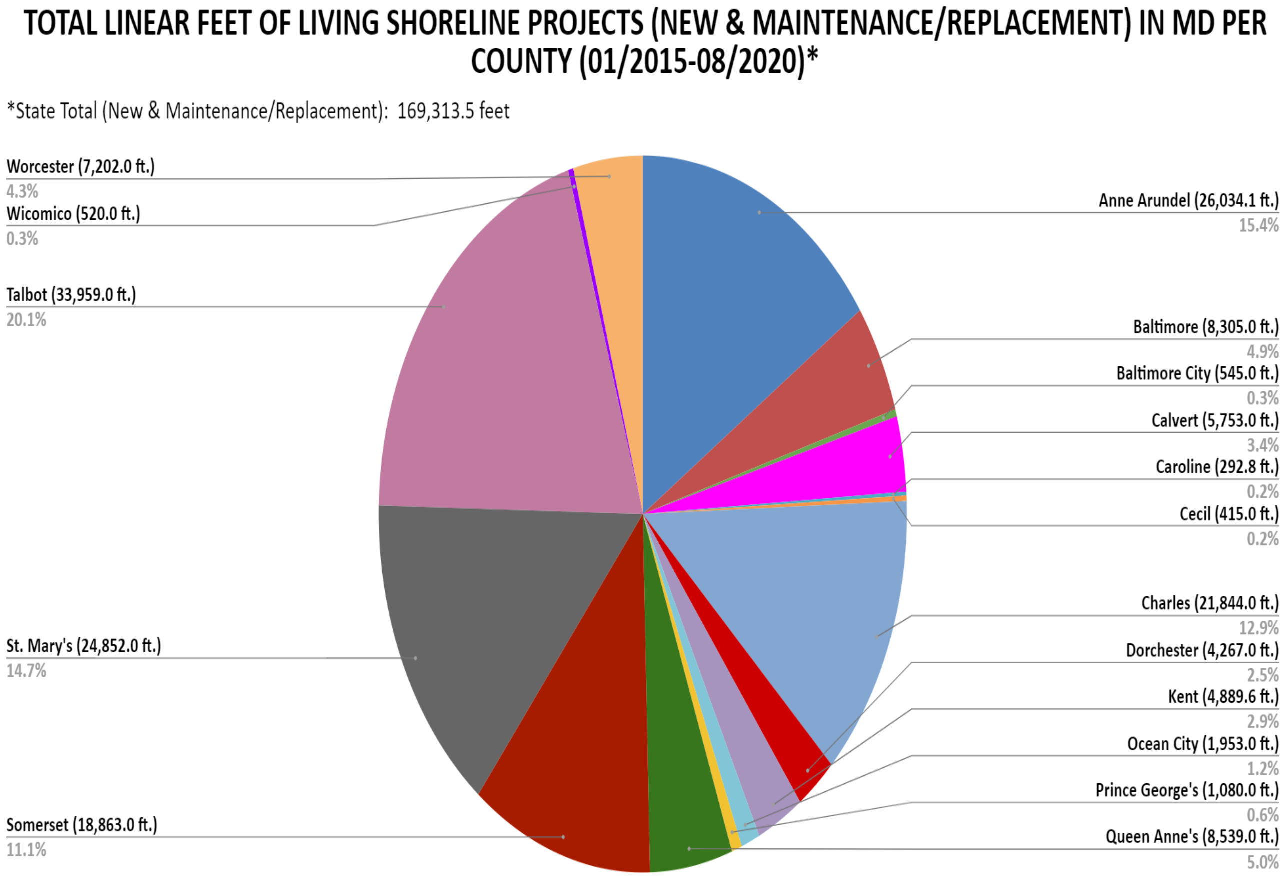

Figure 13. Total linear feet of all LS projects (169,313.5 ft.) with percentages, including new and maintenance/replacement activities, in Maryland Counties on the Chesapeake Bay from January 2015 to August 2020 (n = 439).

The annual averages of linear feet among the Maryland Counties were then determined (Fig. 14). These averages were calculated by dividing the amounts of each new and maintenance/replacement activities by 5.67 years. Significant difference was found between the linear feet averages of the Maryland counties. The significant difference occurred at: Anne Arundel, Queen Anne's, Somerset, St. Mary's, and Talbot Counties. The vast majority of the Maryland counties had a greater annual average for structural controls that included new and maintenance/replacement activities than all LS projects. The one notable exception was Somerset County, which had a larger LS projects annual average.

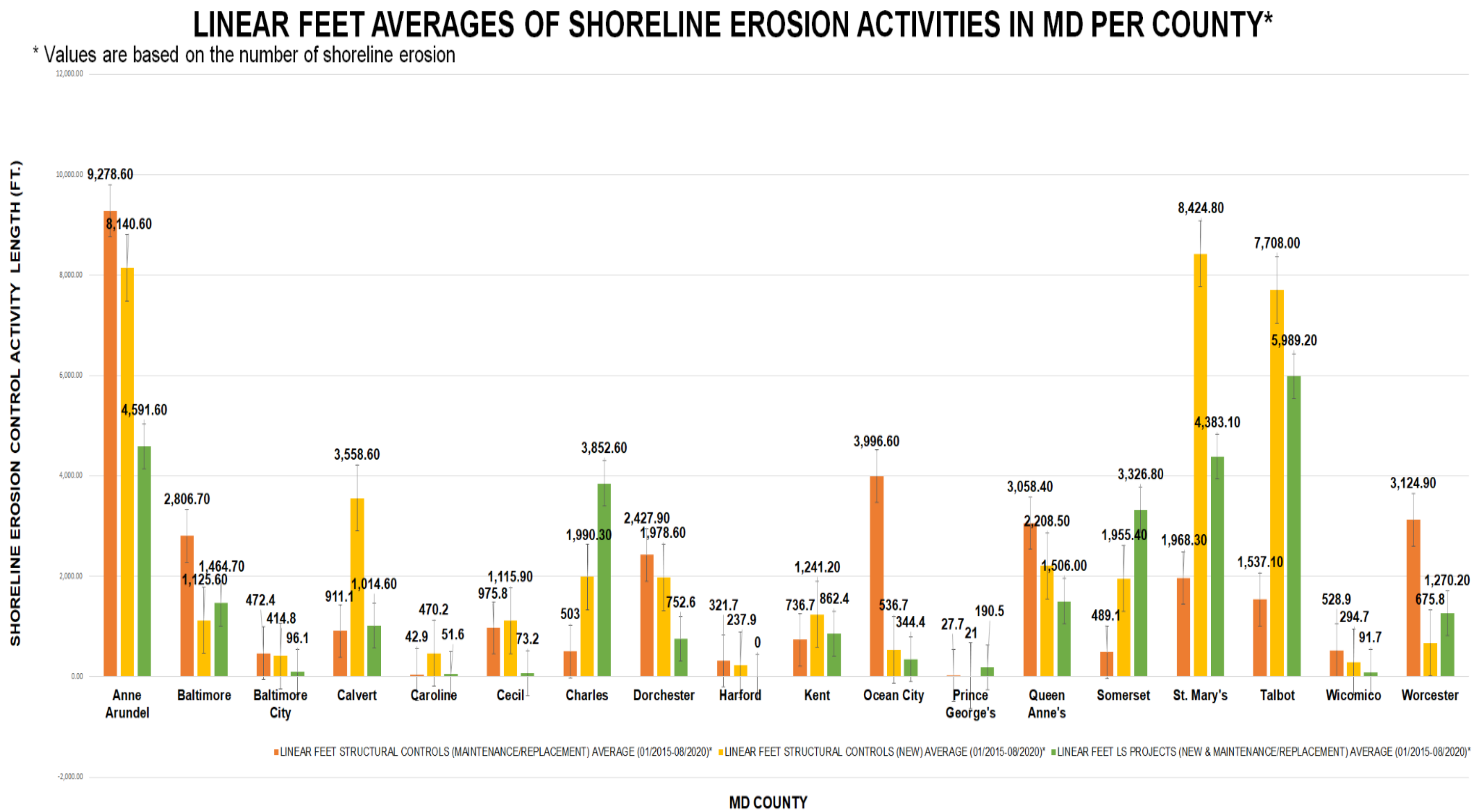

Figure 14. The averages of LS projects and structural controls (±SE), in linear feet, in Maryland counties on the Chesapeake Bay from January 2015 to August 2020 (n = 3,009, Tukey Post-hoc: $P<0.05$).

The final major assessment compared the total number of structural controls and LS projects per year from January 2015 to December 2019, to determine their trends among the Maryland counties. January 2020 to August 2020 was not included in assessing the annual trends due to not being a full year. The annual trends for structural controls that included both new and maintenance/replacement activities were assessed first (Fig. 15). Calvert, Queen Anne's, and Worcester Counties fluctuated the most between January 2015 to December 2019. On the other hand, counties such as Baltimore City and Harford had low, constant annual trends. The major outlier among these trends was Anne Arundel, which had a vastly greater amount of structural controls (new and maintenance/replacement activities) and remained steady from 2017 to 2019.

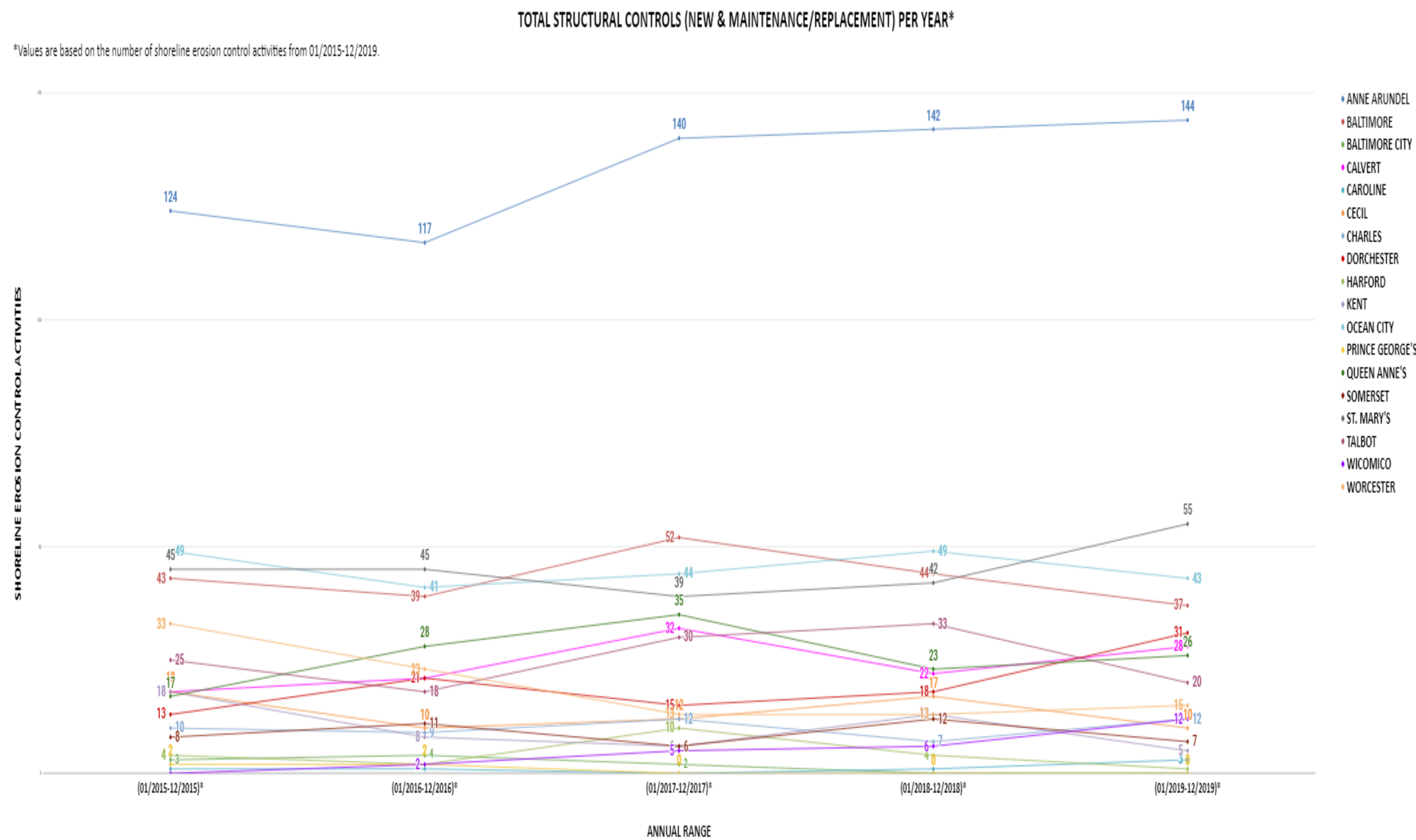

Figure 15. The total number of structural controls per year, including all new and maintenance/replacement activities, in Maryland counties on the Chesapeake Bay from January 2015 to August 2020 (n = 2,470).

All LS projects were the next category to be analyzed for annual trends (Fig. 16). Compared to the structural controls that looked at new and maintenance/replacement work, the LS projects annual trends among the Maryland Counties had more variation. In the annual trends, the greatest variation was from Anne Arundel, St. Mary's, and Talbot Counties due to a majority of the total LS projects coming from these counties. Additionally, most of the Maryland counties had a decrease in the number of LS projects from the 01/2019-12/2019 time range.

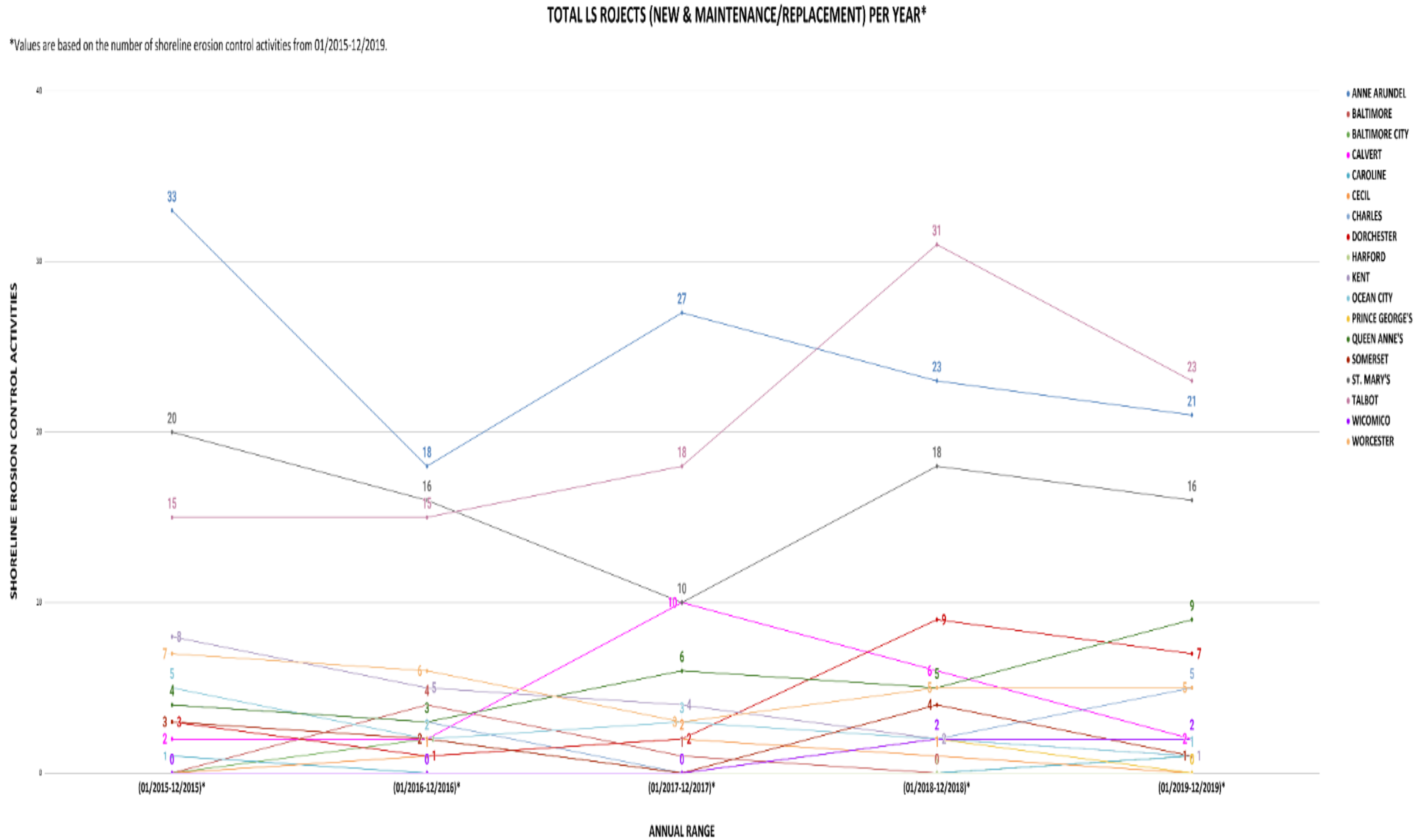

Figure 16. The total number of LS projects per year, including all new and maintenance/replacement, in Maryland counties on the Chesapeake Bay from January 2015 to August 2020 (n = 539).

Discussion

This report aimed to provide statistical analyses of the historical LS projects and structural control data within the MDE ETS database from January 2015 to August 2020. When comparing LS projects to new structural controls, the overall new structural controls total was over twice the total of LS projects in the State of Maryland. The percentages and annual averages of new structural controls were also greater than LS projects on a State level. When evaluating new structural control activities on a county level, most MD counties had new structural control totals and annual averages greater than LS projects, the two exceptions being Talbot and Worcester Counties. Furthermore, aside from St. Mary’s and Talbot, the majority of the Counties when looking at new and maintenance/replacement activities associated with structural controls had roughly equivalent percentages between structural controls and LS projects. Additionally, in terms of marsh establishment acreage among the LS projects, the top five counties with the greatest totals, annual averages, and percentages were Anne Arundel, Baltimore, Charles, Somerset, and St. Mary’s.

In regards to linear feet total, annual average, and percentage, new structural controls were generally significantly greater than LS projects. The few exceptions where LS projects had greater linear feet annual averages were Baltimore, Charles, Somerset, and Talbot Counties. Plus, the only cases where the linear feet percentage of LS projects were greater than structural controls were Charles, Somerset, Queen Anne’s and Talbot Counties. For the annual trends, the structural controls were more constant, while there was a lot of variation among the LS projects. By the January 2019 to December 2019 range, structural controls began to slightly increase, while LS projects trends remained constant.

Based on the results, the five main counties where LS projects are most likely to be waived in favor of structural controls are: Baltimore, Baltimore City, Cecil, Harford, and Ocean City. The activity rates of structural controls that include both new and maintenance/replacement are greater than LS projects (new and maintenance/replacement).While MDE has attempted to promote LS projects over structural controls to prevent excessive shoreline erosion, property owners continue to prefer structural measures if they qualify for a LS project waiver. This preference can be due to the perception of seeing LS projects as inferior to armored structural controls when protecting shoreline from excessive erosion and storm energy (Bilkovic et al. 2016). Since the implementation of LS projects is still an evolving science, a few failures can increase skepticism among shoreline property owners to adopt LS projects (Smith 2006). However, the Gittman et al. 2014 study conducted in North Carolina has shown that LS projects have protected coastlines more effectively than bulkheads during a hurricane. Therefore, to increase acceptance of LS projects, there should be an emphasis on site specific approaches that incorporate both the considerations of property owners and the natural area (Smith 2006, Bilkovic et al. 2016).

Moreover, LS projects and other green infrastructure can be less expensive than structural measures in the long-term, especially when it comes to maintenance. As seen in the MDE ETS database, only five maintenance/replacement activities were associated with LS projects from January 2015 to August 2020, whereas there were a total 1,323 maintenance/replacement activities for structural controls. The benefits of LS projects are many, including improved air quality, carbon mitigation, clean water, and of course, fish and wildlife protection. Additionally, 347 out of the 539 LS projects from January 2015 to August 2020 are in Anne Arundel, Talbot, and St. Mary's Counties. Another key parameter to take into account when promoting more LS projects throughout Maryland's counties are economic restrictions. In 2018, many Maryland Counties on the Eastern Shore had the lowest GDP totals of the State (MDC 2020). Although LS projects can have equivalent installation costs to armored structural controls, lower replacement costs and frequencies have been associated with LS projects compared to structural controls such as bulkheads (Gittman et al. 2014, Bilkovic et al. 2016). This was seen when comparing the total of maintenance/replacement activities between LS projects and structural controls in the MDE ETS database. Thus, in order to promote more LS projects throughout Maryland counties, it is crucial to highlight the potential long-term economic benefits along with ecological benefits (eg. resiliency and effectiveness). For this to occur, there must be further public education and regulatory reform on a county and State level.

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