Seaside to Statewide

The Economic Contributions of Delaware's Coastal Region

James Rising & Caitlin Wilson

School of Marine Science & Policy
University of Delaware
November 2024

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About the Authors

Dr. James Rising is an Associate Professor of Marine Policy at the University of Delaware. Dr. Rising studies the economics of the environment, with an emphasis on risks from climate change and opportunities for better policy in the food system. He has contributed to US climate policy, led reports on Net-Zero economics, climate justice, and the future of coffee, and organized international meetings to improve collaboration in climate research. Before joining the University of Delaware, he held positions at the London School of Economics, University of Chicago, and University of California, Berkeley.

Ms. Wilson is a PhD student in Marine Policy at the University of Delaware. Originally from Lancaster County, PA, she received a Bachelor's Degree in Biology from Elizabethtown College and a Master's Degree in Wildlife and Fisheries from West Virginia University. Caitlin gained experience working on community-based conservation projects as a Peace Corps Volunteer in Ghana and as the Natural Resources Conservation Service Tribal Liaison for Pine Ridge, SD.

Acknowledgements

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[1] *OpenAI. (2023). ChatGPT (Mar 14 version) [Large language model]. https://chat.openai.com/chat*

[2] *Latham, W., & Lewis, K. (2012). The contribution of the coastal economy to the state of Delaware. https://nsgl.gso.uri.edu/delu/delugl2001.pdf*

[3] *Hauser, C. A., & Bason, C. W. (2022). The Economic Value of the Delaware Inland Bays. https://www.inlandbays.org/wp-content/uploads/Economic-Valuation-of-the-Inland-Bays-FINAL-HIGH-REZ-080222.pdf*

Executive Summary

This report provides an updated evaluation of the economic significance of Delaware's coastal economy, indicating significant growth and development since the previous 2012 study. The coastal economy, featuring diverse sectors like tourism, real estate, fishing, agriculture, and emerging sectors such as renewable energy, is a crucial pillar of the state's prosperity. It influences both shoreline and inland businesses, with direct and indirect economic contributions.

The coastal economy contributes significantly to employment, personal income, value added, and industrial output, with growth outpacing both the US and Delaware's overall economies. As of 2022, the direct contribution of Delaware's coastal activities resulted in 74,030 jobs, $4.1 billion in labor income, $7.6 billion in value added and $14.2 billion in industrial output. When indirect and induced activities are considered, coastal activities support a total of 104,540 jobs, generate $6.5 billion in labor income, contribute $10.4 billion in value added to the economy, and add $22.5 billion to the total industrial output.

In terms of taxes, coastal activities generate significant revenue at local, state, and federal levels. The total tax revenue generated by economic activity in the coastal region amounts to over $3.3 billion, with approximately $210 million going to local governments, $820 million going to the state government, and $2.3 billion to the federal government.

However, Delaware's coastal economy also faces significant threats from climate change and sea-level rise, increased storms and flooding, and shifting tourism patterns. Hence, investments in climate resilience are critical to protect these coastal communities and their contributions to the economy. Strategies not only involve hard and soft projects, including infrastructure modifications and maintaining healthy ecosystems, but also emergency

preparedness actions. Additionally, resilient land use practices and modern building codes and hybrid projects combining different approaches can further enhance resilience.

Recognizing the dynamic nature of the coastal economy, this report examined some of the perspectives of local businesses and officials on the long-term resilience of their coastal communities. The individuals shared a common concern about flooding and sea-level rise eventually disincentivizing people from living or working at the coast. They were largely supportive of hazard mitigation efforts but foresaw challenges in implementing those efforts and desired approaches that are locally specific.

In conclusion, Delaware's coastal economy is a robust economic engine that has shown remarkable growth over the last decade. Ensuring its continued success will require careful management, a clear understanding of risks and opportunities, and a proactive commitment to investing in resilience.

Key Findings

As of 2022, the direct contribution of Delaware's coastal activities were:

- **74,030** jobs
- **$4.1 billion** labor income
- **$7.6 billion** value added
- **$14.2 billion** industrial output

When indirect and induced activities are considered, coastal activities support:

- **104,540** jobs
- **$6.5 billion** labor income
- **$10.4 billion** value added
- **$22.5 billion** industrial output

$3.3 billion in local, state, and federal taxes generated.

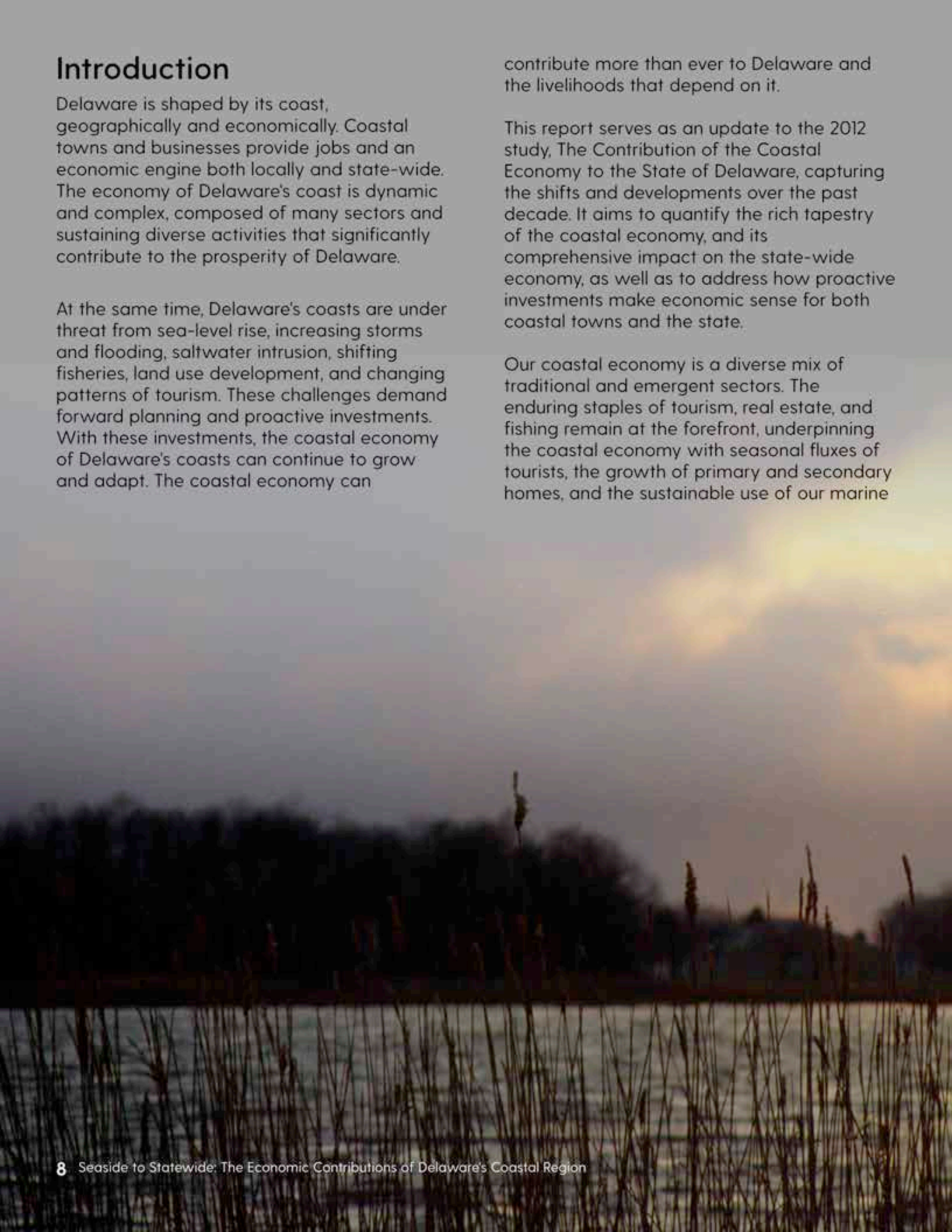
Introduction

Delaware is shaped by its coast, geographically and economically. Coastal towns and businesses provide jobs and an economic engine both locally and state-wide. The economy of Delaware's coast is dynamic and complex, composed of many sectors and sustaining diverse activities that significantly contribute to the prosperity of Delaware.

At the same time, Delaware's coasts are under threat from sea-level rise, increasing storms and flooding, saltwater intrusion, shifting fisheries, land use development, and changing patterns of tourism. These challenges demand forward planning and proactive investments. With these investments, the coastal economy of Delaware's coasts can continue to grow and adapt. The coastal economy can contribute more than ever to Delaware and the livelihoods that depend on it.

This report serves as an update to the 2012 study, The Contribution of the Coastal Economy to the State of Delaware, capturing the shifts and developments over the past decade. It aims to quantify the rich tapestry of the coastal economy, and its comprehensive impact on the state-wide economy, as well as to address how proactive investments make economic sense for both coastal towns and the state.

Our coastal economy is a diverse mix of traditional and emergent sectors. The enduring staples of tourism, real estate, and fishing remain at the forefront, underpinning the coastal economy with seasonal fluxes of tourists, the growth of primary and secondary homes, and the sustainable use of our marine



resources. Agriculture, though facing challenges, still significantly feeds into the coastal economy.

The past decade has also seen noteworthy changes, with new sectors taking root and existing sectors evolving. Renewable energy, particularly offshore wind energy, has started to make waves in the economic landscape, demonstrating the potential of Delaware's coastline as a source of sustainable power. The real estate market has seen substantial development, buoyed by the rising demand for vacation and retirement properties. Climate change has emerged as a significant factor, prompting investments in climate resilience to safeguard our coastal communities and economy.

As we endeavor to capture the breadth and depth of Delaware's coastal economy, we acknowledge the challenge of defining the geographical confines of "the coast". However, we employ a broad perspective, recognizing that the influence of the coast extends well beyond the shoreline, impacting inland businesses and industries, both directly and indirectly.

In this report, we use a sophisticated economic model to capture all direct and indirect contributions of coast-related activities, mirroring the complexity of our subject. Importantly, we will put these numbers into the context of a changing economy and environment and look at how these changes offer risks and opportunities to Delaware communities. We hope that our analysis inspires dialogue and informs decision-making about this vital part of Delaware's economy.

Methodology

Study Area and Industry Definitions

Our geographical scope draws upon the framework laid out by Latham & Lewis in their 2012 report. They defined the coastal economy as the economic activities occurring either along or near the coast, limited to specific postal zip codes (see Appendix for details). While the entirety of Delaware is heavily integrated economically, we adopt similar geographic constraints to avoid overstatement of coastal economic activity. Therefore, the study region is limited to economic activities that occur in close proximity to the coast or in areas and sectors that strongly support these activities.

This report's study region comprises three zones in particular (see Figure 1). First, there economy. While these inland areas engage in diverse economic activities, such as agriculture, our analysis is restricted to coast-related activities within these inland regions. This choice aligns with the migration of the coastal economy inland, as influenced by constraints on coastal real estate, with less expensive real estate further inland, and ongoing population growth. For precise geographic details, please refer to the Appendix.

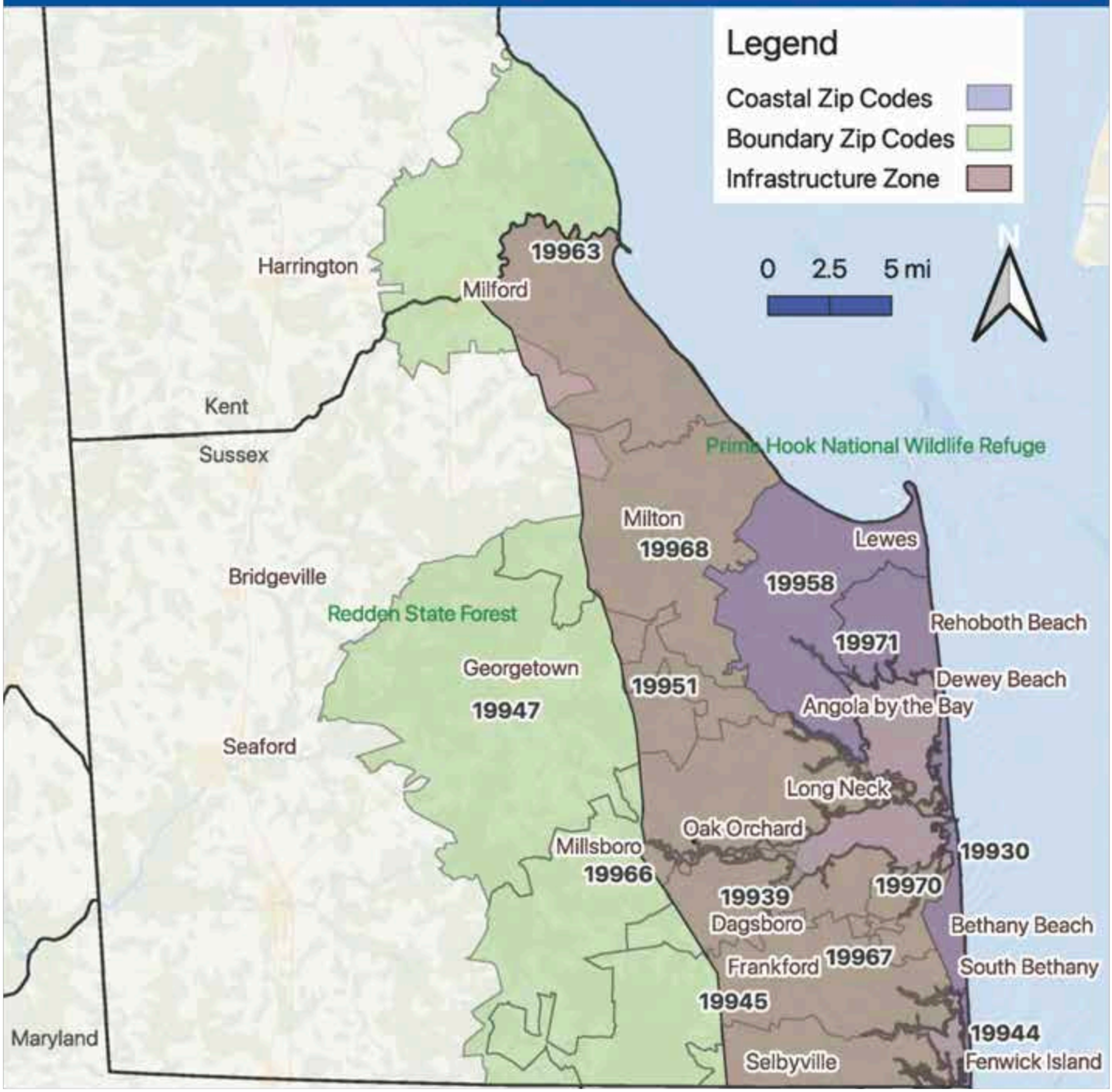
Similar to the approach adopted by Hauser & Bason in their 2022 study, we considered an array of industries within these regions. For the infrastructure zone (including the coastal zip codes), we include all industries. The inland areas, on the other hand, present a more nuanced scenario. Here, only a subset of industries is deemed coast-related, as informed by the approach in the 2012 report by Latham & Lewis. We borrow from their reliance on lists from the Bureau of Labor Statistics (BLS) and academic work, selecting industries that have a clear connection to coast-related activities. This includes sectors like vegetable and melon farming, commercial fishing, construction and maintenance, electric power generation and distribution, among others. Only about 7% of the economy of the inland regions is included as part of the coastal economy. The specific list of these industries is available in the Appendix.

Moreover, this report provides a more detailed

This approach maintains the integrity of the data and ensures a more realistic representation of Delaware's coast-related economy, aiding in the accurate estimation of its economic contribution to the state as a whole.

The methodology in this report complements the study region and industry definitions used in Hauser & Bason (2022), focusing on the Inland Bays. Their delineation of the study area encompasses the coastal zip codes used here, while purposely excluding ocean-related activity

Figure 1: Regional coverage of the coastal economy analysis, covering the coastal infrastructure zone of Delaware's Sussex County. The zip codes colored in blue (4 zip codes) are fully included, and only the coastal-related sectors in the zip codes in green (11 zip codes) are included.



Measuring the Coastal Contribution

Our study of the coastal economy encompasses a broad understanding of economic contributions, including direct, indirect, and induced effects (shown in fig. 2).

Direct effects pertain to the jobs, payroll, value added, and revenues originating explicitly from coastal activities. These are the employees and sales of the coastal industries themselves. Coastal businesses, services, and associated operations form the core contribution of the coastal economy.

However, the economic contribution of the coastal region extends beyond these direct effects. We calculate indirect effects, which capture the economic activity stimulated when coastal businesses procure goods and services from an array of supporting industries. These span numerous sectors such as equipment suppliers, construction, transportation, management services, and food services. Activity within the immediate suppliers drives further economic activity, and the total effect is the indirect contribution.

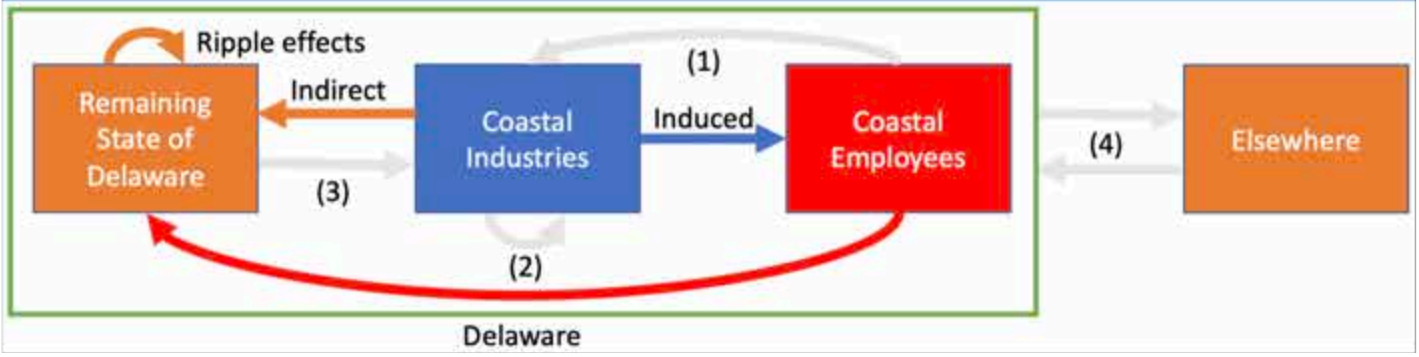
Induced effects reflect the economic ripple effect resulting from employees of direct or indirect businesses spending their earnings on consumer goods, property, services, and taxes. This downstream spending contributes to job creation, payroll increase, and expanded production, reinforcing the economic cycle.

To illustrate, let's consider the case of a beachfront hotel in a coastal town.

Direct impacts arise from the operations of the beachfront hotel itself. The hotel provides employment to local residents in a variety of roles such as management, housekeeping, food and beverage services, maintenance, and more. This directly infuses money into the local economy via the wages paid to these employees. Furthermore, it generates revenues from guests who pay for rooms, dining, and other amenities, and pays local taxes contributing to municipal budgets.

Indirect impacts stem from the hotel's need to source goods and services to support its operation. This includes food and beverage suppliers for the hotel's restaurant, maintenance services for facility upkeep, marketing agencies for advertising, and linen services for room cleaning, among others. Each of these supplier businesses also provides jobs and contributes to the economy,

Figure 2: *Economic flows that produce the total economic contribution of the coastal economy. Arrows show the direction of money flows (products flow the opposite way). The coastal economy (center) buys from suppliers (orange flow), which produces indirect benefits. It also pays its employees (blue flow), who then spend money (red flow) producing induced benefits. Further benefits ripple out from these indirect and induced flows. Several flows are intentionally excluded (grey flows): (1) personal purchases made within coastal areas and (2) supply chain effects within coastal areas are excluded to avoid double-counting; (3) flows of products to the rest of Delaware are already counted in the industrial output or value added; (4) interactions outside of the State of Delaware are not included in the analysis.*



forming an intricate network of interdependent businesses.induced impacts are created when the employees of the hotel and the businesses indirectly supported by the hotel spend their earnings in the local economy and beyond. They might spend on housing, groceries, entertainment, clothing, and other goods and services. Each of these purchases supports other local businesses and their employees, further broadening the ripple effect.

The full benefit of a dollar spent is captured by a “multiplier effect”. For example, a multiplier effect of 1.2 means that each additional dollar spent causes the economy to grow by an extra 20%. As an example of the multiplier effect, let's say a guest at the hotel spends money on a guided tour of local attractions. This payment directly supports the tour company (direct impact). The tour company, in turn, spends money to maintain its vehicles and pay its staff (indirect impact). Then, an employee of the tour company might spend their paycheck at a local grocery store, which supports jobs and incomes there (induced impact).

In essence, the original expenditure by the hotel guest triggers a cycle of spending and re-spending in the local economy and beyond, amplifying each industry’s economic impact. The multiplier effect captures this total economic impact, which can be significant, particularly in regions heavily reliant on coastal tourism.

In this report, we make a distinction between the total value of output and the “value added” by the coastal economy. Total production output is the total of all revenues while value added is revenues minus supply costs. For example, the restaurant industry buys produce and prepares it as menu items. The cost of the produce is included in the price of the final meals, but only part of the

final price is value produced by the restaurant industry because the produce was initially supplied by the agriculture industry. At a regional level, the value added is captured by the GDP of a region, which excludes the money spent on regional imports.

The total output across all industries effectively double counts the value of goods that are bought by other businesses. For example, the value of produce is included in the output of both the agricultural sector and the restaurant sector. For some audiences, the value added may be a more appropriate representation of the contribution of the coastal economy.

When calculating the total contribution of an industry or a region, we also need to be careful about double-counting the portion of indirect and induced effects which already show up in the direct output and value added. Part of the flow of indirect and induced value exits the study area/sectors, and part is included in it. Since our analysis includes all sectors in coastal zip codes, the portion of indirect and induced activity that stays in the coastal zip codes is already represented by the reported direct output or GDP of the region. Economic multipliers represent the full contribution of an additional dollar but are less appropriate when considering dollars that are already being spent. About 1/2 - 2/3 of the economic ripple effect stays within the coasts, so it's already included in the recorded values for the coastal industries.

In this report, we therefore distinguish between a growth multiplier effect and the contribution analysis. The traditional multiplier effect is appropriate when considering further investment in a region, and we report it for this reason. Also, the total contribution is not equal to the recorded economic activity times the multiplier effect, because of this double counting of local activity.

Finally, we do not account for activity outside the State of Delaware. There are both indirect and induced activities which occur in other states but are excluded from our analysis. Furthermore, many of the visitors to Delaware's coasts are from other states and generate activity within the state as they drive to the beaches. This is not accounted for.

Across these considerations, the multi-layered economic contributions of the coastal economy can be appreciated. The direct, indirect, and induced impacts weave together to form a comprehensive economic landscape, each enhancing the coastal region's value and its relevance to Delaware's economy as a whole. This approach enables us to gauge the broad economic footprint of coast-related activities, crucial for informed decision-making and strategic planning.

Economic Modeling and Data

In our study, we adopted the IMPLAN[4] (IMpact analysis for PLANning) software developed by the Minnesota IMPLAN Group to compute the impacts of coastal economic activities. This sophisticated tool is specifically designed for capturing intricate connections within regional economies. Grounded in extensive U.S. government data sources, IMPLAN captures more than 400 detailed industry sectors as defined by established federal statistical bodies like the Department of Labor's Bureau of Labor Statistics and the Department of Commerce's Bureau of Economic Analysis.

One of IMPLAN's key strengths is its ability to account for incremental full-time-equivalent employees across firms resulting from direct, indirect, and induced effects. Furthermore, it tracks all "labor income" paid to employees along with the taxes and fees paid to government entities at state, local, and federal levels.

For this study, we utilized a Multi-regional Input-Output (MRIO) analysis within the IMPLAN framework.[5] MRIO is a powerful analytical tool that helps in capturing both the within-region and beyond-region flows of economic activity. The relevance of MRIO comes from its capacity to model the inter-regional feedback loops, portraying a more holistic and nuanced picture of the economic contribution of coastal activities. We also apply a combination of traditional impact analysis and Industry Contribution Analysis[6] to estimate effects and multipliers.

A fundamental assumption of the Input-Output economic modeling approach is that effects of each dollar spent are the same. This effect is calibrated to reflect the benefits of each additional dollar spent, given the existing size and structure of the economy. However, we go beyond the state-of-the-art in economic modeling, by combining results from Latham & Lewis (2012) and the most recent year of data to represent the changing effect of a dollar spent as the economy grew. Effectively, we assume that each additional dollar has a different effect, smoothly varying from the multiplier effects reported in 2012 to the effects we see today.

Our primary data source reflects the Delaware economy in 2022, the most recent year available within IMPLAN. All values are reported in real 2022 dollars.

[4] IMPLAN® model, 2022 Data, using inputs provided by the user and IMPLAN Group LLC, IMPLAN System (data and software), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078 www.IMPLAN.com

[5] Clouse, Candi. "MRIO: Introduction to Multi-Regional Input-Output Analysis." IMPLAN Support Site, IMPLAN Group, LLC, 3 June 2021, Support.IMPLAN.com/hc/en-us/articles/115009713448-MRIO-Introduction-to-Multi-Regional-Input-Output-Analysis.

[6] Miller, R.E. and P.D. Blair. (2009). Input-Output Analysis: Foundations and Extensions, Second Edition. New York: Cambridge University Press.

Interview Methodology

We also collect qualitative data from individuals directly impacted by environmental risks to deepen our understanding of socioeconomic factors that influence vulnerability in our population. To provide additional context and details to the economic analysis, 11 semi-structured interviews were conducted. Two initial interviews were held by phone to identify relevant topics for further interviews. The bulk of the interviews were conducted over Zoom with nine individuals on the topic of coastal resilience to storms and climate change. The people invited to interview ranged from mayors to town councils, to businesses, to utility companies. Interviewees had to conduct relevant work within the study area to be considered eligible. Of the people who participated two were business owners/ managers, one was a deputy mayor, two were mayors, one was a contractor, two worked for utility companies, and one was a town planner. Within the study area, two participants were from Bethany Beach, four from Lewes, one from South Bethany, one from Fenwick, and one worked throughout the area.

The interview included questions on current impacts due to coastal flooding and sea-level rise, observed changes over time, adaptation methods, and planning efforts for the future. Transcripts and notes from the interviews were analyzed to identify common elements in participants' responses to interview questions.[7]

[7] *Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101.*

The Coastal Economy

Features of the Coastal Economy

The coastal economy of Delaware is a multi-faceted and vibrant component of the state's economic landscape. It is also complex, with a diverse range of industries that contribute to its success (see figure 3 and table 1). Some of the most important industries are:

Tourism and Recreation: Tourism remains an essential cornerstone of the coastal economy. In 2019 alone, Sussex County attracted 7.5 million visitors, contributing significantly to the local economy and making tourism the state's fourth-largest employer (Hauser & Bason 2022). Specifically, accommodation and food services account for about 15% of the employment in the region and generate 8% of total economy-wide revenues. Activities such as fishing, crabbing, boating, bird watching, and beach tourism are also crucial elements attracting visitors from the mid-Atlantic region and beyond.

Real estate: Residential development and real estate have seen a remarkable boom, fueled by retirees, the increasing possibility of remote work, and the coastal region's natural beauty, coupled with the state's favorable tax structures. Despite employing 9% of the total workforce, real estate activities generate an outsized contribution to the economy, producing 14% of total revenues. This reflects the rising property values and the ongoing residential development in the area.

Construction: As a result of a surge in residential development, construction is also a major player in the coastal economy, contributing 9% to employment and 8% to overall revenues. In 2022, construction on residential buildings amounted to about a third of the $1.1 billion spent on construction.

Finance: Despite accounting for only 7% of total employment, the finance sector plays a significant role in Delaware's coastal economy, contributing 10% of total revenues. This reflects the high-value nature of financial services, as well as the investment flowing into the region due to real estate development and other business activities.

Health Care: Parallel to the residential boom, the health care sector has seen substantial growth, accounting for 10% of total employment and 9% of total revenues. This sector plays an integral role in supporting the growing population, particularly the influx of retirees.

Retail: The retail sector, responsible for 11% of employment, contributes 7% to overall revenues, highlighting the role of consumer spending in the coastal economy. Retail services not only cater to the residents of the region but also the millions of tourists visiting each year.

Overall, these industries form the backbone of the Delaware coastal economy, generating jobs and income for a significant proportion of the state's residents and contributing substantially to local and state government tax revenues. The vibrancy and diversity of these sectors attest to the attractiveness of Delaware's coastal region, whether for recreation, retirement, or investment. However, as the coastal economy continues to evolve, careful consideration must be given to ensure that ongoing development is balanced with measures intended to protect and restore the invaluable natural resources of the region.

Figure 3: *Breakdown of the coastal economy by sector in 2022. Box sizes correspond to the number of people in each industry. Colors are a relative measure of the amount of revenue produced per person from red (low) to green (high).*

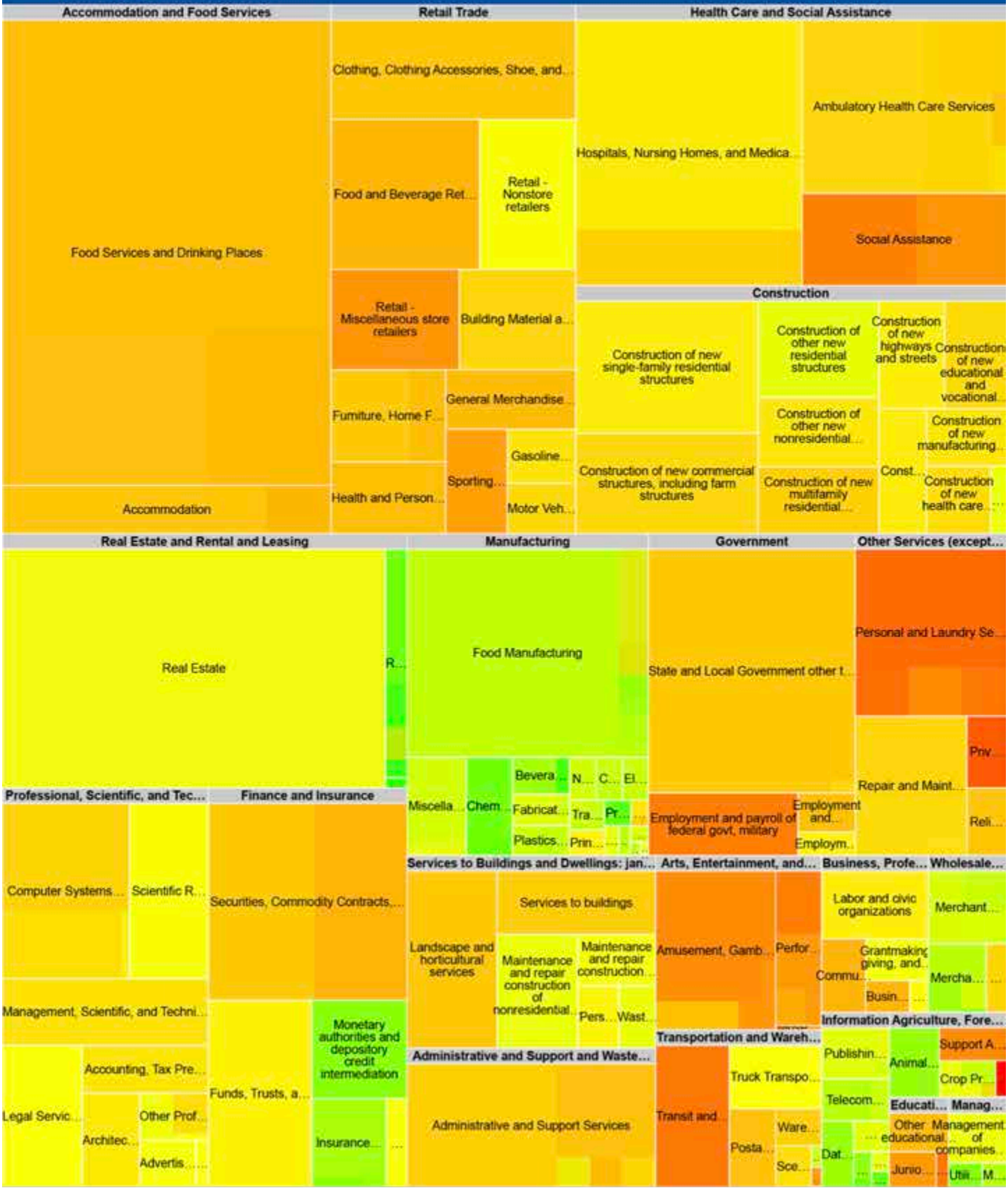


Table 1: Summary of major sectors in the coastal economy in 2022, by total employees, employee income, and production output (revenue) and percent of the whole economy. Only direct values are shown. Bolded entries are highlighted in the results section.

	Total			Percent of Region		
Sector	**Emp. Count**	**Total Income**	**Prod. Outpout**	**Emp. Count**	**Total Income**	**Prod. Outpout**
All	74029	$4,126M	$13,368M	100.00%	100.00%	100.00%
├ Accommodation and Food Services	10812	$382M	$1,049M	14.61%	9.26%	7.85%
| ├ Food Services and Drinking Places	9798	$341M	$941M	13.24%	8.26%	7.04%
| └ Accommodation	1015	$41M	$108M	1.37%	1.00%	0.81%
├ Administrative and Support, Waste and Remediation Services	2173	$109M	$226M	2.94%	2.65%	1.69%
| **├ Employment Placement Services & Temp. Workers**	1305	$53M	$138M	1.76%	1.29%	1.03%
| └ Administrative and Support Services Remaining	868	$56M	$88M	1.17%	1.36%	0.66%
├ Agriculture, Forestry, Fishing and Hunting	629	$60M	$345M	0.85%	1.46%	2.58%
├ Arts, Entertainment, and Recreation	1801	$43M	$91M	2.43%	1.04%	0.68%
├ Construction	6682	$515M	$1,110M	9.03%	12.49%	8.30%
├ Educational Services	340	$12M	$25M	0.46%	0.30%	0.19%
├ Finance and Insurance	4951	$140M	$1,327M	6.69%	3.40%	9.92%
├ Government	4162	$315M	$389M	5.62%	7.64%	2.91%
| **├ State and Local Government other than Education**	3304	$266M	$333M	4.46%	6.45%	2.49%
| └ Government Remaining	858	$49M	$56M	1.16%	1.19%	0.42%
├ Health Care and Social Assistance	7536	$658M	$1,162M	10.18%	15.95%	8.70%
| **├ Hospitals, Nursing Homes, and Medical Care Facilities**	3954	$402M	$775M	5.34%	9.75%	5.80%
| **├ Ambulatory Health Care Services**	2330	$216M	$327M	3.15%	5.22%	2.44%
| | **├ Offices of Physicians, Dentists, & other Practitioners**	2168	$204M	$307M	2.93%	4.95%	2.30%
| | **└ Ambulatory Health Care Services Remaining**	162	$11M	$19M	0.22%	0.28%	0.14%
| └ Health Care and Social Assistance Remaining	1252	$40M	$61M	1.69%	0.97%	0.45%
├ Information	737	$65M	$345M	1.00%	1.59%	2.58%
├ Management of Companies and Enterprises	243	$15M	$61M	0.33%	0.37%	0.46%
├ Manufacturing	4842	$339M	$2,260M	6.54%	8.21%	16.90%
├ Mining, Quarrying, and Oil and Gas Extraction	37	$4M	$18M	0.05%	0.11%	0.13%
├ Other Services (except Public Administration)	3045	$148M	$205M	4.11%	3.59%	1.54%
├ Professional, Scientific, and Technical Services	5130	$377M	$858M	6.93%	9.14%	6.42%
├ Real Estate and Rental and Leasing	6397	$261M	$1,836M	8.64%	6.32%	13.74%
| **├ Real Estate Rental and Management Establishments**	6046	$104M	$1,173M	8.17%	2.53%	8.78%
| **└ Real Estate and Rental and Leasing Remaining**	351	$156M	$663M	0.47%	3.79%	4.96%
├ Retail Trade	8040	$323M	$885M	10.86%	7.83%	6.62%
| **├ Retail Stores: Clothing and Clothing Accessories**	1553	$46M	$162M	2.10%	1.11%	1.21%
| **├ Retail Stores: Food and Beverage**	1413	$56M	$119M	1.91%	1.36%	0.89%
| **└ Retail Trade Remaining**	5074	$221M	$603M	6.85%	5.36%	4.51%
├ Transportation and Warehousing	1627	$82M	$173M	2.20%	1.98%	1.29%
├ Utilities	53	$7M	$69M	0.07%	0.18%	0.51%
├ Wholesale Trade	773	$65M	$291M	1.04%	1.58%	2.17%
├ Business, Professional, Social, and Homeowners Assn.	1038	$37M	$160M	1.40%	0.90%	1.20%
└ Services to Buildings and Dwellings: janitorial, pests, etc.	2980	$167M	$483M	4.03%	4.05%	3.62%

Growth and Changes in the Coastal Economy since 2011

Over the past decade, Delaware's coastal economy has witnessed substantial growth and transformation. Between 2011 and the present, the region has experienced dramatic increases in employment, industrial output, personal income, and value added. This growth is captured in Figure 4, which demonstrates the rapid expansion and resilience of the coastal economy.

A key driver of this growth has been the surge in residential development, primarily fueled by retirees relocating to the region and the rising acceptance of remote work. This trend, coupled with the region's natural beauty and favorable tax structure, has led to a boom in real estate.

The rise in population has, in turn, spurred growth in other sectors, notably construction, healthcare, and service industries. These sectors have expanded to cater to the growing and changing needs of the coastal population, contributing significantly to the

Figure 4: *Recorded and estimated direct values, as totals over the coastal economy from 2011 to 2022. The total number of employees, industrial output (revenue), employee income, and value added are shown. Values after 2018 are calculated based on coastal zip codes and coast-related sectors of the boundary zip codes; before 2018, reported values are modeled using Sussex County data and values from Latham & Lewis (2012).*

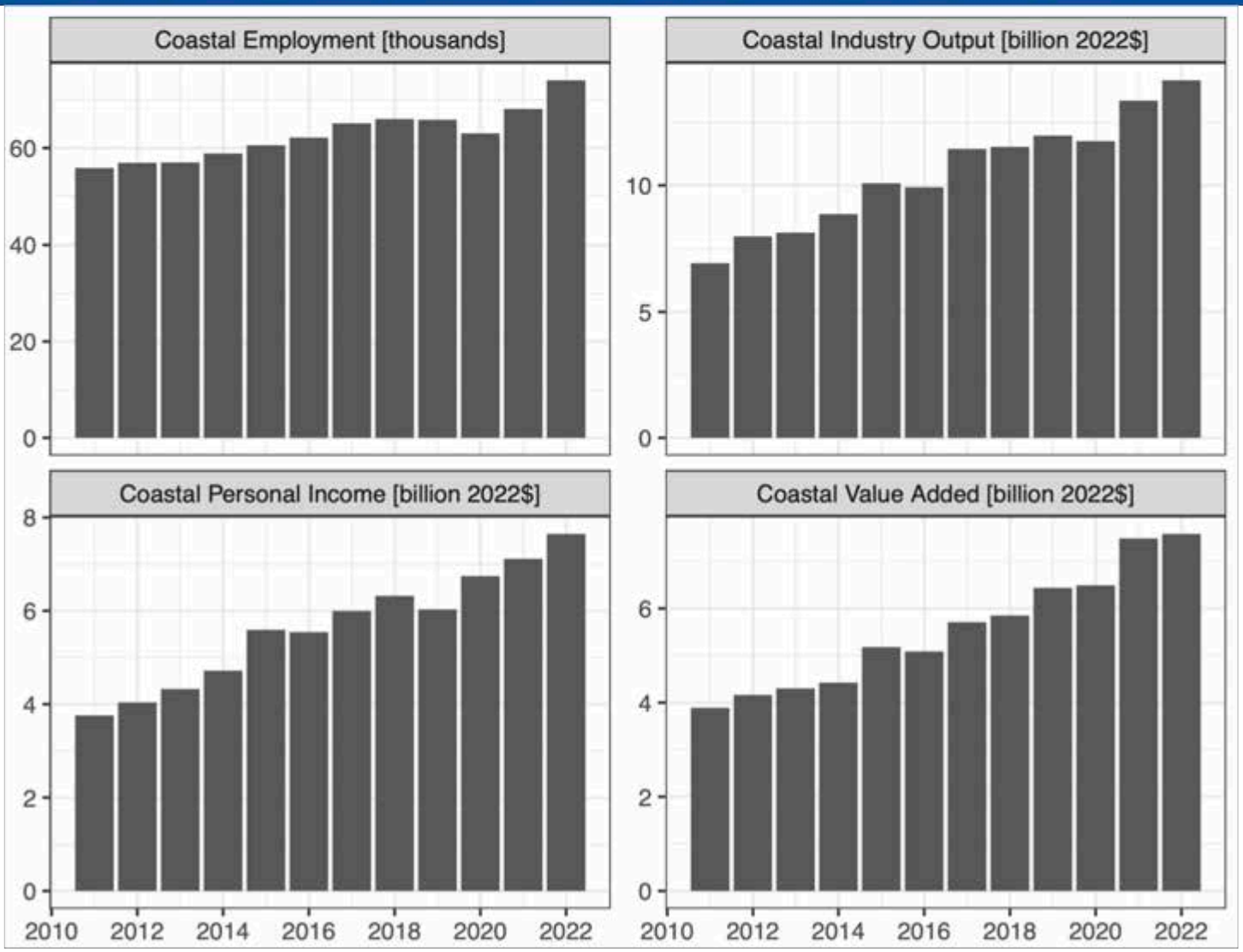


Table 2: Measures of the growth of the Delaware-wide economy and the coastal economy, from 2011 to 2022.

	Delaware-wide Economy			Coastal Economy		
	In 2011	In 2022	Growth	In 2011	In 2022	Growth
Value Added [billion 2022$]	75.59	90.37	20%	3.89	7.59	95%
Personal Income [billion 2022$]	51.68	61.80	20%	3.76	7.65	103%
Total Employment [thousands]	530.33	625.33	18%	55.86	74.03	33%
Industry Output [billion 2022$]	124.30	148.45	19%	6.94	14.17	104%

increased economic output of the region. The tourism industry, already a major part of the coastal economy in 2011, has also seen impressive growth (Delaware Tourism 2021[8]).

In terms of economic output, the coastal economy has seen an extraordinary surge. Comparatively, the growth of the coastal economy has outpaced both the US and the Delaware economies as a whole. The coastal economy has grown at five times the rate of the Delaware-wide economy since 2011. Over this period, while the US GDP has increased by 27% and Delaware's state-wide GDP has risen by 20%, the coastal economy's regional GDP—the total of the value added of coastal industries—has soared by an impressive 95%. This remarkable growth indicates the vitality and resilience of the coastal economy. This exceptional performance is detailed in Table 2.

However, this rapid growth is not without its challenges. The aging population in the region needs both healthcare services and resilient infrastructure, to ensure that it can access the services it needs. As the region continues to develop, careful planning and management are essential to ensure that the economic boom does not come at the expense of the area's invaluable natural resources nor the resilience of the region to extreme weather and climate change. Balancing this growth with local resilience strategies including the protection and restoration of these resources will be vital in ensuring the sustainable development of the region.

The resilience and dynamism displayed by the coastal economy over the past decade are clear indicators of its potential. With strategic planning and careful management, the Delaware coast could play a significantly more influential role in the state's economy.

In conclusion, the Delaware coastal economy has seen remarkable growth and diversification over the past decade, outpacing both the state and national economy. It continues to thrive, fueled by its natural resources, increasing residential development, and diverse service industries.

[8] *Delaware Tourism Office (2021). The Value of Tourism. https://www.visitdelaware.com/sites/default/files/2023-05/The%20Value%20of%20Tourism%202021%20FINAL.pdf*

Coastal Risks and Impacts Today

A White House Executive Order (EO 13563) defined coastal resiliency as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions" (Sutton-Grier et al. 2015[9]). While Delaware's

coastal region is fortunate to have an abundance of coastline and natural resources, these same features also expose the area to considerable impacts from storms and climate change, including flooding, sea-level rise, erosion, and wind. Delaware has the lowest mean land elevation of any state in the United States. The coastal region is particularly low and flat and also has a high water table, limiting the absorption of stormwater and excess inundation. Development patterns have further exacerbated this situation as properties have increased inside the floodplain near the water's edge. The encroachment of development inside the floodplain both

roadways, homes, and businesses. Nearly all participants identified some parts of their town that was affected by flooding on a regular basis. This flooding causes safety concerns for the towns and their residents. Several of the interview participants that held various town council positions voiced concerns about access for residents, especially to emergency services during floods. Whole neighborhoods are cut off when flooding occurs, which strands residents without any medical aid or ability to evacuate safely if necessary. As one mayor noted, many of the residents are elderly and it is a top priority to ensure that they are able to access necessary care during a flood. That participant stated, "We have one road, ... [and] there's standing water on that road too many times throughout the year; sunny day flooding, nuisance flooding, as well as storm related flooding and tidal flooding. And that is sort of priority number one, because we've had instances where emergency vehicles couldn't get through because of the flood water."

Additionally, infrastructure for the towns is at risk from flooding. The wastewater treatment plant in Lewes is one such example of that.

treatment system and outfall. As one participant, a member of the town council, described, hardening the treatment plant would cost the town between $20 and $40 million dollars, while relocating the plant could cost over $100 million dollars. In addition to Lewes, utility companies, such as Delmarva Power, are also adapting their systems to ensure that services are available during a flood event. For power companies, this has included ensuring redundancy and multiple pathways for electricity distribution to towns as well as raising transformers on platforms above base flood elevations.

Another impact, identified by several participants, is the potential for future losses due to a decrease in tourism. The business owners/managers that were interviewed have already experienced losses due to damaged inventory or being forced to close for periods of time for the safety of their employees and customers. However, these losses felt minimal compared to the potential

future losses, should tourists significantly reduce their visits to the Delaware beaches. This was also a concern for the towns, as tourism is a large source of revenue for the area. If the tourism industry slows there is significant concern about how towns will sustain their budgets and how people will continue to make a living. One town planner said "...we're a tourist town- we have all these beautiful beaches, but what happens if you can't get to the beach anymore?"

In addition to the loss of tourism, towns are concerned about losing current and potential future residents and businesses as the risk of flooding grows. There's a concern that those already in the area will decide that the flooding has become too much to deal with and will choose to leave. There is also a concern that potential future residents will be reluctant to invest their time and money in an area that floods regularly. One of the town council members in Lewes noted, "And at what point, though, do people say, you know what, the sea-level is rising, flooding is increasing; beach replenishment used to happen every 5 years, now it's happening every 2, 3 years. At what point do people say, 'Why invest in Lewes?'".

Planning for the Future

When thinking about the future of these coastal towns, plans are already being made to ensure that people can continue living on the coast. Many towns are introducing regulations around adapting homes, buildings, and other infrastructure to deal with flood waters. This includes requirements for newly built homes, or homes being significantly renovated, to be elevated one or more feet above base flood elevation in order to keep flood waters out of any living spaces. Towns are also changing regulations regarding impervious surfaces such as driveways or patios, to ensure that more areas are available for rainwater to infiltrate. Utility companies are installing sturdier, storm-resistant electrical poles and raising sensitive equipment out of reach of flood waters. The

majority of adaptation methods discussed by participants were hard or gray methods involving construction and physical changes to buildings and other infrastructure.

Other adaptation methods mentioned during the interviews included education and changes to policies or plans. Several of the towns had created resiliency or sea-level rise mitigation committees to explore policies, including updates to the Comprehensive Plans in order to ensure that resiliency and adaptation were more thoroughly considered.

Comprehensive Plans are developed through an intensive process to determine community development goals and priorities for the future. Many towns were also conducting studies to have the best available data or examine different resilience strategies for the future. Education was also discussed as important to any adaptation strategy. Ensuring that members of the community and government had the best available information helped people to understand the reasoning behind the chosen adaptation method, which increases community buy-in.

Barriers to Resilience

While various resilience strategies are being implemented by the towns, there are barriers that make it difficult to achieve long-term and large-scale adaptation. Funding was one of the most commonly mentioned barriers during interviews. Many of the smaller beach towns have little revenue and require outside grant funding to complete projects. However, grants can be competitive and require considerable effort for local governments to secure. One town council member in South Bethany said, “We're one little town and this is a problem that all the towns that back up to the bay are facing. And we don't have any jurisdiction over the water or anything, so, there's nothing we can do out there. We have to protect our own infrastructure, our system, and our roads. We can do that but there's only so much that we can do without help from partners with deeper pockets.”

Another barrier is the issue of scale. Several participants mentioned issues with jurisdiction and the geographic scale of projects their towns were working on. Local governments only have jurisdiction over municipal-owned infrastructure and projects within town boundaries and are focused on doing the best they can for their communities. Sea-level rise, however, is not a localized issue and a call for more regional partnerships and collaborative projects was raised several times during the interview process. A member of a utility company stated, “We know that there's a lot of coastal towns that are going through the same situation. So, you don't necessarily have to reinvent the wheel. But at the end of the day coastal communities should be having these discussions holistically. You know, community-to-community because what people are seeing in Charleston isn't necessarily much different than what they're seeing in Lewes or Bethany.”

In addition, the uncertainty that accompanies sea-level rise raised additional barriers for Delaware’s coastal communities. This

uncertainty was present in a couple of different ways during the interviews. There was uncertainty about how effective and accepted adaptation strategies such as higher home freeboard requirements were. Communities were concerned that it could affect the resale value of their homes. There is also uncertainty surrounding the actual impacts and timing of sea-level rise and coastal flooding. Participants noted increased frequency and intensity of flooding and storms but are uncertain what the next decades will actually bring. Even with some impacts being felt, sea-level rise is still an incremental and abstract problem for local communities and governments trying to deal with urgent and emergent issues that community members are facing today.

Increased Flooding Along the Coast

Business Perspective

Marian Parrott, the former owner of Sedona restaurant in Bethany Beach, DE, provided firsthand insights into the economic losses incurred due to frequent flooding. Located near the loop canal, Sedona was frequently impacted by coastal flooding which led to a loss of customers and spoilage of food. The restaurant, earning an average daily income of about $3,000, lost not only its daily revenue but also an estimated $500 to $1500 worth of food product during each flooding event. A notable incident occurred over one Columbus Day weekend when King Tide flooding resulted in an electrical outage, causing Marian a loss of around $10,000 in revenue and $5,000 worth of spoiled products. Flooding impacted Marian and her business 6-8 times per year.

Governmental Perspective

Jim Pappas, former DelDOT Director of Transportation, Resiliency, and Sustainability, highlighted the critical issues of increasing frequency and severity of flooding in Delaware. The division, created about 2 years ago, is currently focusing on addressing flooding issues with Route 1 (SR1), a crucial route for evacuations during emergencies. Flooding remains the most significant climate change impact within the state, causing major concerns in Sussex County and beaches frequented by tourists. The inundation of the primary and alternative evacuation routes (Routes 24 and 20) further complicates the situation, especially during emergencies. Barriers to mitigation efforts include challenges in community involvement, coordination of utilities, acquiring private property for right of way, and lengthy permitting processes.

Conclusion

The stories highlight the considerable economic and operational challenges faced by local businesses and governmental entities due to the increasing threat of coastal flooding in Delaware. They underline the need for effective mitigation strategies and long-term solutions to protect the valuable economic contribution of Delaware's coast and to ensure the safety and convenience of both residents and tourists.

Economic Contribution Results

The mix of current impacts, future needs, and barriers presented in the previous section highlights the need for a careful assessment of the economic contribution of the coastal economy. By understanding what is at risk, planners can identify appropriate responses.

Economy-wide contributions

The data presented in Table 3 illustrates the direct, indirect, and induced economic contributions of coastal activities.

Direct coastal activities alone contributed 74,030 jobs, $4.1 billion in labor income, $7.6 billion in value added, and $14.2 billion in industrial output. Following the inclusion of indirect and induced activities, the total economic contributions of coastal activities to the state are even more significant:

- 104,540 jobs supported
- $6.5 billion in labor income
- $10.4 billion in value added to the Delaware economy
- $22.5 billion of total industrial output

That means that for every 100 jobs in the coastal region, 41 additional jobs are supported throughout the state. This amounts to 30,500 additional jobs supported by coastal activities outside the coastal region.

Similarly, for every $100 of revenue generated in the coastal region, an extra $59 in revenue is earned throughout the state. This amounts to $8.3 million in revenue annually.

Further increases in the economy are estimated to produce a pronounced multiplicative effect of 20%. This effect is approximately the same whether the outcome is employees, income, value added, or revenues. Multipliers reflect the benefits of an additional dollar, including growth within the coastal economy, and so have benefits that are excluded from the reported indirect and induced contributions. For instance:

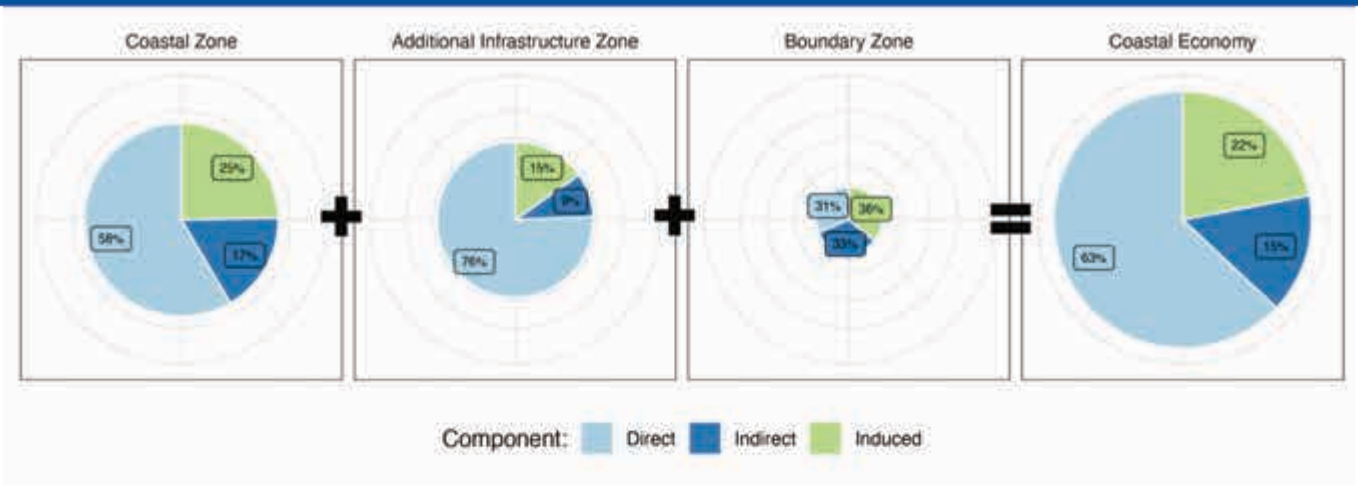
- Every 100 new coast-related jobs would be estimated to give rise to an additional 20 jobs across the state.
- For every $100 of additional revenues to coastal-related industries, an additional $20 is generated throughout the state.

It's worth noting that the majority of these economic contributions are driven by industries vital to supporting residents who live in proximity to the coast (e.g., infrastructure and services). These industries encompass residential and non-residential construction, grocery stores, healthcare services, and real estate. Figure 5 shows how these total contributions break down by the coastal region included in the analysis.

Table 3: The direct, indirect, and induced contributions of the coastal economy to Delaware, reported for jobs, total labor income, industrial output, and total value added.

	Jobs	Labor Income	Value Added	Revenue
Direct	74,030	$4,120,944,000	$7,585,971,000	$14,172,991,000
Indirect	11,670	$1,013,264,000	$1,141,419,000	$3,395,810,000
Induced	18,840	$1,327,718,000	$1,687,933,000	$4,946,334,000
Total	104,540	$6,461,926,000	$10,415,323,000	$22,515,135,000

Figure 5: *The breakdown of direct, indirect, and induced economic activity by the regional zone. The coastal zone (coastal zip codes), additional land inside of the infrastructure zone, and additional coast-related industries in zip codes overlapping the infrastructure zone combine to form the total coastal economy.*



Coast-related activities continue to play a significant role in Delaware's economy, not just in terms of the sizable economic output and labor income they generate, but also in their capacity to create jobs and stimulate additional economic activities statewide. The interplay of direct, indirect, and induced impacts magnifies the overall economic significance of these activities, underscoring the importance of Delaware's coastal region in the broader state economy.

Breakdown of Contributions by Specific Sectors

Table 4 shows the total contribution results for ten top industry sectors influenced by coastal-related activities, considering direct, indirect, and induced impacts. These sectors serve as indicators of the economic vitality of Delaware's coastal region.

Table 4: The total contributions of ten sectors of the coastal economy to Delaware, reported for jobs, total labor income, industrial output, and total value added. Multipliers reflect the benefits of an additional dollar, including growth within the coastal economy, and so have benefits that are excluded from the reported indirect and induced contributions.

	Jobs	Labor Income	Value Added	Revenue	Multi-pliers
Food Services and Drinking Place	14,740	$502,800,000	$736,630,000	$1,405,129,000	1.1
Real Estate Rental and Management	8,360	$150,796,000	$588,853,000	$1,596,934,000	1.2
Hospitals, nursing homes, and other medical care facilities	6,670	$650,973,000	$740,002,000	$1,269,966,000	1.1
State and Local Government other than Education	3,110	$262,887,000	$236,903,000	$275,966,000	1.0
Offices of physicians, dentists, and other healthcare practitioners	3,570	$332,124,000	$346,732,000	$513,351,000	1.1
Retail Stores- Food and Beverage	2,550	$96,661,000	$118,592,000	$208,614,000	1.1
Retail Stores- Clothing and Accessories	2,400	$71,199,000	$100,917,000	$255,077,000	1.2
Employment Services Including Temporary Workers	2,380	$95,797,000	$125,493,000	$231,342,000	1.1
Business, professional, labor, civic, social, and homeowners' organizations	2,410	$89,378,000	$177,315,000	$306,906,000	1.1
Services to buildings- including janitorial, pest control, landscaping, carpet and upholstery cleaning, pool maintenance, power washing, etc.	4,350	$217,547,000	$304,813,000	$619,560,000	1.2

As anticipated, the sector comprising restaurants, bars, and places offering food services (to consume on the premises or for takeout) is the most significant in terms of employment, providing 14,740 jobs. Retail stores, encompassing grocery stores and clothing and accessories shops, are also significant contributors to employment, cumulatively supporting 4,950 jobs.

Medical care facilities, including hospitals and nursing homes, stand as the leading sector concerning labor income, generating $650 million, attributable to the high wages in this field. This sector also ranks high in terms of employment, standing third. The offices of healthcare practitioners also make

considerable contributions to labor income and employment, reinforcing the significance of healthcare in Delaware's coastal communities and its ever-increasing importance in the national economy.

Real estate rental and management is the top contributor regarding revenues, adding $1.6 billion to the state's economy. The high level of direct activity in this sector also makes it the second-largest contributor to employment.

Real estate, clothing and accessories stores, and building services provide the highest production multipliers, all around 1.2. This reveals their greater propensity to purchase inputs from other sectors, thereby stimulating additional economic activity.

The "value added" figures in Table 4 reflect the net economic value each sector contributes to the economy. It is calculated by subtracting the cost of inputs from the total value of output, and avoids double counting the value of inputs. The value added is roughly half of the revenue for each sector, although some sectors have particularly large value added amounts. Almost all of the revenue attributed to state and local government is value added (86%), and offices of healthcare practitioners also produce high value added (68%).

The multiplier effect illuminates how an additional dollar spent in each sector resonates throughout the economy, generating indirect and induced impacts. Although the multipliers in Table 4 aren't equivalent to those for the total economic contributions of the current economy, they are still useful for capturing the ripple effect of additional investment within these sectors.

In conclusion, sectors such as tourism, real estate, and healthcare play pivotal roles in Delaware's coastal economy. Their direct, indirect, and induced contributions not only generate considerable value but also stimulate further economic activities, reinforcing the significance of these sectors in the overall coastal economy.

Tax Implications of Coastal Activities

Activities within the coastal region significantly contribute to tax revenue for local, state, and federal governments. This is apparent in the wide array of tax and fee revenue sources, such as business levies, personal income tax, property taxes, and real estate transfer taxes. Notably, the comprehensive economic impact of the coastal region on Delaware's fiscal landscape extends beyond direct tax generation, by also stimulating indirect and induced tax revenues.

Taxes are closely related to both the economic prosperity of the coastal region and its contribution to the rest of the state. For example, a strong tourism sector supports activity across a wide range of firms, which then produce taxes. Several beach towns also generate a substantial portion of their budget revenue from parking fees, forming a more direct connection to the tourism economy.

According to Table 5, the total tax revenue generated by the coastal region amounts to over $3.3 billion. Of this total, approximately $1.0 billion is accrued to state and local governments while the federal government receives around $2.3 billion.

Table 5: Contributions of the coastal economy to tax revenues, accounting for indirect and induced effects, broken down by tax authority. The first several rows show reported taxes, split by source. These are only available at the county level. These values are then repeated in the lower rows, which show modeling analysis of how they are divided by authority and their ripple effects. Ripple effects accruing to local government are not included, due to double counting.

	Municipal	Special Districts	County	State	Federal	All State + Local	Total
Dividends to Government					$30,874,988	$4,587,374	$35,462,362
Corporate Profits Tax					$149,600,530	$48,654,421	$198,254,951
Personal Tax: Income Tax					$938,026,990	$335,199,661	$1,273,227,645
Personal Tax: Fines, Fees					$7,184,996	$27,691,384	$34,876,380
Personal Tax: Other Taxes					$0	$8,683,280	$8,683,280
Social Insurance Tax: Employee Contribution					$298,466,841	$0	$298,466,841
Social Insurance Tax: Employer Contribution					$234,929,072	$0	$234,929,072
Business Tax: Custom Duty					$4,892,801	$0	$4,892,801
Business Tax: Excise Taxes					$4,391,384	$0	$4,391,384
Business Tax: Property Tax					$0	$92,637,898	$92,637,898
Business Tax: Receipts					$0	$58,758,384	$58,758,384
Business Tax: Other Taxes					$0	$231,747,458	$231,747,458
Direct Recorded (total of above rows)					$1,668,367,602	$807,959,859	$2,476,328,457
Direct Estimated	$27,982,883	$87,867,467	$91,973,321	$600,137,184	$1,668,367,602	$807,959,859	$2,476,328,457
Indirect + Induced				$223,834,213	$622,254,277	$223,834,213	$846,088,490
Total	$27,982,883	$87,867,467	$91,973,321	$823,971,397	$2,290,621,879	$1,031,794,072	$3,322,416,946

The direct tax payments to the state from coastal activity amount to $600 million, while local governments receive an additional $210 million. Accounting for indirect and induced effects brings this total to $820 million in tax revenue to the State of Delaware. Similarly, federal tax payments are heavily influenced by these secondary effects. Direct federal tax payments amount to approximately $1.7 billion, while indirect and induced tax payments contribute an additional $0.6 billion. A detailed breakdown of the local tax contributions shows that approximately $28 million goes to municipal coffers, while around $88 million goes to sub-county special districts, such as fire and school districts.

Meanwhile, county governments directly receive about $92 million.

In summary, the coastal region plays a critical role in sustaining Delaware's tax revenue streams, contributing over a billion dollars annually in direct, indirect, and induced tax payments. This tax revenue underscores the economic significance of the coastal region and supports various public services and infrastructure at local, state, and federal levels. Therefore, investment in this region has far-reaching fiscal implications and contributes to the overall economic health of the state and beyond.

Investing for Resilience

Within that idea of resiliency, the National Oceanic and Atmospheric Administration has identified three core components of resilience: society, economy, and environment. Coastal resiliency means not only resilient physical infrastructure, but resilient socio-economic and ecological systems as well (Almutairi et al. 2020[10]). For example, communities that have established community organizations and strong social connections are better able to recover from flooding and storm events.

Infrastructure and environmental projects that aim to improve coastal resilience of the built environment fall under three different categories. There are hard or gray projects that focus on physical infrastructure; soft or green projects that focus on natural systems and ecological restoration; and hybrid projects that incorporate aspects of both green and gray projects (Jarret & Davies, 2020[11]; Sutton-Grier et al., 2015).

[10] *Almutairi, A., Mourshed, M., & Ameen, R. F. M. (2020). Coastal community resilience frameworks for disaster risk management. Natural Hazards, 101, 595-630.*

[11] *Jarratt, D., & Davies, N. J. (2020). Planning for climate change impacts: coastal tourism destination resilience policies. Tourism Planning & Development, 17(4), 423-440.*

Hard projects are the most traditional way of thinking about coastal resiliency (Jarret & Davies, 2020; Polk et al., 2021[12]; Sutton-Grier et al., 2015; Hamin et al., 2018[13]). These types of projects include building sea walls, levees, raising roads and buildings, and installing better drainage systems. This can also include communication and utility systems that can withstand major flooding and disaster events (Almutairi et al., 2020). The cost and benefits of this type of project are well understood

and studied. There are years of expertise and experience behind each project, and they are effective in mitigating issues as soon as construction is completed. However, once constructed, gray projects cannot be changed or altered inexpensively in order to adapt to changing conditions. They also require regular maintenance and will eventually need replacement if under designed or once the maximum lifespan has been reached. The construction process or completed project itself may cause environmental degradation as well. Under some circumstances, these types of projects may also provide a false sense of security to society and inhibit people from adopting other mitigation strategies (Sutton-Grier et al., 2015; Hamin et al., 2018; Polk et al., 2021).

In the context of sea-level rise and increased storm surge under climate change, proactive management through hard projects can reduce total costs to society by an order of magnitude (Diaz 2016[14]). However, the upfront

and ongoing costs to achieve these benefits can be considerable. One study in 2018 of the costs of coastal resiliency projects, estimated the implementation cost of built projects to be between $6,500 to $9,800 per meter with additional annual maintenance costs of up to $1,710 per meter (Sutton-Grier et al., 2018[15]).

Soft projects or nature-based projects are those that focus on ecosystem restoration or the expansion of natural features (Jarret & Davies, 2020; Sutton-Grier et al., 2015). These types of resiliency projects include expansion of open space and wetland buffers, restoring wetlands, sand dunes, barrier islands, seagrass beds, and mangroves to their full state in order to gain storm and flood protection. Nature-based projects are beneficial because they can adapt with climate change and there are usually naturally occurring co-benefits for fisheries and water quality in the area. They also

[12] *Polk, M. A., Gittman, R. K., Smith, C. S., & Eulie, D. O. (2022). Coastal resilience surges as living shorelines reduce lateral erosion of salt marshes. Integrated Environmental Assessment and Management, 18(1), 82-98.*

[13] *Hamin, E. M., Abunnasr, Y., Roman Dilthey, M., Judge, P. K., Kenney, M. A., Kirshen, P., ... & Fricke, R. (2018). Pathways to coastal resiliency: The adaptive gradients framework. Sustainability, 10(8), 2629.*

[14] *Diaz, D. B. (2016). Estimating global damages from sea level rise with the Coastal Impact and Adaptation Model (CIAM). Climatic Change, 137(1-2), 143-156.*

[15] *Sutton-Grier, A. E., Gittman, R. K., Arkema, K. K., Bennett, R. O., Benoit, J., Blitch, S., ... & Grabowski, J. H. (2018). Investing in natural and nature-based infrastructure: building better along our coasts. Sustainability, 10(2), 523.*

require less maintenance than gray projects and, in some ways, can self-repair without the need for human intervention. Based on maintenance and installation costs versus the benefits provided, nature-based projects are more cost effective than gray ones are (Hamin et al., 2018; Polk et al., 2021). However, nature-based projects take a long time to implement and for the full benefits to be realized in addition to being larger than most built projects. The available knowledge and experience about best practices is also more scattered as it is difficult to design a one-size-fits-all approach. Thus, their cost and their effectiveness can vary drastically from place to place. Sutton-Grier et al. (2018) estimated installation costs of up to $6,562/m and maintenance costs of up to $328/m/year. They also estimated additional co-benefits of $1-7/m^2 through ecosystem services provided by the restoration project. A different study in 2020 that examined the cost of restoring a coral reef, estimated costs around $1290/m (Reguero et al., 2020[16]). The total cost of the project was estimated to be $6.4 million but had risk reduction benefits around $67.9 million.

Hybrid projects incorporate elements of both green and gray projects (Sutton-Grier et al., 2015; Hamin et al., 2018; Polk et al., 2021). Some examples of this include ecological engineering, beach nourishment, and shore stabilization. In hybrid projects typically the natural landscape is used to reduce flooding and erosion (Jarret & Davies, 2020). This type of project has been used in the United States for over 50 years (McNamara et al., 2015[17]). Between 1995 and 2002 the Federal Government provided around $787 million to subsidize hybrid resiliency projects. These types of projects are beneficial because they can utilize the best elements of green and gray projects. Similar to nature-based projects, there may be some co-benefits for fisheries and water quality through ecosystem services. Hybrid projects also require less space than nature-based projects and provide more public confidence similar to built projects. However, the drawbacks from both hard and soft projects can also be compounded within a hybrid project. Also similar to nature-based projects, within hybrid projects there are still a lot of research gaps, including estimates of their cost-effectiveness. Permitting complications may also be a boundary to completing hybrid resiliency projects.

Other adaptation methods exist outside of coastal resiliency infrastructure projects (Jarret & Davies, 2020; Almutairi et al., 2020). These can include moving further inland, away from coastal areas with the highest risk of flooding. However, this adaptation method presents its own challenges and undermines the strength of coastal communities.

[16] *Reguero, B. G., Beck, M. W., Schmid, D., Stadtmüller, D., Raepple, J., Schüssele, S., & Pfliegner, K. (2020). Financing coastal resilience by combining nature-based risk reduction with insurance. Ecological Economics, 169, 106487.*

[17] *McNamara, D. E., Gopalakrishnan, S., Smith, M. D., & Murray, A. B. (2015). Climate adaptation and policy-induced inflation of coastal property value. PloS one, 10(3), e0121278.*

Monitoring for the Future

Understanding the dynamism of the coastal economy is a prerequisite for better resource allocation and maximizing economic potential. Both internal and external forces can present risks and opportunities. Developing a “Coastal Barometer” of these changing forces would crucially inform a holistic understanding of the coastal economy's health.

The coastal economy is subject to a spectrum of economic risks and opportunities. Infrastructure and assets are vulnerable to flooding and sea-level rise. Tourism, a vital sector, is subject to fluctuations due to shifting behaviors. Additionally, the natural environment faces mounting threats from multiple forms of environmental change. However, within these challenges lie significant economic opportunities. As appreciation for beautiful environments escalates, and businesses adapt to the changing needs of an aging population, new avenues for growth become apparent.

Therefore, it is essential to realize that a healthy economy is not merely prosperous but resilient, armed to adapt to and mitigate risks, and ready to seize the ensuing opportunities. The complexity of the coastal economy, laden with diverse risks and opportunities, makes it challenging to capture its entirety within any set of metrics. However, the methodologies born from sustainable development and inclusive accounting offer a robust foundation for encapsulating the economic underpinnings of future prosperity. A "Coastal Barometer" could serve as an invaluable tool for Delaware's coasts, offering a regularly updated dashboard of indices on the coastal economy's health. This tool would not simply reflect the immediate condition of the coastal economy but would also elucidate its connections to the broader state and national economies. In essence, the Barometer would offer an integrated, up-to-date snapshot of the economy's overall health, spanning from the local to the national level.

The proposed Coastal Barometer is more than a mere statistical index; it is a pathway towards comprehensive economic understanding. By making these data readily available, coastal community officials will be better equipped to identify beneficial infrastructure investments and make more informed land-use decisions. Understanding the scale of the economic contributions from coastal-related activities also helps planners forecast the effects of new developments more accurately, ensuring that investments are appropriately sized.

Thus, the Coastal Barometer serves as a critical instrument, not only monitoring the pulse of the coastal economy but also guiding its future, making it a potential cornerstone of sustainable and inclusive development for Delaware.

Research Needs

The future economic contribution of Delaware will depend on its resilience to risks and the investments it makes to be prepared to take advantage of opportunities. In this project, a number of key research needs have been identified which can support future work.

Projected Impacts of Climate Change

Climate change projections will form the basis of many assessments of risk in coastal areas. Understanding the potential magnitude of sea-level rise, increased storm frequency and intensity, and the subsequent effect on the coastal economy is of utmost importance.

Research is needed to identify risk tolerances among residents, visitors, and sectors and to quantify the potential loss to Delaware's coastal economy due to climate change, including loss of property, revenue, and jobs. Further investigation is required into Delaware's disaster preparedness and potential outcomes in the event of increased climate change-induced incidents. This research should include an examination of current plans, their adequacy, whether they integrate climate change, and potential gaps that need to be addressed.

Effectiveness of Nature-based and Hybrid Systems

Understanding the role and effectiveness of nature-based and hybrid systems in mitigating coastal risks will help inform policy decisions.

- Comparative studies on the cost-effectiveness and other relative advantages of nature-based versus hybrid systems specifically tailored for Delaware's coastal characteristics are needed.
- An assessment of the value of these systems and their co-benefits through increased ecosystem services should be performed. This would also include an evaluation of their resilience to sea-level rise and larger storms and their potential protective value compared to built infrastructure.

Barriers to Implementing Natural Projects for Coastal Protection

Understanding the challenges to implementing nature-based projects in the United States could inform local decision-making. A comprehensive review of barriers at the local, state, and national level is required to understand the factors influencing the selection of different protection methods. In particular, the permitting process for each type of project should be reviewed to understand if it presents any barriers to implementation.

Investigating these research needs will provide a more complete understanding of the economic contribution of Delaware's coastal area and the risks it faces due to ongoing changes. This will help guide strategic planning and policy development to protect and preserve this valuable region.

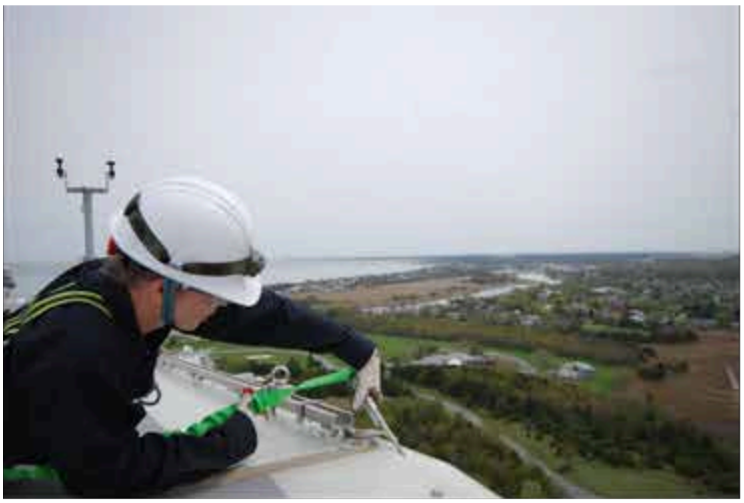
Summary and Conclusions

The importance of Delaware's coastal economy cannot be overstated, acting as a vital cornerstone for the state's overall economic health. Its diverse range of contributing industries, ranging from the booming real estate and tourism sectors to service industries, reflect its dynamic and adaptive nature. This has led to significant growth over the past decade, positioning the coastal economy as a potent driver of state-wide economic prosperity. Furthermore, the exceptional resilience demonstrated by this economy in the face of changing environmental conditions and shifts in economic demand underscores its potential for sustained growth and adaptability.

The economic contribution of coastal activities in Delaware extends beyond the immediate economic output to stimulate job creation and other economic activities statewide. The multiplier effects within the coastal economy, particularly those driven by key sectors such as tourism, real estate, and healthcare, exemplify the interconnectedness of economic interactions within and beyond the coast. This is further highlighted by the considerable tax revenue generated from the coastal region, contributing over three billion dollars annually in direct, indirect, and induced tax payments.

At the same time, the environmental risks faced by Delaware's coast can threaten this economic engine. In the long term, risks like sea-level rise can even present an existential threat. One participant raised the topic of impermanence, saying,"...we are building what we perceive to be permanent communities in what is actually impermanent land." Coastal towns are faced with an uncertain future. In other areas of the US, families are able to pass homes down through the generations. But in coastal towns, this will become more challenging without robust local and regional adaptation and mitigation measures.

Nevertheless, these coastal communities are part of Delaware's history and have become significant to the state's culture and economy. As one participant stated, "The beach is a powerful draw". People are drawn to the ocean and to the coast. Coastal communities in Delaware are still attracting new residents and providing homes for their current residents. These communities have dealt with generations of flooding and storms and will continue to do so. A mayor of one of the



towns commented, “Mother Nature's knocked us down and like a phoenix, we keep rising. So, I do think that we just need to keep working the problem, and we will find some solutions that make it workable and will give us a community that will survive into the future.”

Investing in the resilience of the coastal economy is a strategic imperative, given the anticipated environmental changes and potential disruptions. The exploration of hard, soft, and hybrid projects for enhancing coastal resilience indicates an adaptive strategy that goes beyond immediate protection to sustainable long-term growth. These investment decisions, alongside a deeper understanding of the cost-effectiveness and long-term benefits of these systems, would significantly shape the future trajectory of the coastal economy.

Given the dynamism of the coastal economy, monitoring its health is a strategic necessity. The development of a "Coastal Barometer" could offer a comprehensive understanding of this vibrant economy's state and its capacity to mitigate risks and seize emerging opportunities. Such an instrument could guide informed decision-making regarding infrastructure development, land use, and potential impacts of new investments, thereby steering sustainable and inclusive growth in Delaware.

In conclusion, the strategic investment in climate adaptation and monitoring of Delaware's coastal economy are essential steps in maintaining its economic vitality and resilience. Recognizing its economic

significance and understanding its dynamism will facilitate the evolution of a sustainable and resilient coastal economy, thereby contributing to the continued prosperity of the State of Delaware.

Appendix

Additional Methodology Details

IMPLAN Modeling

Three different regions were used in the modeling process. All three regions were built based on research conducted in 2012.

The Coastal Zone was the primary focus of this study. It contained four zip codes (19930, 19944, 19958, and 19971). The Boundary Zone was the 11 zip codes neighboring the Coastal Zone (19939, 19945, 19947, 19951, 19963, 19966, 19967, 19968, 19969, 19970, 19975). The third region was the rest of Delaware. It contained all of the remaining zip codes in the state and excluded those in coastal or boundary zones.

Since IMPLAN data is only available at the zip code level, and the Boundary Zip codes span the Infrastructure Zone border, we apply a fractional amount of the Boundary Zone to the Infrastructure Zone. This means that direct economic outcomes are calculated as

[Coastal Baseline Output] + ([Infrastructure Zone Portion]) ([Boundary Coastal-Sector Baseline Output]) + (1 - [Infrastructure Zone Portion]) ([Coast-Related Boundary Industries])

That is, the total of coast-related boundary industries is included, but only part of all other industries. This portion is calculated based on the portion of the population in Boundary Zone zip codes that are in the Infrastructure Zone. We partition economic activity within zip codes based on the population inside and outside the Infrastructure zone according to the Global Human Settlement Layer GHS-POP dataset[18].

The coast-related sectors in boundary zip codes represent a relatively small share of the employment (8%), income (10%), and output (7%) of that region.

Baseline information for each region and industry was obtained from IMPLAN at the zip code level for the years 2018, 2019, 2020, 2021, and 2022. It was also obtained at the Sussex County level for the years 2012, 2015, 2018, and 2021.

[18] *Schiavina M., Freire S., Carioli A., MacManus K. (2023): GHS-POP R2023A - GHS population grid multitemporal (1975-2030).European Commission, Joint Research Centre (JRC) PID: http://data.europa.eu/89h/2ff68a52-5b5b-4a22-8f40-c41da8332cfe, doi:10.2905/2FF68A52-5B5B-4A22-8F40-C41DA8332CFE*

Building the Industry Aggregations

Two different industry aggregation schemes were used in the modeling process. The first was the All Industry Aggregation which contained each of the 546 industries available within IMPLAN aggregated together. The second aggregation scheme was used for the analysis conducted for Table 4. It contained 10 different industry categories. Those categories were Food Service and Drinking Places; Real Estate Rental and Management Establishments; Hospitals, Nursing Homes, and other Medical Care Facilities; State and Local Government; Office of Physicians, Dentists, and other Health Care Practitioners; Retail Food and Beverage; Retail Clothing and Clothing Accessories; Employment Placement Services, including temporary workers; Business, Professional, Labor, Political, Civic, Social, and Homeowners Associations; and Services to Buildings and Dwellings. The remaining industries within IMPLAN were left unaggregated for this scheme.

Table 2 Industries and their corresponding IMPLAN sector codes:

1. Food Services and Drinking Place: 509, 510, 511
2. Real Estate Rental and Management Establishments: 447, 448
3. Hospitals, Nursing Homes, and Medical Care Facilities: 490, 491, 492, 540
4. State and Local Government- other than Education: 529-534, 539, 541, 543, 544
5. Offices of Physicians, Dentists, and other Health Practitioners: 483-486
6. Retail Food and Beverage: 406
7. Retail Stores- Clothing and Clothing Accessories: 409
8. Employment Placement Services, Including Temp Workers: 472
9. Business, Professional, Labor, Political, Civic, Social, and Homeowners Associations: 473, 495 522, 523, 524
10. Services to Buildings and Dwellings- janitorial, pest control, etc: 60, 61, 476, 477, 479, 516
11. All other industries left unaggregated

The coast-related activities are shown in the table below.

IMPLAN Code	Sector Description	Boundary Total Employment	Boundary Total Labor Income	Boundary Total Output
3	Vegetable and Melon Farming	60.71	$10,686,023.13	$16,601,266.70
4	Fruit Farming	2.13	$490,038.49	$508,344.22
14	Animal Production, except cattle, poultry, and eggs	3.93	$1,041,396.32	$1,085,487.54
17	Commercial Fishing	28.88	$101,471.45	$234,650.52
20	Oil and gas extraction	8.08	$464,933.66	$7,281,517.22
29	Sand and Gravel Mining	23.16	$2,430,717.81	$6,272,216.79
30	Other clay, ceramic, and refractory mineral mining	0	$0.00	$0.00
35	Drilling oil and gas wells	0.5	$28,725.90	$170,906.58
39	Electric power generation - Hydroelectric	0	$0.00	$0.00
40	Electric power generation - Fossil fuel	4.72	$775,462.99	$7,909,538.15
41	Electric power generation - Nuclear	0	$0.00	$0.00
42	Electric power generation - Solar	0	$0.00	$0.00

IMPLAN Code	Sector Description	Boundary Total Employment	Boundary Total Labor Income	Boundary Total Output
43	Electric power generation - Wind	0	$0.00	$0.00
44	Electric power generation - Geothermal	0	$0.00	$0.00
45	Electric power generation - Biomass	0	$0.00	$0.00
46	Electric power generation - All other	0	$0.00	$0.00
47	Electric power transmission and distribution	32.76	$4,380,024.93	$46,531,557.16
49	Water, sewage and other treatment and delivery systems	5.68	$621,746.89	$2,388,907.27
50	Construction of new health care structures	199.62	$15,542,718.37	$27,699,200.90
55	Construction of new commercial structures, including farm structures	764.85	$58,090,754.44	$99,280,412.02
56	Construction of other new non-residential structures	349.95	$26,768,625.81	$54,068,614.31
57	Construction of new single-family structures	1,168.09	$90,370,975.01	$200,158,671.17
58	Construction of new multifamily structures	398.71	$30,878,635.54	$45,795,236.77
59	Construction of other new residential structures	562.64	$43,611,838.57	$158,405,235.05
60	Maintenance and repair of nonresidential structures	384.59	$29,803,354.12	$98,459,972.04
61	Maintenance and repair of residential structures	199.57	$14,518,879.97	$44,006,461.61
74	Non chocolate confectionery manufacturing	0	$0.00	$0.00
84	Fluid milk manufacturing	0	$0.00	$0.00
85	Creamery butter manufacturing	0	$0.00	$0.00
92	Seafood product preparation and packaging	52.77	$4,636,657.09	$31,555,121.53
93	Bread and bakery product, except frozen manufacturing	124.77	$4,541,860.81	$18,783,199.57
106	Breweries	38.83	$1,321,843.25	$11,392,505.47
142	Prefabricated wood building manufacturing	21.14	$1,320,652.20	$6,009,531.92
	Total	**4436.08**	**$342,427,336.75**	**$884,598,554.51**
	Total Boundary Zone	**57,137.49**	**$3,408,577,633.47**	**$13,103,944,911.13**
	Portion of Boundary Zone	7.76%	10.05%	6.75%

Creating the Models

The core economic contribution estimates shown in Tables 3 and 4 were calculated using "Industry Contribution Analysis" (ICA), which calculates indirect and induced effects, while constraining industries to match their observed levels. We also report multiplier effects for further growth, which are calculated using an output impact model.

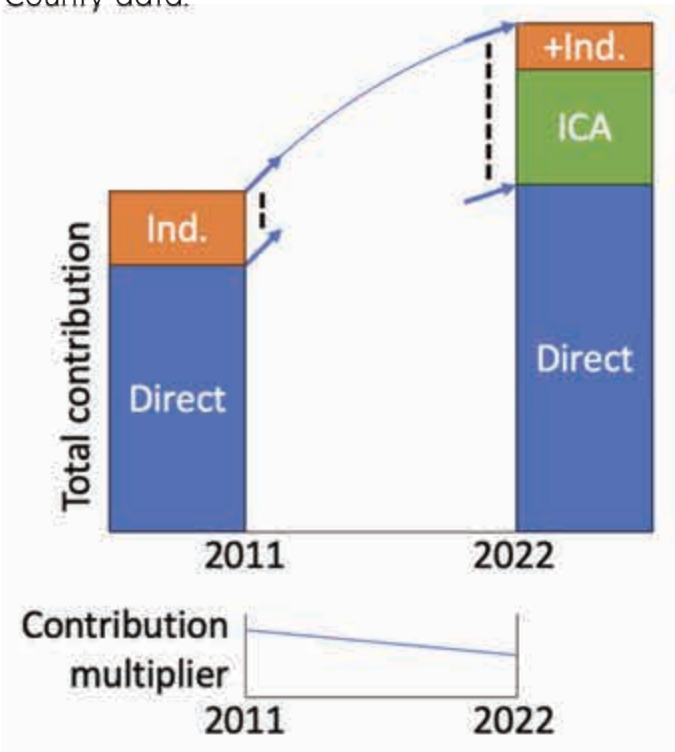
In both cases, the coastal, boundary, and remaining regions are constructed as above in IMPLAN. All IMPLAN modeling is performed using multi-regional input-output (MRIO) calculations. The models were calculated for an ICA and for an output impact, and applied separately to the coastal zone and boundary zone.

For Table 3, we aggregate all industries into one aggregate sector. For Table 4, each of the 10 sectors is left unaggregated, along with an additional remaining aggregate sector.

Economic dynamics

We use the baseline in 2011 to develop a calculation of the economic contribution that accounts for the changing structure of the economy from 2011 to 2022. This is conceptually diagrammed below.

We assume that the multipliers calculated for the 2012 report zone (consisting of the coastal zone and the coast-related portion of the boundary zone) apply to the new zonal definitions used here (that is, to the infrastructure zone, plus the remaining coast-related portion of the boundary zone). Whenever results from the 2012 report are used, the values are extrapolated to the new zonal definitions, using models fit to Sussex County data.



Let the 2011 direct be D_0 and the indirect+induced I_0, with a multiplier $1 + \frac{I_0}{D_0}$.

Let the corresponding 2022 values be D_1, I_1, and $1 + \frac{I_1}{D_1}$.

Assume that the multiplier changes linearly, so the indirect+induced addition is: $A(D) = (\frac{I_1}{D_1} - \frac{I_0}{D_0})(\frac{D - D_0}{D_1 - D_0}) + \frac{I_0}{D_0}$.

The total indirect+induced is then $B = \int_{D_0}^{D_1} A(D)dD = \frac{((I_1 D_0 + I_0 D_1)(D_1 - D_0)}{2\, D_0 D_1}$. The total is $D_1 + B + I_0$.

Data Collected

All data was collected in 2024 dollars and from the results of each model the total impact, employment, labor income, and value added information was collected. The data was the direct, indirect, induced, and total effect from the model. For the Boundary Zone and the remaining Delaware zip codes, only indirect, induced, and total data was collected.

Interview Methodology

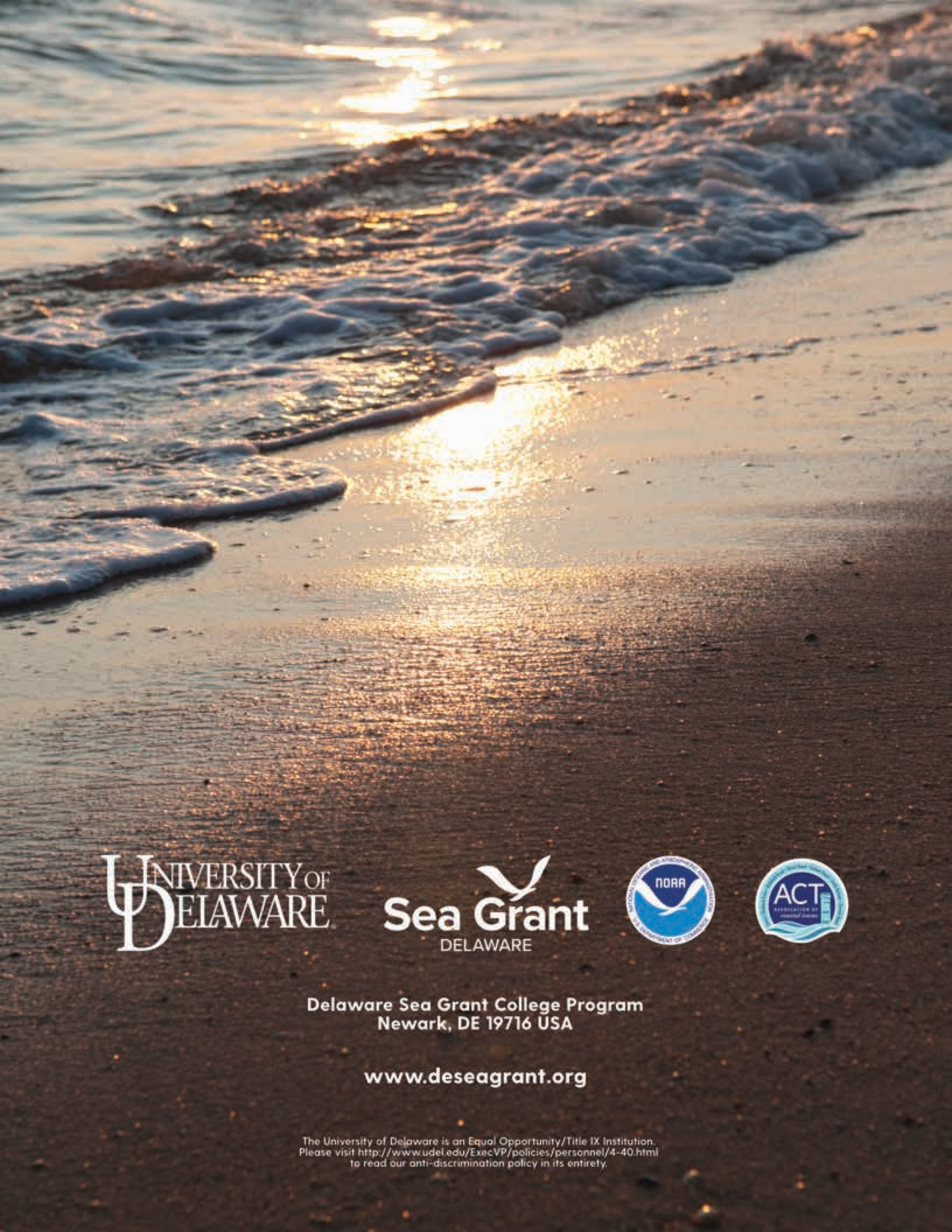
Two exploratory interviews were conducted with a business owner from Bethany Beach and the Director of Transportation Resiliency and Sustainability from the Delaware Department of Transportation. The interviews were conducted in a semi-structured format over telephone and video conference. The focus of both interviews was the impact of climate change, flooding in particular, on communities in the study area from each person's perspective. These exploratory interviews were then used to focus the development of questions for additional interviews. Main themes of flooding and climate change were identified and used to develop further questions for additional interviews.

A second round of semi-structured interviews were conducted over Zoom with nine individuals. Potential participants were recruited by email invitation. Selected participants responded to the email invitation and indicated their willingness to participate in an interview. Follow up emails were sent if no response was given.

The interviews were recorded and transcribed by Zoom for coding and analysis. Notes were also taken during the interview. Transcripts were cleaned and reviewed for accuracy before being analyzed. The interview guide included questions on current impacts due to coastal flooding, observed changes over time, adaptation methods, and planning efforts for the future. Inductive coding was used to identify common elements in participants' responses to interview questions (Braun & Clarke 2006[19]). Responses were coded at a topic or concept level which varied in length between a sentence to a couple of sentences. When the topic switched, a new code was identified. Broader themes were then identified from the codes based on commonalities between them (Braun & Clarke 2006, Jackson & Nowell 2021[20]).

[19] *Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101.*

[20] *Jackson, J., & Nowell, L. (2021). "The office of disaster management" nurse managers' experiences during COVID-19: A qualitative interview study using thematic analysis. Journal of Nursing Management, 29(8), 2392–2400.*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