The Economic Contribution of Casco Bay

Prepared for:
Casco Bay Estuary Partnership

Prepared by:
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University of Southern Maine
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LETTER FROM CBEP's DIRECTOR

Casco Bay shapes our region's character and identity. From Portland's working waterfront, to the Phippsburg peninsula, to the islands, the Bay has shaped our history, our economy, and our communities. The Bay attracts residents, visitors, industry, and businesses, and is an asset of significant ecological and economic value that provides a living for thousands and indirectly supports many more.

This report takes a close look at direct economic contributions of the Bay to the Maine economy. On one level, the report confirms what we already knew -- that the Bay is an important regional asset. Looking deeper, it provides a sense of the magnitude of the Bay's direct economic importance, and identifies the relative contribution of economic sectors closely tied to the Bay.

As with any economic analysis, this one has a limited scope. For example, the study did not consider the "ecosystem services" provided by the Bay, such as the ability of our tidal wetlands to reduce shoreline erosion and support migratory birds, or the potential for eelgrass beds to improve water quality and remove carbon dioxide from the atmosphere.

Even so, the study quantifies the enormous contributions that Casco Bay makes annually to the economy. That is worth remembering, as we collectively confront choices about how best to invest in protecting water quality, conserving coastal habitats, and safeguarding communities from the impacts of coastal change.

Thank you to our partners, the Maine Center for Business and Economic Research and rbouvier consulting, for this timely research to help us quantify the importance of Casco Bay and establish a framework for measuring the Bay's economic contributions over time.

Curtis C. Bohlen
Director, Casco Bay Estuary Partnership

Casco Bay Estuary
PARTNERSHIP

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TABLE OF CONTENTS

TERMINOLOGY

Average Earnings: Also called "Current Total Earnings," this is the total industry earnings for a region divided by number of jobs. Includes wages, salaries, supplements (additional employee benefits), and proprietor income. (Source: Economic Modeling Specialists Inc. (EMSI))

Employment: Employment, also referred to as "jobs," includes any position in which a worker provides labor in exchange for monetary compensation. This includes those who work as employees for businesses (a.k.a. "wage and salary" employees) and proprietors who work for themselves. (Source: EMSI)

Gross Regional Product (GRP): Gross regional product is analogous to the countrywide measure Gross National Product (GNP) which is a measure of the market value of all final goods and services produced in the region. Measurement of GRP varies slightly from GNP, in that the regional and state measure excludes some activity, such as federal government output, though this is included in national measures (GNP). GNP and GRP are standard broad economic measures of regional and national economic activity used by economists and policymakers to gauge a region's and nation's growth.

Market Value: This refers to economic value that can be revealed through prices, or the value someone is willing to pay for things, such as lobster, fish, lodging, or other goods and services.

Non-Market Values: Contrary to market values, non-market values reflect things that are not traded or easily priced through markets, such as the value of a walk on the beach, the value of clean air and water, or the cost of pollution. These types of values are much more difficult and costly to measure compared to market values.

Ocean Economy: The ocean economy includes the economic activity that directly or indirectly uses Casco Bay and its resources as an input. The ocean economy of Casco Bay is comprised of five sectors that include tourism and recreation, marine transportation, marine construction, living resources, and ship and boat building.

Watershed Economy: Includes all economic activity (all industries) located within the watershed, regardless of relation to Casco Bay resources.

ACRONYMS

BEA	**US Bureau of Economic Analysis**
BIW	**Bath Iron Works**
BLS	**US Bureau of Labor Statistics**
CBASS	**Casco Bay Aquatic System Survey**
CBWR	**Casco Bay Watershed Region**
CSO	**Combined Sewer Overflow**
DEP	**Maine Department of Environmental Protection**
DMR	**Maine Department of Marine Resources**
EMSI	**Economic Modeling Specialists Inc.**
ENOW	**Economics: National Ocean Watch**
EPSCoR	**Experimental Program to Stimulate Competitive Research**
GMRI	**Gulf of Maine Research Institute**
GRP	**Gross Regional Product**
IMT	**International Marine Terminal**
MEIF	**Maine Economic Improvement Fund**
MSA	**Metropolitan Statistical Area**
MTI	**Maine Technology Institute**
NAICS	**North American Industrial Classification System**
NEOC	**New England Ocean Cluster**
NOAA	**National Oceanic and Atmospheric Administration**
NOEP	**National Ocean Economics Program**
NSF	**National Science Foundation**
QCEW	**Quarterly Census of Employment and Wages**
SEANET	**Sustainable Ecological Aquaculture Network**
SMCC	**Southern Maine Community College**
STEM	**Science, Technology, Engineering and Mathematics**
UMM	**University of Maine Machias**

EXECUTIVE SUMMARY

Casco Bay is an ecological and environmental treasure to the people who live and work there, to the visitors it attracts, and to the diverse wildlife and living resources that make the Bay and watershed their home. However, the Bay also makes significant economic contributions in the form of jobs, provision of natural resources, and the provision of services. The natural amenities provided by Casco Bay also play a very important role in attracting and retaining high-skilled workers to the region that support a growing innovation-based regional economy. The Casco Bay Watershed Region is home to one-quarter of Maine's population and one-third of the total jobs in the state, despite containing just 4.4 percent of the state's land mass. It follows that the health of the regional economy is highly dependent upon the health of Casco Bay and its resources, providing a strong case for protecting and caring for Casco Bay and the watershed. Yet, policy makers, business leaders, and the public do not have a strong sense of the scale and ways in which the Bay contributes economic value or how this may change over time. This study addresses these gaps and sets out to achieve three objectives:

1. To provide estimates of the current economic market value that Casco Bay contributes to the regional and state economy;
2. To understand the potential economic implications of changes to the ecological health of the Bay, specifically as a result of the impacts anticipated from climate change; and
3. To establish a framework for continued monitoring and tracking of the health of the ocean economy.[1]

This study adapts and applies the measurement framework developed by the National Ocean Economics Program (NOEP) and used by the National Oceanic and Atmospheric Administration's (NOAA) Economics National Ocean Watch (ENOW) program for measuring the market value[2] of

[1] Continued monitoring of Casco Bay's Coastal and Ocean Economy could be simply implemented using the framework established in this report. The methods used here are based on consistent and reliable data sources that are not expected to substantially change in the foreseeable future. These methods are based on working economic definitions (the Coastal and Ocean Economies) that can be carried forward, while allowing for slight adjustments as necessary. Furthermore, these definitions have the advantage that the Casco Bay economy can be easily compared to other coastal, marine, or estuarine regions if warranted.

[2] This study focuses solely on the market value of Casco Bay, defined as value that is revealed through market transactions, such as purchases of goods and services by people and businesses or the selling of labor for wages. It does not address the non-market values, which are values not exchanged in normal market transactions, such as the value of a walk on the beach or of ecosystem services provided by Casco Bay. Nonmarket values are equally important for understanding how the Bay contributes to the regional economy, however they are costly and difficult to measure.

economic activity linked to the ocean and coastal areas. Specifically, this report considers two measurements in the NOEP framework: 1) the "watershed economy" which includes all economic activity that takes place in the Casco Bay watershed region, and 2) the "ocean economy," which is a more specific representation of economic activity dependent upon Casco Bay and is used to approximate the *economic contribution* of Casco Bay. The ocean economy in Casco Bay includes 5 economic sectors: Tourism and Recreation, Marine Transportation, Living Resources, Marine Construction, and Ship and Boat Building, all of which are comprised of more specific industries.

Drawing upon NOEP's framework, the market-based economic contribution of the ocean economy and each of the 5 sectors are assessed using estimates of employment and Gross Regional Product (GRP). Employment is a measure of the number of jobs supported. GRP is a measure of the final market value of goods and services produced in the economy and is a standard metric used by economists to measure the 'size' of an economy, in this case the ocean economy.[3] In addition, we report supplemental indicators for each sector which are discussed in the full report.

The Economic Contribution of Casco Bay

Casco Bay contributed an estimated $704 million of direct economic activity in 2016 measured as GRP and supported approximately 18,500 jobs (Table ES.1). This activity, which is based on the ocean economy of Casco Bay, accounted for 4 percent of GRP in the Casco Bay watershed region and 1.2 percent of total for Maine. In terms of employment, the ocean economy accounted for 8.4 percent of total employment in the watershed region, and 2.7 percent of Maine employment.

[3] GRP is analogous to the commonly reported macroeconomic indicator gross domestic product (GDP) reported for the nation. In this case, GRP is measured as sales minus the cost of inputs, also referred to as 'value-added'.

Table ES.1: Economic Contribution of the Casco Bay Ocean Economy, 2016

	Employment				Gross Regional Product	
Ocean Economy Sector	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Total	Number	Share of Total
Tourism and Recreation	14,797	1,561	12%	80%	$491,643,093	70%
Marine Transportation	2,433	1,246	105%	13%	$125,955,604	18%
Living Resources	1,139	-217	-16%	6%	$76,012,659	11%
Marine Construction	94	25	36%	1%	$7,777,813	1%
Ship and Boat Building	30	11	58%	0%	$2,540,313	0%
Ocean Economy Total	**18,493**	**2,626**	**16%**	-	**$703,929,482**	-

Source: EMSI, 2017.1 data series; MCBER calculations

Employment growth in the ocean economy has been steady since 2006, growing by 16 percent over the 10-year period. This is significantly higher than employment growth in the broader watershed economy, which grew at just 1 percent over the same period. The 18,500 jobs in the ocean sectors support another 5,700 jobs indirectly through recurrent rounds of spending in the economy, such as through purchases by ocean economy businesses to support operations and spending of wages by ocean economy workers.

Ocean Economy Sector Findings

Tourism and Recreation

Tourism and recreation is the largest source of jobs (14,800) accounting for 80 percent of total bay ocean economy employment. The sector also contributed $491 million (70 percent) in GRP to the ocean economy. Under the ocean economy definition, this includes tourism and recreation industries that are in shore adjacent zip codes. However, the lakes area in the upper watershed of Casco Bay is a significant area of tourism and recreation, which supports another 5,500 jobs and $173 million in GRP.

Marine transportation

Marine transportation employment is comprised primarily of jobs in warehousing and storage services, which support over 95 percent of all jobs and GRP in the sector. The number of jobs in this industry more than doubled between 2006 and 2016, with a large spike in 2008. Overall the sector contributed upward of $126 million to GRP, the second largest of the regional ocean sectors. Marine transport facilitates the shipment of local exports to market opportunities that might

not otherwise be cost competitive or accessible to reach, therefore this number likely underestimates the full impact of the marine transportation sector. Accessing new markets enables regional manufacturers to sell more goods, thereby increasing production and the number of workers they employ in the region.

Living resources

The living resources ocean sector includes not only harvesting of ocean species, such as lobsters, groundfish, and other shellfish, but also value-added processing and packaging of seafood products. Despite its close affiliation with marine economic activity, the sector makes up a proportionally smaller share of the bay ocean economy contributing $76 million in 2016 (11 percent of total ocean GRP) compared to tourism and recreation and marine transportation. Over the 10-year period jobs in the living resources sector decreased by 16.7 percent (- 246 jobs) compared to a 9.2 percent (-52,834) decrease at the national level and 10.1 percent decrease (-903) in Maine as a whole. Declines were primarily in finfish fishing, shellfish fishing, and retail distribution, while employment in seafood processing and distribution increased by 200 percent since 2006 to 337 in 2016. Portland is a regional center for the processing and distribution of seafood related products. [4]

Marine construction

The marine construction sector makes up a very small portion of the overall ocean economy of Casco Bay, totaling just 94 jobs in 2016 and adding about $7.8 million to GRP. Future growth in the sector may be tied to investments in climate change and sea level rise adaptation, such as raising port related infrastructure (piers), as well as potential for new industries in renewable energy that are growing in the northeastern US. Some of the best offshore wind resources in the US are off the coast of Maine and southern New England.

Ship and boat building

The sector is comprised of two more detailed industries differentiated by whether a company's core business is with large marine vessels or smaller recreational or lifestyle vessels. There

[4] Traditional employment measures based on public secondary data such as those used in this study do not capture all self-employment in the fisheries industry. The full report considers two alternative measures of fisheries employment, in order to paint a more complete picture of jobs in the fishing industry.

is some debate about the best way to portray the ship and boat building sector in the Casco Bay region because of the presence of Bath Iron Works (BIW) in Bath.

BIW, one of the largest employers in Maine, lies in a municipality adjacent to the ecological boundary of the Casco Bay watershed. The company, however, is highly integrated in the broader economy that lies within the Casco Bay watershed.

Without considering BIW, the ship and boat building sector in the Casco Bay region is very small, accounting for just $2.5 million in GRP and employing just 30 workers in 2016. With the addition of Bath/West Bath (which includes BIW), the sector as a whole makes a major contribution to the ocean economy of the region, accounting for over $533 million in GRP. BIW employed almost 5,800 workers in 2016, up 11 percent from 2006. In addition, including Bath/West Bath in our analysis brings the total jobs in boat building to 223 (197 of which are located in Bath/West Bath).

Economic Effects of Changes to Bay Health

The health of Casco Bay can have significant impacts on the ocean economy associated with it. Changes in bay health are most likely to occur from the impacts of climate change, such as warming waters, ocean acidification, and sea level rise, and from polluted runoff leading to water quality issues. Living resources is the most obvious sector to experience direct impacts of changes to bay health, including climate change, though the direction and magnitude of impacts could be both positive and negative. Studies on lobster, for example, predict that as waters warm, thermal habitat for lobster in Casco Bay may increase, but there is uncertainty as to how lobsters' shells, growth rate, and immune system will respond to acidification. Small island communities and parts of northern communities of the Bay such as Harpswell, that are highly dependent on the decentralized lobster fishery, are most vulnerable to a declining lobster industry. In contrast, seafood processing is rather centralized in greater Portland and can thus likely absorb fluctuations in local lobster catches more readily, although the sector could be affected over the long term as lobster landings shift further downeast or sources of fresh fish from elsewhere (e.g., northern Europe) decline.

Tourism and recreation may be less impacted as a percentage to changes in bay health, but as the largest ocean sector, the impacts overall (which could be positive or negative) may dwarf impacts in the smaller ocean sectors. However, sea level rise will likely have the most significant impact on costs across the entire economy, stemming primarily from the need to make critical infrastructure

improvements to adapt to changing water levels and more frequent flooding and weather related events (Colgan et al, 2017).

Given the uncertainty presented by climate change and other environmental stressors, the impacts on ocean dependent economies are not easily discerned, but will likely take multiple directions and affect communities that depend on those industries differently. Continued scientific research will help us better understand direction and magnitude of impacts.

The health of Casco Bay is vital to our economy. Climate change and other pollution stressors jeopardize that economic activity. Even beyond the effects outlined here, an unhealthy bay can imperil the health and the well-being of the population that chooses to call Casco Bay home. As our economy shifts from a goods-focused economy to a service-oriented one, the condition and vitality of the Bay and the ecosystems it supports are crucial to attracting and retaining the necessary high-skilled workers (Brookings Institution, 2006; Reilly and Renski, 2008; Moretti, 2012). Part of the Casco Bay region's appeal is its ocean economy: its fishing, boat building, and shipping industries, not to mention its beaches and outdoor-related tourism. The health of Casco Bay itself may be the most important economic resource we can protect.

Chapter 1. Introduction

To simply say that Casco Bay is valuable is an understatement. Not only is Casco Bay an ecological and environmental treasure to the people that live and work there, to the visitors that it attracts, and to the diverse wildlife and living resources that make the Bay and watershed their home, the Bay also makes significant contributions to the economy, both directly and indirectly, in the form of jobs, provision of natural resources, and of services. The regional economy and Casco Bay are deeply intertwined and as a result the health of the regional economy is highly dependent upon the health of Casco Bay and its resources. It is no coincidence that the Casco Bay Watershed Region as defined in this report,[5] is home to one-quarter of Maine's population and one-third of the total jobs in the state, despite containing just 4.4 percent of the state's land mass. Casco Bay plays an increasingly important role in this respect.

Yet, policy makers, business leaders, and the public do not have a strong sense of the economic value of Casco Bay or the different ways in which the Bay contributes to the regional economy. An understanding of such relationships is critical to making decisions that affect the economy and the Bay's health. This study attempts to fill this gap in our appreciation of Casco Bay and achieves three primary objectives in doing so. The first is to provide estimates of the current economic market value that Casco Bay contributes to the regional and state economy. The second is to understand the potential implications for the regional economy of changes to the ecological health of the Bay, specifically as a result of the impacts anticipated from climate change. The third objective is to establish a framework for consistent tracking and monitoring of Casco Bay's ocean economy in future years and to establish a baseline from which to repeatedly measure the Bay's economic contribution in the future. To this end, the scope of work addresses three sets of questions:

- What is the current contribution (in terms of market value) to the regional economy of economic activity related to Casco Bay? How has this changed in the recent past? How is economic activity expected to change going forward?
- What are the potential economic implications due to changes in the health of Casco Bay?
- What indicators can we use to consistently measure the Bay's economy in the future in order to monitor its economic contributions to the region and how they are changing?

[5] For purposes of this report, the Casco Bay Watershed Region, also referred to as the CBWR or the watershed economy, is comprised of 54 zip codes that are either all or in significant part within the ecological watershed boundary. Definitional zip codes are provided in Table A.1 of Appendix A and discussed in Chapter 2 of the report.

The study is prepared for the Casco Bay Estuary Partnership and follows directly from a key priority identified in the Partnership's five-year plan 2016-2021 (Action 3.1.A: Highlight Casco Bay's Economic Importance). This action is important in helping to achieve the goal of fostering healthy and resilient communities connected to Casco Bay and informing business and policy leaders so that policy can be best guided towards the most desirable outcomes.

The study focuses on the market value of Casco Bay, defined as value that is revealed through market transactions, such as purchases of goods and services by people and businesses or the selling of labor for wages. These types of transactions are reflected in measures of gross regional product, which measures the overall size of the economy, and in employment and wage data, as well as other data that provides some measure of the exchange of goods and services for currency. Of course, market values are but one dimension of the value a resource may provide and are different than value that may be derived from an ocean view at sunrise or a walk along the shore. Similarly, there is significant value provided by coastal marshlands and estuaries in the form of 'ecosystem services,' including habitat for marine wildlife and fisheries as well as barriers to storm surge and erosion.

Non-market values, as they are called, have increasingly been recognized to provide significant economic value to society. However, no consistent systematic framework currently exists for measuring non-market values from place to place and resource to resource, although a large number of studies have attempted to estimate these values. Measuring non-market value requires a great deal of time and significant financial resources and is therefore beyond the scope of the current study. Nonetheless, the reader should understand that the findings of this study represent only one component of the overall value of Casco Bay, and the value of the Bay likely extends well beyond these market-based measures.

Past research

While there are several studies and analyses of the regional economy in the Casco Bay region and numerous others on the environmental and ecological contribution of Casco Bay, there has been but one study that explicitly quantifies the economic value of Casco Bay (Colgan 1990).[6] This

[6] Several organization, research centers, and government bodies have reported relevant economic data and activity that is connected to Casco Bay and are valuable resources for the reader. These include The City of Portland's Comprehensive Plan (2017), the Island Institute's Waypoints 2016 Community Indicators, the Gulf of Maine Research Institute's publication and project database, the National Ocean Economics Program at the Monterey Institute for the Blue Ocean

study provided several measures of the market value of goods and services in the Casco Bay region that were linked or dependent upon the Bay and served as a part of the impetus for a federal designation naming Casco Bay an estuary of national significance, and forming the Casco Bay Estuary Partnership.

Two measures of market value were used in the 1990 study, including:

1. A broad approximation of market value based on the concept of Gross Domestic Product[7] (GDP); a measure of the final market value of all goods and services, and
2. Industry-based estimates that capture more detailed data on activity directly tied to Casco Bay, including port activity, fishing, and recreational boating.

The study also provided approximate estimates of nonmarket values from parks and wetlands, values derived from investments in environmental management, and value of land and housing in shore adjacent communities.

Rather than specific industry sectors such as those used in the current methodology, economic activities were broken down by those that were "coast-dependent," "coast-linked," and "coastal services." The first measure refers to activity that directly draws upon Bay resources, such as fishing, marine transport, and beach or boating recreation. Coast-linked refers to the supplier industries that provide intermediate input goods and services that support coast-dependent activities. Coastal services include all other coastal economic activity such as retail, business services, and other service activities that support tourists and residents of the region.

The primary finding of the 1990 study revealed that over $520 million on a GDP basis in output and about 13,000 jobs were associated with Casco Bay. This translates into approximately $1.09 billion of output in today's dollars (2017). While these values are not directly comparable to the present analysis because of differences in methods and data sources, they do provide a general reference point. However, the estimates in the 1990 study were subject to limitations related to the availability of data and lack of a consistent framework for analyzing coastal and ocean economies. Since 1990, data and technology for measuring and tracking economic value of ocean economies

Economy, and the US National Oceanic and Atmospheric Administration's Digital Coast and Economics: National Ocean Watch online portals.

[7] Gross national product (GNP) is the broadest measure of economic activity and includes any production of a person or entity associated with a geography, in this case the Casco Bay region, regardless of where the production took place. Gross domestic product (GDP) or gross regional product (GRP) refer to total production that takes place within a geography. Alternatively, GNP can be thought of as production linked to the people and firms of a geography or nation, while GDP is linked to the production that takes place within the geography or nation. GNP is much less commonly used at present. The Colgan (1990) study estimated Casco Bay's value based on national GNP estimates.

have significantly improved.

Structure of report

The remainder of the report is structured as follows. Chapter 2 describes the methodological framework used in developing this report and that can be applied to future measurement of the Casco Bay economy. Chapter 3 provides a regional overview of the broader watershed economy of Casco Bay - that is, all economic activity that occurs in the watershed region - and its role in the broader state economy. Chapter 4 provides our estimates of the ocean economy of Casco Bay and discusses the contribution of each of the ocean sectors defined and employed by NOEP and NOAA. Chapter 5 provides a discussion of the potential implications of ocean economy sectors due to changes in Bay health, including changes brought about by sea level rise, ocean warming, and ocean acidification. The last section provides conclusions of the study and direction for future research.

Chapter 2: Methodological Framework

One of the outcomes of this study is to establish a systematic process to track the economic contribution of Casco Bay over time. This study draws upon the methodological measurement framework developed by the National Ocean Economics Program (NOEP) and used by the National Oceanic and Atmospheric Administration's (NOAA) Economics National Ocean Watch (ENOW) program to monitor economic activity associated with the nation's oceans and coastal regions in a consistent manner (Colgan 2007).[8] The framework used in the present study of Casco Bay considers two components: the watershed economy, comprised of all economic activity that occurs in the Casco Bay watershed region; and the ocean economy, which is comprised of more specific economic activity that is either directly or indirectly dependent upon the natural resources provided by Casco Bay and its watershed. While our analysis of the watershed economy provides a broader picture of the importance of the broader economy in relation to Casco Bay, the measurement of the Casco Bay ocean economy is a measure of the 'economic contribution' Casco Bay makes to the broader watershed and Maine economies. This chapter proceeds with a detailed framework used in our analysis that may be used in future years to monitor and track the economic contribution of Casco Bay.

Following NOEP definitions, we define the Casco Bay coastal watershed economy as inclusive of all economic activity that takes place in the coastal watershed zone regardless of its link to the ocean. It is the broadest definition of economic activity in the coastal region and is designed to measure the type and scope of activity shaping land and resource use in coastal areas. Coastal regions are attractive to people and businesses not only because of direct economic activity associated with the ocean, but also for other reasons, including history, prior concentration of economic activity, and quality of life. Assessments of the coastal economy clarify the degree to which economic activity is concentrated in coastal regions. In the case of the current study, we refer to this broad definition as the "watershed economy" and assess the watershed economy throughout the Casco Bay Watershed Region (CBWR) by estimating economic activity that takes place throughout the watershed region ("the region"). We characterize the size and composition of the Casco Bay watershed economy in Chapter 3.

NOEP's definition of the ocean economy is a more specific representation of marine dependent economic activity and is the focus of our measurement of the economic contribution of

[8] More information on the NOEP and this framework can be found at www.oceaneconomics.org.

Casco Bay. NOEP defines the ocean economy as inclusive of ocean dependent economic activity which directly or indirectly uses the ocean as an input. Explicitly, economic activity is included in the definition of the ocean economy when it either "(1) is included in an industry whose definition explicitly ties the activity to the ocean (ex. Deep Sea Freight Transportation), or (2) is located in an industry which is partially related to the ocean and is located in a shore-adjacent zip code (ex. Hotels in Cape Elizabeth)." (Colgan 2007, pg. 5).

The Casco Bay ocean economy is comprised of 5 sectors: Tourism and Recreation, Ship and Boat Building, Marine Transportation, Living Resources, and Marine Construction. These sectors include 37 detailed industries defined using the North American Industrial Classification System (NAICS) and shown in Table 2.1.[9] These definitions are consistent with that of the NOEP sector definitions, with the exception of slight modifications in the tourism and recreation sector, to include additional industries deemed relevant to Casco Bay's tourism economy. We refer to the ocean economy of Casco Bay as "the bay economy" throughout this report.

We report on three primary macroeconomic indicators across the ocean sectors to characterize the size and value of the ocean economy: employment, average earnings, and gross regional product (GRP). These indicators are the most common and straightforward measures used in industry and economic studies of economic activity and are the core indicators used in NOEP's framework. Employment is a measure of the number of jobs, while average earnings are reported for each industry and ocean sector to provide comparison of the differences in job 'quality'. Relative average earnings can also be considered a comparison of skill requirements of different industries and ocean sectors. GRP is a measure of the contribution of the ocean economy to the final market value of goods and services produced in the economy and can be considered a measure of the 'size' of the ocean economy. GRP is analogous to the commonly reported macroeconomic indicator 'gross domestic product' (GDP) reported for the nation. In this case, GRP is measured as sales minus the cost of inputs, also referred to as 'value-added'. In addition to employment and GRP, we report supplemental indicators for each sector including average earnings of workers and sector specific data. We also report on employment and GRP, in addition to other pertinent economic measures, for the entire watershed economy in Section 3.

[9] The NOEP ocean economy definition includes a total of 6 sectors, including offshore minerals. The offshore minerals sector is very limited in the Casco Bay watershed (less than 10 jobs) and is therefore excluded from our definition of the ocean economy of Casco Bay for purposes of this analysis. However, in the event an offshore minerals sector were to develop significantly in the future, it should be included in a full accounting of the Casco Bay ocean economy.

Table 2.1: Industry Definitions of the Ocean Economy Sectors

Sector	Industry		NAICS
Tourism and Recreation	Amusement & Recreation Services	*All Other Amusement & Recreation Industries*	713990
		Museums	712110
		Sports and Recreation Instruction	611620
		Recreational Goods Rental	532292
	Boat Dealers	*Boat Dealers*	441222
	Eating & Drinking Places	*Cafeterias, Grill Buffets, and Buffets*	722514
		Full-Service Restaurants	722511
		Limited-Service Restaurants	722513
		Snack and Nonalcoholic Beverage Bars	722515
		Drinking Places (Alcoholic Beverages)	722410
	Hotels & Lodging Places	*Bed-and-Breakfast Inns*	721191
		Hotels (except Casino Hotels) & Motels	721110
	Marinas	*Marinas*	713930
	RV Parks & Campgrounds	*Recreational & Vacation Camps*	721214
		RV Parks & Campgrounds	721211
	Scenic Water Tours	*Scenic & Sightseeing Transportation, Water*	487210
	Sporting Goods	*Sporting Goods Stores*	451110
	Travel arrangement & Reservation Services	*All Other Travel Arrangement/Reservation Ser*	561599
		Convention and Visitors Bureaus	561591
		Tour Operators	561520
		Travel Agencies	561510
Ship and Boat Building	Ship Building and Repairing		336611
	Boat Building		336612
Marine Transportation	Freight Transportation Arrangement		488510
	General Warehousing and Storage		493110
	Marine Cargo Handling		488320
	Navigational Services to Shipping		488330
	Other Support Activities for Water Transportation		488390
	Port and Harbor Operations		488310
	Refrigerated Warehousing and Storage		493120
Living Resources	Animal Production and Aquaculture		112000
	Finfish Fishing		114111
	Fish and Seafood Markets		445220
	Seafood Product Preparation and Packaging		311710
	Shellfish Fishing		114112
Marine Construction	Oil and Gas Pipeline and Related Structures Construction		237120
	Other Heavy and Civil Engineering Construction		237990

Source: Colgan (2007); National Ocean Economics Program (NOEP); author adaptations.

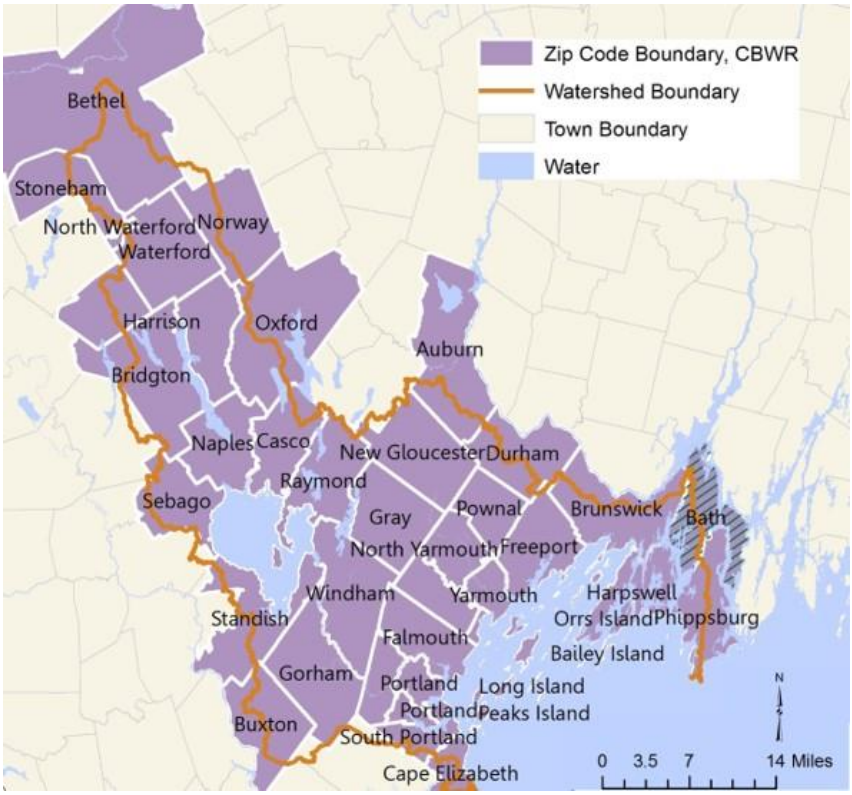
Geographic definition of Casco Bay [10]

Ecological boundaries do not align with political boundaries. Similarly, economies do not neatly adhere to political or ecological boundaries. While Casco Bay is largely included in Cumberland County, the watershed also stretches into parts of Oxford and Androscoggin counties.

[10] Geographic definition of Casco Bay watershed provided by Casco Bay Estuary Partnership.

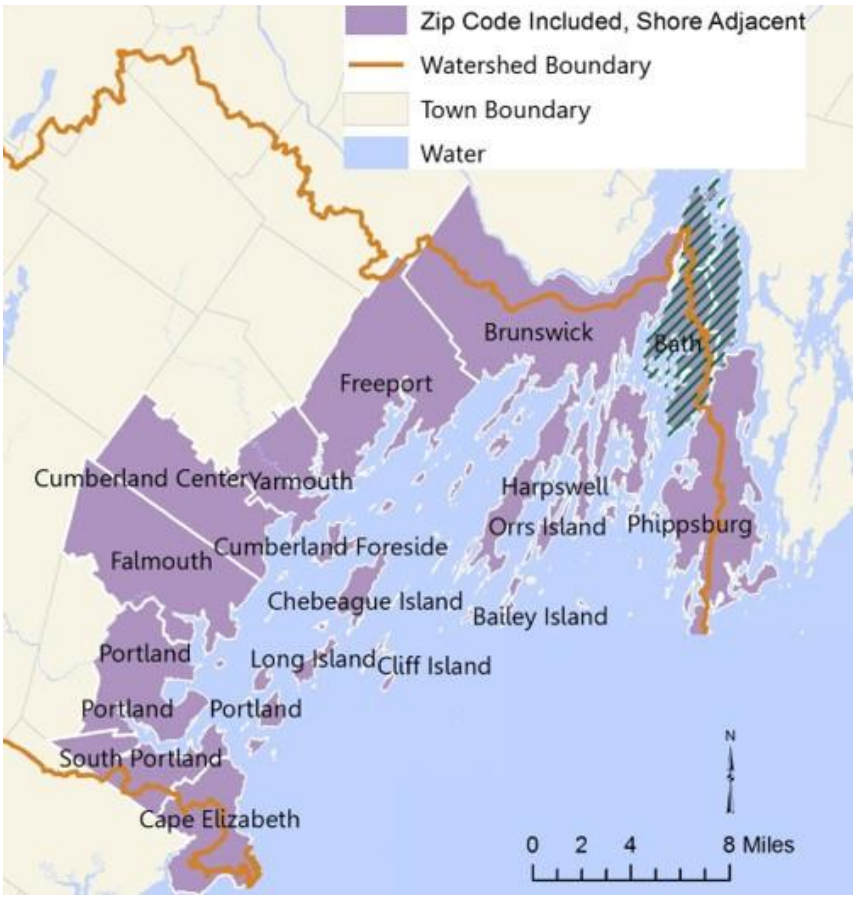
Likewise, Cumberland County includes municipalities outside of the Casco Bay watershed region. For the purposes of this study, we provide geographic definitions as follows. The Casco Bay watershed region, also referred to as the CBWR or the watershed economy, is comprised of 54 zip codes that are either all or in significant part within the ecological watershed boundary. Those municipalities that are included are shown and labeled in Figure 2.1 and listed in Table A.1. in Appendix A. We also distinguish zip codes and municipalities that are 'near-shore' or 'shore adjacent' to align with the operational definition of ocean economy used by NOEP and ENOW, and include 25 zip codes in 14 municipalities that are bordered by Casco Bay and are shown in Figure 2.2 and listed in Table A.2. of Appendix A.

Figure 2.1: Zip Code Geographic Definition of the Casco Bay Watershed Region



Note: Zip codes included in the watershed definition are listed in Table A.1 of Appendix A.

Figure 2.2: Zip Code Geographic Definition of the Casco Bay Ocean Economy (Shore Adjacent)



Note: Zip codes included in the shore adjacent definition are listed in Table A.2 of Appendix A.

There is one important implication to these definitions that warrants discussion. The ecological boundary of the Casco Bay watershed is inclusive of West Bath (See Figure 2.1 and 2.2 hatched area). Under our geographic definition of the ocean economy (near-shore zip codes), West Bath shares a zip code with the town of Bath, which does not fall within the Casco Bay watershed. For most ocean sectors, including activity in Bath does not make a significant impact. However, Bath is home to Bath Iron Works, a major shipbuilding employer and contributor to the region's economy, which also comprises one of the ocean sectors (Ship and Boat Building). Including shipbuilding in Bath runs the risk of inflating the total value of the Casco Bay economy, despite the fact that BIW technically lies outside of the Casco Bay watershed boundary. However, Bath Iron Works, as a major employer, is heavily integrated and has a significant impact on the broader regional economy, including within the Casco Bay watershed. To address these concerns, we present

our estimates both with and without BIW. The default estimates for the Casco Bay ocean economy summary exclude BIW.

Data sources

This analysis draws upon a variety of data sources to provide a comprehensive overview of activity in each ocean economy sector and for the entire watershed economy (Section 3). The primary data source for measurement of the economic contribution of the ocean economy is economic data provided by Economic Modeling Specialists Inc. (EMSI), a proprietary source of economic and workforce data. EMSI data is based on public secondary economic, labor market, and demographic data from the BEA Regional Accounts, US Census, and US Bureau of Labor Statistics (BLS) Quarterly Census of Earnings and Wages (QCEW).

There are two primary advantages to using EMSI as a data source for this analysis. First, EMSI provides comprehensive industry data by zip code, which allows us to build a region that is more reflective of the Casco Bay watershed than is typically available. Most detailed economic data are only available by county or Metropolitan Statistical Area (MSA), which serve as the basis for how NOAA ENOW and NOEP data are reported. Second, EMSI provides estimates of self-employed persons that are typically not included in traditional industry employment data. Traditional employment data is derived principally from the BLS QCEW data series, which is derived from federal and state unemployment insurance programs. QCEW data includes most private employment, with the exception of self-employed workers, railroad employees, the military, and certain types of employment including most jobs in the fisheries harvesting sector. Many workers in the living resources sector, such as Maine lobstermen or fishermen, are self-employed and therefore are not well captured in the QCEW data. EMSI's industry data is compiled from QCEW data, combined with the US Census Non-employer Survey, which captures self-employed individuals, and more closely reflects total employment in an industry.

Limitations of data and methods

Like most data sources and methodological frameworks, those discussed here are subject to certain limitations. The primary limitation is that because of the nature of the NAICS classifications it is impossible to distinguish exactly which employment in an industry is directly or indirectly related to Casco Bay or the ocean economy. This is particularly a challenge in the tourism and

recreation industry, which includes retail and restaurants, for instance. Some of these businesses undoubtedly serve local markets in addition to visitors to the region. However, it is impossible to differentiate which employment can be attributed to tourism and which to the local market demand. In aggregate, it can be assumed that without demand for recreation and tourism, many businesses may not be able to continue operation. Likewise, there are subtleties in the marine transportation sector, which is defined using industries that serve not only marine markets, but also land-based transportation that has nothing to do with marine transport. Again, if this is the case there is no means to differentiate the share of economic activity that is directly or indirectly connected to the ocean economy. Given the location, however, it is likely that most if not all firms in these general industries serve the ocean economy in some way and are therefore appropriate to include in economic measures. Despite the minor limitations, primarily related to data availability, the method to assess the economic contribution of Casco Bay draws upon a well-established and utilized method for understanding economic activity linked to the ocean and coasts and one that is used by the US government (NOAA), which faces similar data challenges.

Long-term economic monitoring

The methods and definitions put forth in our framework can be used to measure changes in the Casco Bay ocean and watershed economies over time in a consistent manner. Geographic and industry definitions have been provided, while additional data sources for supplemental information specific to each sector's analysis in Section 4 is outlined in the Appendices. It should be clear however, that the primary indicators used to characterize the size and contribution of Casco Bay in terms of market values are GRP, employment, and average wages. These measures can be consistently tracked through time and across sectors. While we use a proprietary platform to collect employment, earnings, and GRP data (EMSI), these data can easily be replicated from publicly available data sources discussed in this section, including the BLS QCEW employment and wages data, the US Census non-employer employment data and zip code business patterns, and the US BEA regional economic accounts data which reports on gross regional product.

Chapter 3. The Casco Bay Watershed Economy

The purpose of this chapter is to place Casco Bay into a regional economic context. In doing so, we provide a discussion of the Casco Bay watershed economy which includes all economic activity that occurs within the Casco Bay watershed region, regardless of whether it is directly linked to Casco Bay. In line with NOEP's framework, we use common economic measures, including GRP, employment, and population, which underlie economic growth. We first discuss the importance of the Casco Bay region and the region's contribution to the state's economy. Next we provide an overview of the industry sectors, in terms of employment, employment growth, and specialization that comprise the broader regional economy. We then provide a discussion of population change, a factor that underlies all economy growth. This chapter concludes with a brief discussion of regional workforce challenges, a key issue facing firms and companies in the region.

The Casco Bay region in context

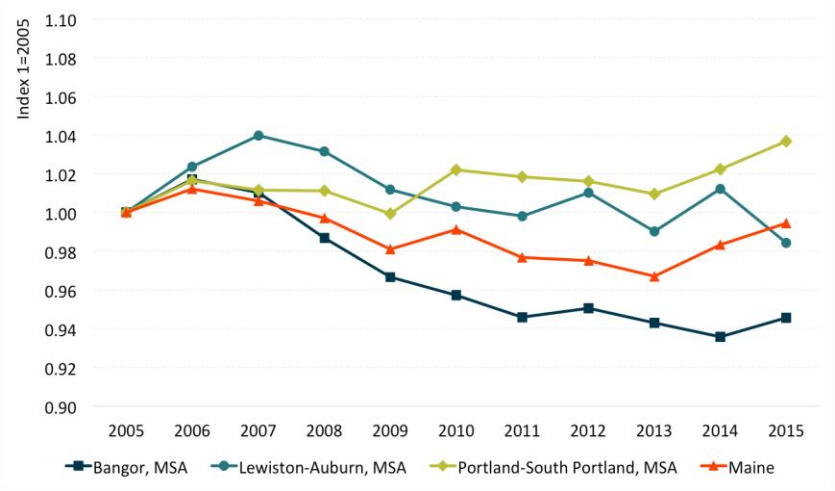
The Casco Bay region lies at the economic and cultural center of Maine and maintains locational advantages relative to other areas of the state due to its proximity to one of the largest innovation and technology centers in the world in Boston, as well as a diverse network of transportation connectivity via road, air, rail, and marine transport infrastructure. Casco Bay is home to the City of Portland, the largest city in Maine and the northernmost urban region situated on the east coast of the US, boasting trade networks with Atlantic Canada and North Atlantic European countries. The region has developed as the service center of Maine and is home to a diverse set of industries, including healthcare and education, manufacturing, tourism, and business and professional service industries that rely on access to dense labor pools of skilled workers and advantages provided by urban scale economies. These factors contribute to the economic engine that is the Casco Bay region.

The Casco Bay region is situated within the Portland Metropolitan Statistical (MSA) area which includes all of Cumberland County, in addition to Sagadahoc and York counties. The Portland MSA accounted for just over 50 percent of the state's total economic output measured by GRP in 2015.[11] The region's share of the state's total output has been growing as other parts of the

[11] Source: US Bureau of Economic Analysis, Regional Accounts. Gross regional product is analogous to the countrywide measure Gross National Product (GNP) which is a measure of the market value of all final goods and services produced in the region. Measurement of GRP varies slightly from GNP, in that the regional and state measure excludes some activity, such as federal government output, though this is included in national measures (GNP). GNP and GRP are

state struggle with declines in traditional industries as well as in population levels. Since 2005, the Portland MSA has been the only region to show an increase in real GRP, increasing by just about 4 percent (Figure 3.1). The state as a whole has only recently returned to a level of output achieved prior to the 'Great Recession' which began in 2008. The other metropolitan areas in Maine (Lewiston-Auburn and Bangor) have struggled to regain a consistent growth path and return to prerecession levels.

Figure 3.1: Real Gross Regional Product Growth Index, 2005-2015



Source: US Bureau of Economic Analysis, Regional Accounts. Real GRP growth index calculated using millions of constant 2009 dollars to account for inflation.[12] Growth rate indexed to base year of 2005 = 1. Index indicates change in real GRP relative to base year.

The struggles of Maine's other MSAs are largely a result of declines in core manufacturing industries, such as pulp and paper manufacturing, which have suffered severe declines over the past several decades as a result of global market and production pressures. Ultimately, these dynamics reflect a more fundamental shift in the industrial composition of economic activity away from traditional manufacturing and durable goods to an economy oriented around services, information, and innovation. These growing sectors tend to locate in more urban areas where access to dense labor pools of talented workers are higher. Likewise, there is overwhelming evidence that these types of workers will prefer to live in places with high quality of place aspects such as access to natural

standard broad economic measures of regional and national economic activity used by economists and policymakers to gauge a region's and nation's growth.

[12] The underlying real GRP values in this index used chain-weighted dollars expressed using 2009 as a base year. Chain-weighted dollars are a method for accounting for differences in value that arise as a result of changes in prices (i.e., inflation). The result is annual values that are comparable and controlled for price changes.

amenities, and will in fact make location decisions based in part on high quality of life measures (Moretti 2012).

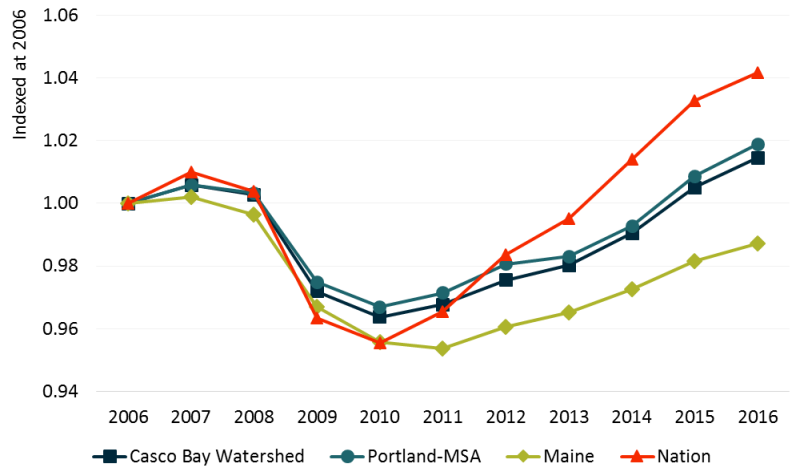
The effect is that any growth in the state's economy has been a result of growth in southern Maine (measured by the Portland-South Portland MSA) and the Casco Bay region specifically, which is clearly reflected in Figure 3.1, especially over the last three years shown. This trend is expected to continue into the foreseeable future, when a majority of economic growth that does occur in Maine, will likely concentrate in the Portland and Casco Bay region, the largest urban center in the state. In fact, in 2016, GRP for the Casco Bay watershed region is estimated to have reached $17.1 billion, making up about 64 percent of GRP of the Greater Portland-South Portland MSA ($26.7 billion) and one-third of Maine's total GRP ($54.1 billion).[13]

Regional industry employment overview

The watershed economy employs (on a place of work basis) about 219,000 people, making up about 32 percent of total state employment. Overall employment growth has been meager since 2006, up just 1.4 percent over the 10-year period because of the intervention of the Great Recession (Figure 3.2). Recovery after the 2009-10 recession was much slower compared to the US as a whole. Over the five-year period 2011 to 2016 total employment in the CBWR increased by 4.8 percent or 10,085, about half the US employment growth rate (8 percent), though slightly faster than the state of Maine, where jobs increased by 3.7 percent (24,400 jobs).

[13] Source: EMSI 2017.1 data based primarily on the Quarterly Census of Employment and Wages (QCEW) from the Bureau of Labor Statistics (BLS) and the Bureau of Economic Analysis (BEA).

Figure 3.2: Employment Growth Index, 2006 - 2016



Source: Economic Modeling Specialists Inc. (EMSI), 2017.1 data series. Growth rate indexed to base year of 2006 = 1. Index indicates change in real GRP relative to base year.

Understanding which industries are growing and why is at the heart of any regional economic analysis and is of interest to both business leaders and policy makers. The focus is often on the industries that employ the most people, which industries are growing or declining, and which industries are most concentrated in a region. Like species in an ecosystem, economic activity is not equally distributed across space and it is important to have an understanding of the industrial characteristics of a region, particularly with respect to understanding a more specialized sector of the economy, such as the ocean economy.

Figure 3.3 shows the level of employment (bubble size), employment growth from 2006 to 2016 (X-axis), and the degree to which each industry is specialized in the Casco Bay watershed region, (Y-Axis) for 13 high level industry sectors.[14] Industry specialization is measured with location quotients (LQs) which are a way of measuring the relative specialization of a given industry in a region compared to a reference geography.[15] This measure is used to highlight specialized industries within the Casco Bay watershed region relative to the Maine economy. It should be clear from the chart that the industries concentrated in the Casco Bay region are based around services, including financial activities, professional and business services, and to a lesser extent information and trade

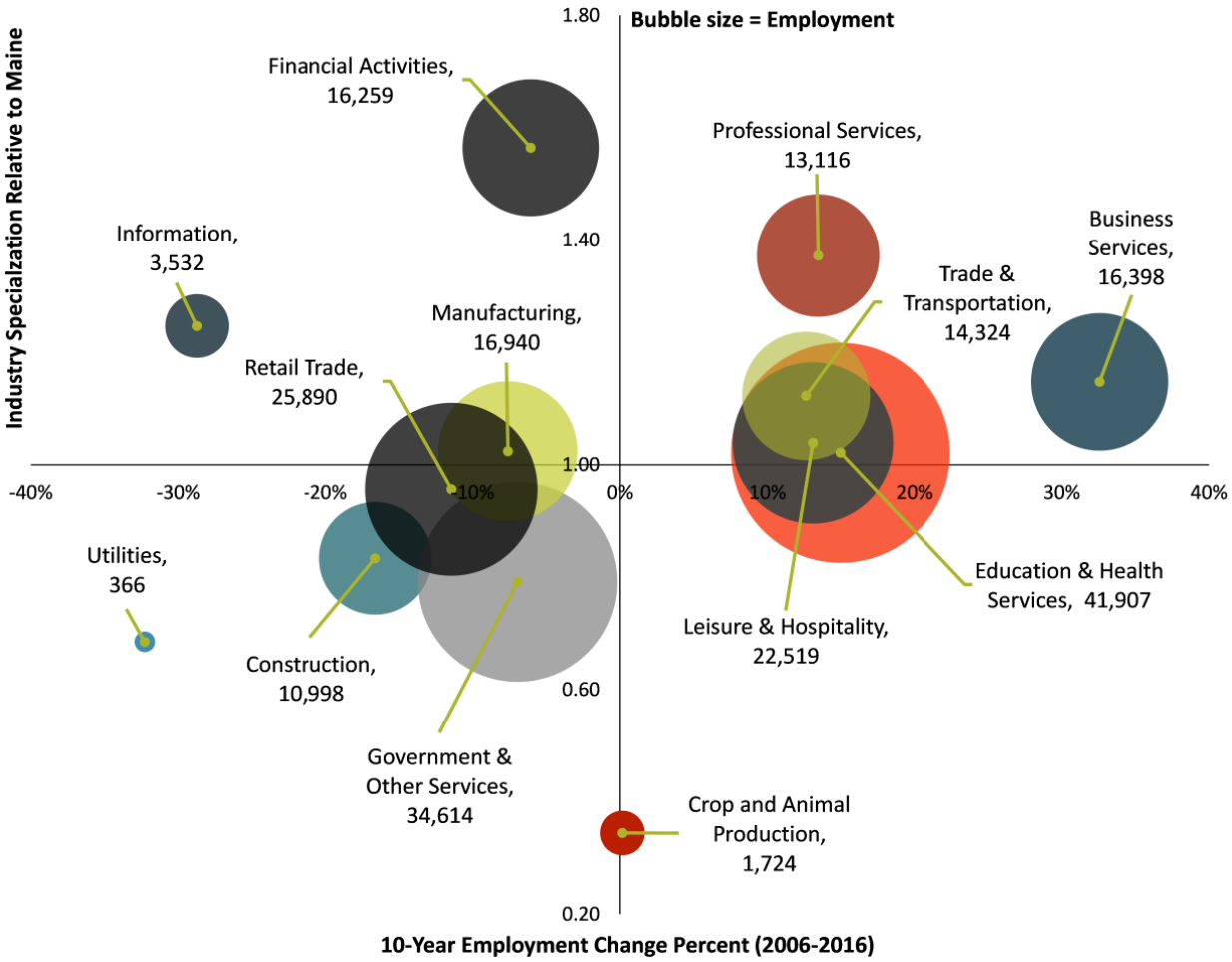
[14] The industry sectors are based on 13 'super sectors' under the NAICS (discussed in Chapter 2). The super sectors are high-level industry sectors that provide a broad overview of industrial activity.
[15] When interpreting location quotients, a value greater than 1 means a larger share of employment in the region is specialized/concentrated in the respective industry, while a value below 1 suggests the industry is less specialized/concentrated. Values are relative to Maine.

and transportation, all of which have an LQ above 1.The largest non-government (public administrative) sector employment is in the education and health services sector (41,907), retail trade (25,890), leisure & hospitality (22,519), business (16,398), financial (16,259), professional services (13,116), and manufacturing (16,940).[16] These sectors are anchored by some of the region's and state's largest employers including MaineHealth, Unum, LL Bean, WEX, and IDEXX, among a number of other significant firms.

Health care has been a significant driver of much of the employment growth over the last decade and a half, although in recent years, growth rates have slowed and have been replaced as the leader by growth in professional and business services. Industries within the business services sector increased by 33 percent from 2006 to 2016; education & health services increased by 15 percent; and professional services, leisure & hospitality, and trade & transportation all increased by 13 percent over the same 10-year period. The significance of this is that the types of workers in these industries (business, education, and professional services) are typically higher skilled workers and prefer high quality of place, while leisure and hospitality workers are also highly dependent on the quality of place to attract tourists. As these industries continue to grow and become more specialized in the region, natural amenities provided by Casco Bay that help attract workers and tourist spending and contribute to quality of place will become increasingly important.

[16] For sector industry NAICS definitions, refer to https://www.census.gov/eos/www/naics/.

Figure 3.3: Industry Employment, Growth, and Specialization, 2016



Source: EMSI, 2017.1 data series. Includes QCEW, non-QCEW, and self-employment. Specialization is measured relative to the state of Maine and expressed as a location quotient. A value greater than 1 indicates specialization in the region and a value under 1 indicates a smaller relative share of the industry in the region.

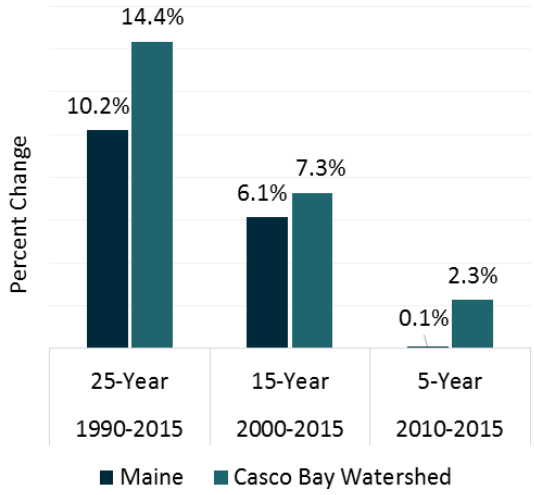
Population growth and change

Population dynamics underlie all economic change. A region's ability to grow or decline is directly tied to the growth or decline in population. Likewise, understanding interregional population movements, including where people live and where people work, is important to understanding how the location of economic activity *within* the region is changing.

Since 1990, the population residing in the Casco Bay Watershed region has increased by 14.4 percent to 332,215, roughly a quarter of the State's total population in 2015 (Figure 3.4). The total population within the region has grown by 7.3 percent (22,566 persons) between 2000 and 2015, while the remaining portion of Maine's population grew at just 4.3 percent (54,250 persons) over the

same time period. However, more recently any population growth experienced in the state has been in the Casco Bay and Southern Maine region.

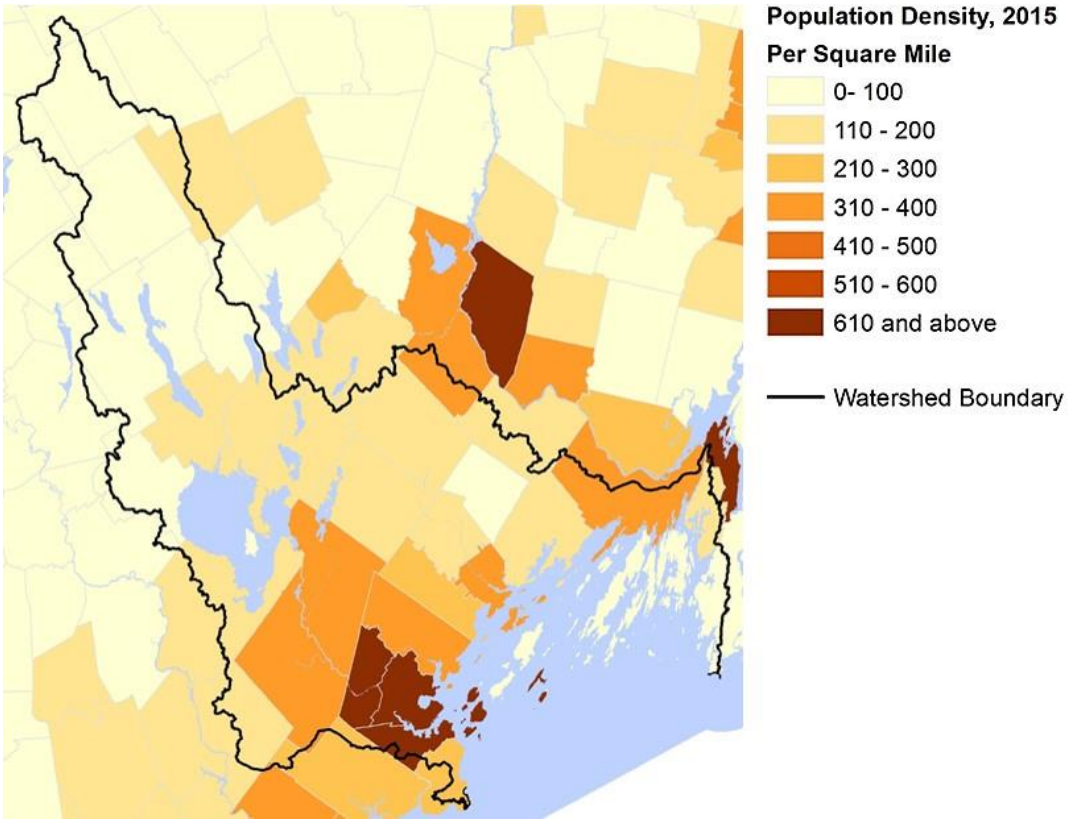
Figure 3.4: Population Growth in CBWR and Maine, 1990-2015



Source: US Census, Population Estimates; American Community Survey (ACS) 5 year estimate 2011-2015.

Population is split somewhat evenly between coastal municipalities (53 percent) and those that are inland (47 percent). Over both the 1990-2015 and 2000-2015 periods, the inland population increased more than 3 times faster than the coastal population, but during the most recent 5-year period (2010-2015) inland and coastal populations grew at roughly the same rate, 2.3 and 2.2 percent respectively. As expected, the highest levels of density are in downtown (especially peninsular) Portland, with people somewhat more dispersed away from the urban center and deeper into the watershed region, where most areas are considered rural (Figure 3.5). Most inland growth in the past has been characterized by sprawl and lower density development. While there has been some reinvigoration of the urban areas in Portland and South Portland, it is unclear to what extent these trends will continue or whether land use development trends will revert to sprawl. This is also closely tied to commercial and industrial development, which has trended towards locating in the areas surrounding Portland in recent years. The shape of future growth will have very significant implications for the health of the watershed.

Figure 3.5 Population Density by Municipality in the Casco Bay Region, 2015

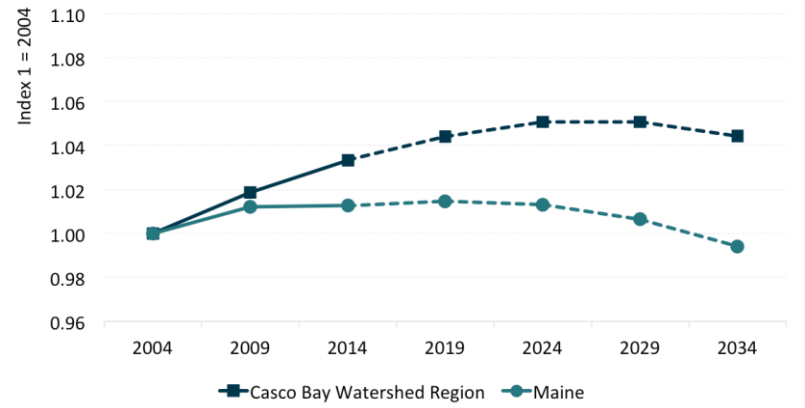


Source: US Census, Population Estimates; ACS 5 year estimate 2011-2015.

Figure 3.6 illustrates population trends from 2014, projected to the year 2034.[17] Within the Casco Bay Watershed region population is projected to increase by 1.7 percent or by 5,534 over a ten-year period from 2014 to 2024, after which population is expected to remain stagnant before beginning to decrease slightly by 2034. This runs counter to the statewide population projections which are forecast to be flat or show slight declines before falling sharply. Maine has among the oldest population of any state in the US, and as people age, they have fewer children. Given Maine's older population, virtually all of this growth is predicated to reflect in-migration, including both domestic and international, as the region is home to a number of refugee and immigrant resettlement populations. Migration patterns, particularly in Maine, have been notoriously difficult to predict and can fluctuate significantly from year to year.

[17] Source: Maine Office of Policy and Management Population Projections; US Census.

Figure 3.6: Population trend and forecast, 2004-2034.



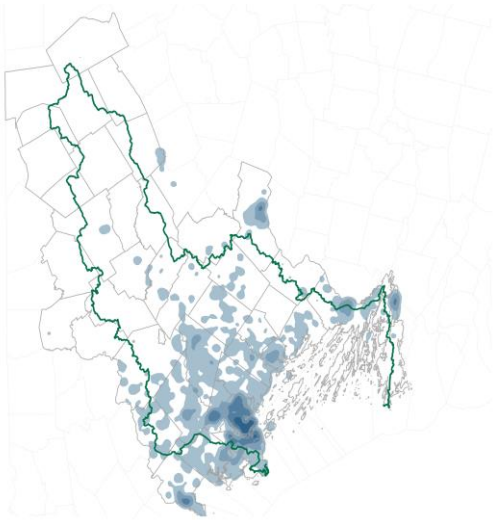
Source: Maine Office of Policy and Management, Population Projections; US Census; MCBER calculations.

The Casco Bay region is not likely to experience the growth pressures of other parts of the US. Still as far as Maine is concerned, both the economic and population growth likely to occur over the next several decades will occur principally in and around the Casco Bay Watershed region.

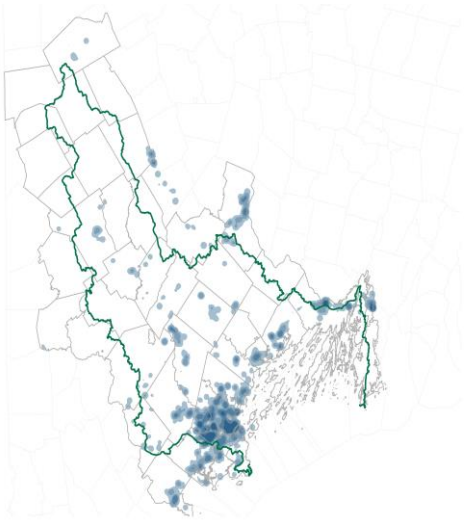
There are distinct differences between where people live in the watershed region and where people work. Figure 3.7A shows the location of where people reside in the watershed region, while Figure 3.7B shows the location of where people work in the region. The region's population swells by about 20 percent with the daily work commute, where job locations are concentrated in just a few job centers in the region. Jobs are most dense in Portland, where approximately 57 percent of the people who work in the City, commute from away (US Census 2014). Concentration of jobs also exists in South Portland and in coastal municipalities along the Route 1 corridor running north with pockets in Falmouth, Yarmouth, and extending into Brunswick.

Figures 3.7 A & B: Live and Work Commuting Patterns in the Casco Bay Region

A



B



Source: US Census, On the Map; MCBER representation

Regional workforce challenges

Like the rest of Maine and many New England regions, the Casco Bay region is facing challenges related to aging demographics and tight labor market conditions that make it difficult for area businesses and organizations to find appropriately skilled labor to meet demand. Many regional industries, including manufacturing, health care, and ocean sectors, are facing an aging workforce that threatens to impede competitiveness.

Furthermore, many of the industries that are growing in the Portland region, such as business and professional services, require high skilled workers with higher levels of formal educational training. The shift towards more service oriented, knowledge based industries in the Portland region will mean a need to recruit and retain these high skilled workers. There is overwhelming evidence that these types of workers, in general, prefer places with high amenities, including natural and cultural (Brookings Institute, 2006). Casco Bay has a critical role in helping to attract high skilled workers to the region which is fundamental to the economic competitiveness of these types of industries.

Chapter 4. The Ocean Economy of Casco Bay

This section provides estimates of the economic contribution of Casco Bay's ocean economy using the framework discussed in this report's Introduction and Chapter 2. This chapter first provides an overall summary of the estimated economic contribution of Casco Bay's ocean economy in terms of direct employment and GRP, as well as average earnings. This is followed by employment estimates of the indirect and induced effects (also referred to as multiplier effects) of ocean economy employment. This chapter then discusses each of the 5 ocean sectors in the Casco Bay ocean economy in more detail by first discussing the core employment and GRP measures, followed by discussion of 'supplemental data' specific to each sector that provides a more robust understanding of economic activity associated with that sector. By using consistent industry and geographic definitions, measurement indicators (employment and GRP), and economic data sources (EMSI), this framework allows sectors to be both compared across ocean sectors and aggregated to present an overall consistent estimate of economic contribution.

The Economic Contribution of Casco Bay

The ocean economy of Casco Bay accounted for $704 million of GRP in 2016 and supported approximately 18,500 jobs (Table 4.1). Ocean economy GRP accounts for 4.1 percent of the total Casco Bay Watershed economy's GRP and 1.3 percent of the total Maine economy. Measured in terms of employment, the ocean economy accounted for 8.5 percent of total watershed employment and 2.7 percent of Maine employment. As a point of comparison, the entire US ocean economy accounted for about 2.2 percent of national GDP and employment in 2013 (NOEP). As a point of comparison, the Maine Forest Products industry had total direct employment of 16,550 jobs in 2014 (Maine Forest Products Council).

Ocean economy employment growth has been steady since 2006, growing by 16 percent over the 10 year period, which is significantly higher than the watershed economy as a whole, which grew at just over 1 percent over the same period. The largest source of jobs is tourism and recreation (14,800), accounting for 80 percent of all ocean economy employment. Marine transportation accounted for over 2,400 jobs in 2016 and upwards of $126 million in GRP. Despite a close association in many people's minds to ocean activity, the living resources sector makes up just 11 percent of all bay economy GRP. Employment in that sector is estimated at about 1,140 jobs,

though there are measurement challenges related to employment, discussed below. Marine construction makes up a very small share of the overall ocean economy.

Table 4.1: Economic Contribution of the Casco Bay Ocean Economy, 2016

	Employment				Gross Regional Product	
Ocean Economy Sector	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Total	Number	Share of Total
Tourism and Recreation	14,797	1,561	12%	80%	$491,643,093	70%
Marine Transportation	2,433	1,246	105%	13%	$125,955,604	18%
Living Resources	1,139	-217	-16%	6%	$76,012,659	11%
Marine Construction	94	25	36%	1%	$7,777,813	1%
Ship and Boat Building	30	11	58%	0%	$2,540,313	0%
Ocean Economy Total	**18,493**	**2,626**	**16%**	**-**	**$703,929,482**	**-**

Source: EMSI, 2017.1 data series & MCBER calculations. Note: The ship and boat building sector excludes the zip code inclusive of Bath, which has the effect of excluding Bath Iron Works from these estimates, which is technically not contained in the Casco Bay watershed region.

The same is true for ship and boat building, which accounts for just 30 jobs and $2.5 million in GRP. However, this picture changes significantly if Bath Iron Works (BIW) is accounted for in the Casco Bay ocean economy. With BIW, the ship and boat building sector would account for 6,000 jobs. Likewise, the contribution of the ship and boat building sector to GRP would rise to 43 percent ($533 million) of all ocean sector GRP, making ship and boatbuilding the largest of the ocean economy sectors. Total GRP of the Casco Bay ocean economy would jump to $1.2 billion (Table 4.2). This is discussed in more detail below in the sector specific sections.

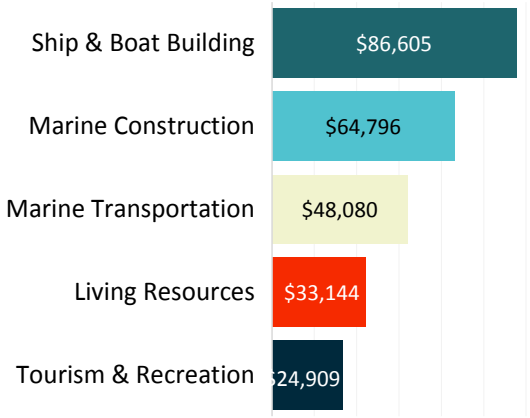
Table 4.2: Economic Contribution of the Casco Bay Ocean Economy, 2016 (Inclusive of Bath Iron Works)

	Employment				Gross Regional Product	
Ocean Economy Sector	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Total	Number	Share of Total
Tourism and Recreation	14,797	1,561	12%	60%	$491,643,093	40%
Ship and Boat Building	6,002	595	11%	25%	$533,180,004	43%
Marine Transportation	2,433	1,246	105%	10%	$125,955,604	10%
Living Resources	1,139	-217	-16%	5%	$76,012,659	6%
Marine Construction	94	25	36%	0%	$7,777,813	1%
Ocean Economy Total	**24,465**	**3,210**	**16%**	**-**	**$1,234,569,173**	**-**

Source: EMSI, 2017.1 data series & MCBER calculations. Note: The ship and boat building sector includes the zip code for Bath, which has the effect of including Bath Iron Works in these estimates.

In general, workers in the bay economy are paid below average earnings ($43,318) compared to the broader regional watershed economy ($53,684), with some exceptions (Figure 4.1). Workers in ship and boat building are paid significantly higher earnings,[18] double the ocean economy average and well above regional watershed average earnings. The sector sells to the federal government and is comprised of mostly union employees, who are paid union wages, typically substantially higher than non-union wages. Second, the sector employs a high share of high skilled occupations, such as engineers, as well as a large share of skilled production workers that earn what is traditionally considered middle class wages. Likewise, marine construction workers, despite the relatively small number, earn significantly higher wages than other ocean economy jobs. The tourism and recreation sector, on the other hand, employs a large number of service sector jobs and seasonal workers. Likewise, those jobs generally do not require high levels of skill or training. Both of these factors are reflected in the lower average earnings for the sector.

Figure 4.1: Average Annual Earning by Ocean Sector, 2016



Source: EMSI, 2017.1 data series & MCBER calculations.

Economic Contributions in the Upper Casco Bay Watershed

By NOEP's definition, tourism and recreation in the ocean economy only includes near shore (shore adjacent) places. However, the upper watershed of Casco Bay, "the Lakes Region," is an important tourist and recreational destination that is tied to the natural amenities that are part of the upper watershed, such as Sebago Lake and Long Lake. While the NOEP ocean economy

[18] Ship and boat building average earnings are based on employment of the 30 jobs and do not account for wages with Bath Iron Works. The average wage in ship and boat building inclusive of Bath Iron Works is $88,367.

definition does not include other sectors that are not shore adjacent, we supplement the analysis with estimates of tourism and recreation in the upper watershed to more accurately capture the economic activity connected to the Casco Bay watershed. Tourism and recreation jobs in the upper watershed contributed another 5,500 jobs and $173 million to GRP.

Direct, Indirect, and Induced Economic Impacts of the Ocean Economy

An important point regarding economic activity in the ocean economy is that virtually all of that activity can be considered "traded," meaning goods and services in the ocean economy typically serve "export" markets rather than local markets. Thus activity in the bay economy has the effect of importing dollars into the region, a process that is fundamental to regional and local economies.

As an additional measure of the full scope of Casco Bay's contribution to the regional economy, we provide estimates of the indirect and induced activity that results from direct jobs, earnings, and output. The indirect and induced effects, often referred to as the multiplier effects, are a result of spending by businesses linked to the Bay at other regional businesses. Indirect activity stems from expenditures of Bay-related businesses on supplies and services. Induced activity reflects the spending by workers of earnings from bay-related industries in the regional economy on things like home repair, groceries, and other goods and services. Money derived from activities in the ocean economy cycles through the regional economy through recurrent rounds of spending. Since the ocean economy can generally be thought of as an exporter of goods and services (importer of dollars to the region), the ocean economy has greater impact than reflected in only the directly supported jobs and income. Of course, many of the businesses in Tourism and Recreation, such as restaurants, also serve the local market. But they serve an important role in attracting visitors, and as a result the money visitors spend, to the region.

Table 4.3 shows the multiplier effects of jobs in Casco Bay's ocean economy sectors. "Direct jobs" refers to employment in the ocean sectors. Indirect and induced jobs are jobs supported by firm and worker consumer spending in the Casco Bay region. These values are based on estimates of industry and consumer spending patterns produced by the US Bureau of Economic Analysis (BEA) and reported by EMSI. Multiplier coefficients can be multiplied by the number of direct jobs to approximate the number of indirect and induced jobs supported elsewhere in the region's economy. For instance, for every 100 jobs in the living resources sector, an additional 36 jobs are supported. In sum, more than 5,700 additional jobs are supported by Casco Bay's ocean economic sectors, bringing total estimated contribution of Casco Bay's ocean economy to regional employment to over

24,000 jobs in 2016. Sectors with the largest multipliers are in high value-added sectors such as ship and boat building (1.58),[19] marine transportation (1.51), and marine construction (1.43). Tourism and recreation is the largest sector in terms of direct employment, and total indirect and induced jobs associated with this sector is also large. Proportional to direct jobs, however, this sector supports many fewer indirect and induced jobs than do the more heavy industrial sectors of the ocean economy.

Table 4.3: Employment Multiplier Effects (Indirect and Induced) of Ocean Economy Sectors, 2016

	Employment		
Ocean Economy Sector	Direct Jobs	Indirect & Induced	Total Jobs
Tourism and Recreation	14,797	4,046	18,843
Marine Transportation	2,433	1,236	3,669
Living Resources	1,139	410	1549
Marine Construction	94	40	134
Ship and Boat Building	30	17	47
Ocean Economy Total	**18,493**	**5,749**	**24,242**

Source; EMSI, 2017.1 data series. Multipliers based on US Bureau of Labor Statistics RIMS II coefficients.

Sector Specific Analyses

In the sections that follow, we provide details of each of the Casco Bay ocean economy sectors. The format includes a brief introduction of the sector, followed by a summary of the detailed NAICS-based industries that comprise each ocean sector and their economic contribution in terms of employment and GRP. This is followed by ancillary data specific to each sector that provide greater insights into the composition and dynamics of each sector, where available and warranted.

Tourism and Recreation

As the slogan "Vacationland" implies, tourism and recreation are fundamentally linked with the Maine brand. Maine is a top destination for tourists from the Northeastern US and Eastern Canada, drawing millions of visitors each year. The Maine Office of Tourism (MOT) estimates approximately 14.1 percent of the state's overnight and day visitors – about 5.57 million people in

[19] Including Bath Iron Works, an additional 3,400 jobs are indirectly supported or induced in the region.

2016 – made the Casco Bay and Portland region their primary destination.[20] Of those visitors, about 58 percent visited for the day, while 42 percent stayed at least one night. People come to the region for the Portland Waterfront and Old Port district and to enjoy the Bay and islands, but also to shop in Freeport and participate in outdoor activities in the Lakes Region in the upper Casco Bay watershed.

Visitors contribute a significant amount of economic activity to the Casco Bay ocean economy. As the largest ocean economy sector, tourism and recreation employed almost 14,800 workers in 2016, increasing by 12 percent since 2006 (Table 4.4). The vast majority of tourism-related jobs (87 percent) and contribution to GRP (83 percent) are in food and drink and lodging.[21] Much of this growth has been driven in and around Portland with a number of new hotels under development or recently constructed, and substantial growth around the gastronomy culture and notoriety of Portland as a foodie and craft beer destination. Growth in the food-related economy is reflected in the increase of eating and drinking employment, which grew by 16 percent since 2006, spanning the Great Recession period. Tourism and recreation also includes industries more directly connected to the marine environment, such as marinas, boat dealers, and water tours, but these industries make up just a small share of the overall sector, though the jobs in these industries tend to pay higher wages than those in food and lodging.

[20] Source: Maine Office of Tourism 2016 Annual Report, accessed at https://visitmaine.com/research/. This estimate is not inclusive of visitors to the Lakes Region of the watershed due to differences in geography. The Maine Office of Tourism includes the upper Casco Bay watershed in another geographic region and does not provide readily interpreted estimates of visitors specific to Lakes Region alone.

[21] Estimates for hotel and lodging places do not include activity related to Airbnb, Vacation Rentals By Owner (VRBO), and other digital sharing economy arrangements that are connected to the tourism and recreation economy, but are not counted in traditional economic data.

Table 4.4: Tourism and Recreation Summary, 2016

	Employment				Gross Regional Product	
Industry Description	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Sector	Number	Share of Sector
Eating & Drinking Places	10,345	1,447	16%	70%	$284,883,982	58%
Hotels & Lodging Places	2,574	231	10%	17%	$125,736,817	26%
Sporting Goods Stores	559	-333	-37%	4%	$20,162,379	4%
Amusement & Recreation Services	537	155	41%	4%	$15,656,610	3%
Marinas	380	-7	-2%	3%	$19,941,975	4%
Travel Arrangement & Reservation Services	194	19	11%	1%	$11,226,287	2%
Boat Dealers	111	43	63%	1%	$9,249,589	2%
RV Parks & Campgrounds	59	-2	-3%	0%	$3,236,035	1%
Scenic Water Tours	39	8	26%	0%	$1,549,419	0%
Tourism and Recreation Total	**14,797**	**1,561**	**12%**	**-**	**$491,643,093**	**-**

Source: EMSI, 2017.1 data series & MCBER calculations.

Sector Specific Supplemental Data

Seasonal population change

A significant seasonal rise of economic activity is accompanied by an influx of people to the region. Populations in the region are estimated to grow by 22 percent on average during the summer season (including the months of July and August) relative to annual average populations, based on shares of seasonal housing in the housing stock and the number of hotels units (Table 4.5).[22] In some cases seasonal population in coastal and small island municipalities swells by 400 percent, as summer residents, vacationers, and tourists visit and stay in the region. Interestingly, the magnitude of the seasonal population influx differs between coastal towns and inland communities, including towns in the Lakes Region. The greatest seasonal increase in population is in non-coastal areas (about 31 percent) primarily around Sebago Lake. This estimate does not include day trippers and other transient visitors to the region which would send the daytime and nighttime population even higher. Increased numbers of visitors are accompanied by increased use of Casco Bay and watershed natural resources.

[22] Our estimates are based on seasonal housing vacancy rates and an assumed average of 4 persons per unit during seasonal months. This measure does not include increases from hotel and motel lodging nor campground and RV park occupancy, as it is difficult to collect vacancy data for all official lodging in the region. Furthermore, this estimate does not include day trippers.

Table 4.5: Seasonal Housing Population Change in the Casco Bay Watershed

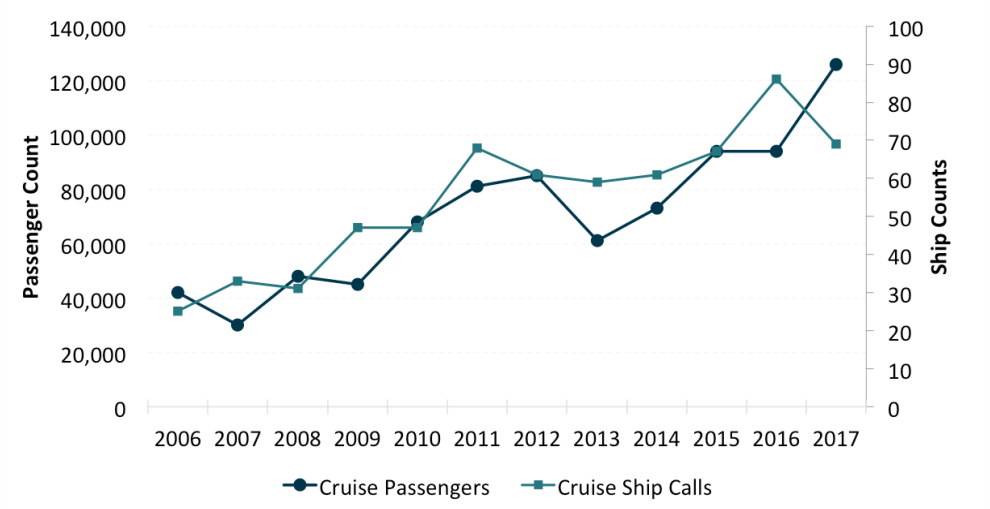
	Population	Seasonal Population	Change	Percent Change
Coastal	172,821	196,792	23,971	13.9%
Non-coastal	151,971	198,999	47,028	30.9%
Watershed Total	324,792	395,791	70,999	21.9%

Source: US Census, 2010 Decennial Census; MCBER calculations.

Cruise ship and passenger ferry activity

With the $6 million expansion of the Ocean Gateway terminal in the Old Port allowing for deeper berthing, larger cruise ships are visiting the Port of Portland, bringing a significant increase in day and night time visitors since 2006. While estimates vary, an estimated 100 ships are scheduled to visit the City in 2017, bringing an estimated 121,000 passengers and 47,000 crew (Figure 4.2).[23] Demand is also increasing for visits starting earlier and extending later in the season with port schedules beginning in May and continuing into the first days of November 2017. While cruise ships bring significant volumes of visitors to the region, the impact of increased spending by visitors at local businesses has not recently been estimated.

Figure 4.2: Port of Portland Cruise Ship Passenger and Port Counts, 2006-17



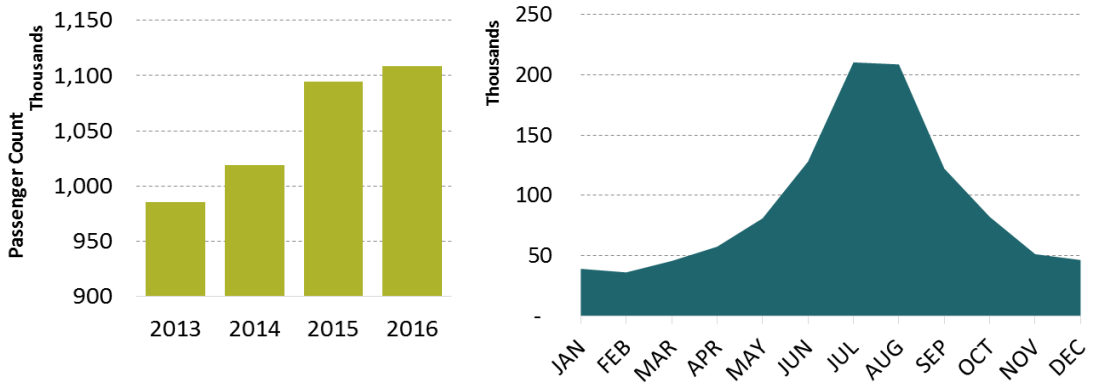
Source: CruiseMaineUSA and Port of Portland (2017). Note: Year 2017 is projected.

[23] Estimates are from Cruise Portland Maine, Cruise Schedule accessed on June 22, 2017 at www.cruiseportlandmaine.com.

In addition, several other passenger operators flow through Portland and within Casco Bay. Bay Ferries operates the Nova Star, a high-speed ferry service between Yarmouth, Nova Scotia and Portland, which transported 35,550 passengers in 2016, mostly visitors destined for Atlantic Canada. Though the number of passengers was well short of previous years' service, the number of passengers is expected to grow as the faster service gains popularity and improves the flow of people between Maine and its neighbors to the north.

The Casco Bay Lines (Casco Bay Island Ferry) includes year-round service from the downtown Portland waterfront to eight Casco Bay islands primarily for year-round and summer residents. Casco Bay Lines also offers charter services, and scenic and special event cruises, which are directly tourism related. Ridership has increased slowly but steadily over the last four years, increasing by 12.5 percent between 2013 and 2016 (Figure 4.3). Ridership intensity follows a clear seasonal trend, increasing in early May, peaking in July and August, before falling off in September and October (Figure 4.4).

Figures 4.3 and 4.4: Intra-harbor ferry total annual (2013-16) and monthly (2016) ridership



Source: Casco Bay Cruise Line; MCBER calculations.

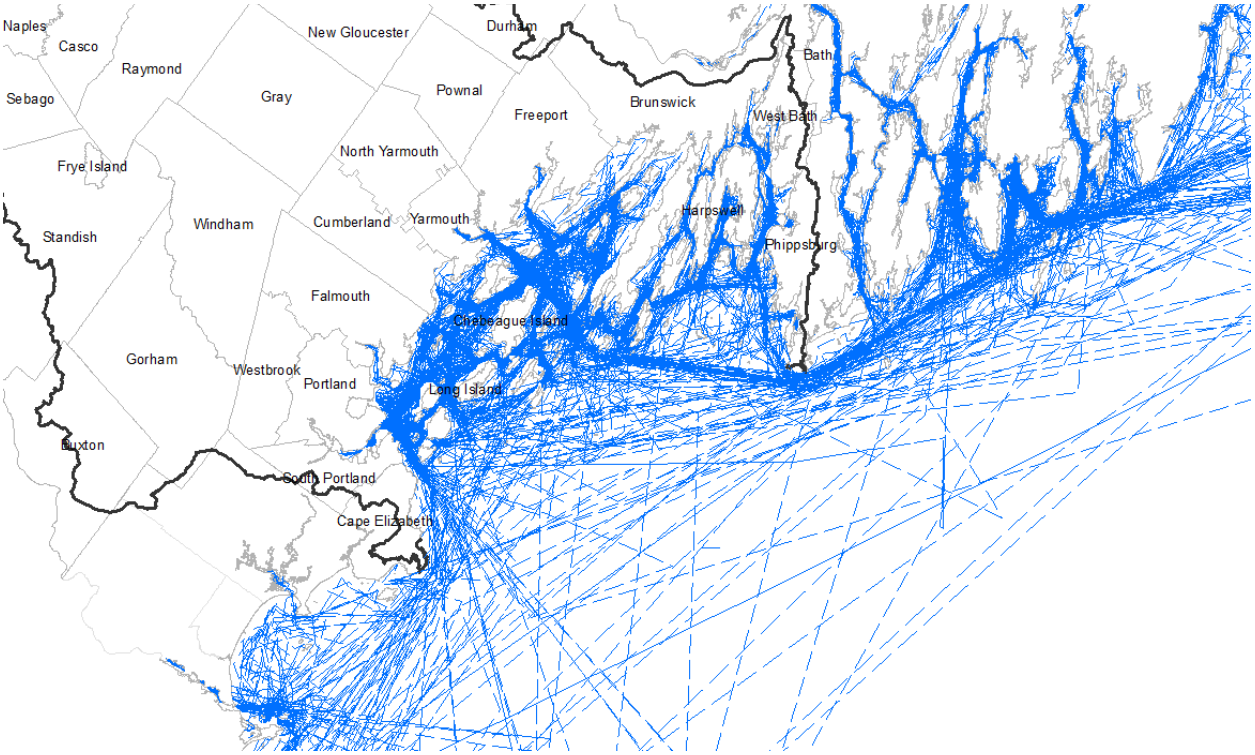
Recreational Boating and Other Ocean Uses

Another popular activity in the Casco Bay region is recreational boating, with approximately 50 marinas, including several in the Lakes Region of the watershed, and numerous launch points for motorized and non-motorized boating. While the extent and value of recreational boating is very difficult to estimate, recent surveys allow an understanding of the movements of recreational boaters in Casco Bay and how the resource is used. Figure 4.5 provides a snapshot of recreational boating density and boater start and end points within and around the Bay. Casco Bay is a very active recreational boating destination relative to points further north and south. Most activity is

concentrated close to the coast, though it is clear that boaters will travel greater distances noted by connection points outside of Casco Bay.

The Bay is used for a number of different recreational activities, including fishing, boating, diving, swimming, and wildlife viewing, among others. While data is not available to gauge intensity of these activities, there is some indication about where in the Bay recreational boaters undertake different types of activities.

Figure 4.5: Recreational Boating Activity and Ocean Recreational Uses



Source: Northeast Ocean Portal, 2014 recreational boating and use survey. Dashed blue lines are recreational boater paths, defined by starting and ending points of individual trips. Heavier blue areas represent higher intensity of boating. Watershed boundary is identified in black.

Lakes Region Tourism and Recreation

Table 4.6 provides estimates of tourism-related economic activity in the Lakes Region in the upper Casco Bay Watershed. These figures are in addition to the numbers presented in the discussion of the bay economy (Tables 4.4 and 4.5). Sebago Lake is a popular destination for many seasonal vacationers looking for outdoor recreation. Similar to the tourism and recreation sector in the shore adjacent zip code areas, eating and drinking places make up the majority of the sector – 75 percent in the Lakes Region. However, there is a significant difference in the types of lodging that

dominate in the two regions. Employment in campgrounds and RV parks in the Lakes Region makes up 12 percent of all jobs in the sector, compared to less than half of one percent near the coast. Conversely, hotels and other lodging places employed just 4 percent of workers in this sector near the lakes, but 17 percent along the coast. Still, tourism and recreation in the Lakes Region provided almost 5,500 jobs in 2016 and contributed almost $173 million to GRP.

Table 4.6: Tourism and Recreation in the Lakes Region of the Casco Bay Watershed

	Employment				Gross Regional Product	
Industry Description	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Sector	Number	Share of Sector
Eating & Drinking Places	4,115	272	7%	75%	$105,765,023	61%
Hotels & Lodging Places	263	13	5%	5%	$11,280,385	7%
Amusement & Recreation Services	198	75	61%	4%	$5,415,367	3%
RV Parks & Campgrounds	646	62	11%	12%	$34,930,705	20%
Sporting Goods Stores	100	-29	-22%	2%	$3,473,558	2%
Marinas	37	4	12%	1%	$2,429,615	1%
Travel arrangement & Reservation Services	50	24	91%	1%	$2,353,205	1%
Boat Dealers	83	31	60%	2%	$6,910,045	4%
Scenic Water Tours	5	1	25%	0%	$189,914	0%
Tourism and Recreation Total	**5,496**	**453**	**9%**	**-**	**$172,747,817**	**-**

Source: EMSI, 2017.1 data series & MCBER calculations. Includes economic activity in non-shore adjacent zip codes within the watershed, primarily in the upper watershed surrounding Sebago Lake.

Marine Transportation

The marine transportation sector includes activities that facilitate the movement of goods and people, including transportation and shipping services, storage and warehousing services, as well as supplier industries that support transport, such as navigational services to the shipping industry (Table 4.7). Marine transportation employment is comprised primarily of jobs in warehousing and storage services, which support over 95 percent of all jobs and GRP in the sector. The number of jobs in this industry more than doubled between 2006 and 2016, with a large spike in 2008. Overall the sector contributed upward of $126 million to GRP, the third largest of the regional ocean sectors.

Table 4.7: Marine Transportation Summary, 2016

	Employment				Gross Regional Product	
Industry Description	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Sector	Number	Share of Sector
General Warehousing and Storage	2,319	1,240	115%	95%	$119,700,190	95%
Navigational Services to Shipping	39	7	22%	2%	$2,413,160	2%
Marine Cargo Handling	26	2	8%	1%	$1,035,846	1%
Refrigerated Warehousing and Storage	21	-13	-38%	1%	$1,146,965	1%
Port and Harbor Operations	15	-	-	1%	$1,002,087	1%
Other Support Activities for Water	13	-	-	1%	$657,356	1%
Marine Transportation Total	**2,433**	**1,236**	**105%**	**-**	**$125,955,604**	**-**

Source: EMSI, 2017.1 data series; MCBER calculations.

It is important to note that this number likely underestimates the full impact of the marine transportation sector. Marine transport facilitates the shipment of local exports to market opportunities that might otherwise not be in reach. For instance, local manufacturers may be able to cost-effectively access foreign markets through marine trade facilitated by the marine transport sector. Ongoing investments in the International Marine Terminal (IMT) were a key factor in the Icelandic shipping company Eimskip's decision to establish its North American headquarters at the port focusing primarily on containerized cargo, including cold containers which move refrigerated seafood and other goods between Maine, Canada, and northern Europe.

As a deep water port with several terminals, the Port of Portland has the capacity to transmit all forms of cargo. South Portland hosts storage capacity for over 8.5 million barrels of liquid bulk and is the Atlantic terminus pipeline for oil shipments to and from Canada.

Sector Specific Supplemental Data

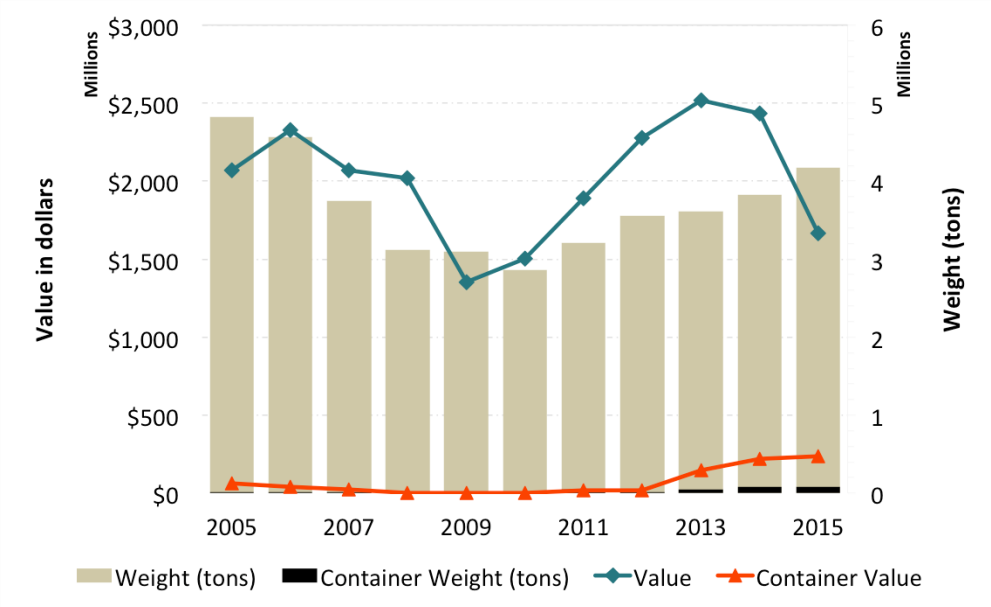
Imports [24]

Imports have traditionally made up the majority of cargo moving through the Port of Portland, primarily accounted for by the shipments of petroleum in South Portland. Total import values dropped significantly between 2013 and 2015 as a result of the price of oil declining during the period (Figure 4.6). Overall import values of petroleum are expected to continue to decline moving forward. However, more recently containerized imports have ticked up with increases beginning in 2013 with the arrival of Eimskip (Figure 4.6). Containerized imports, while still a small

[24] For detailed data and analysis on import and export activity in the Port of Portland, see the report by the Maine Center for Business and Economic Analysis titled "An Export Market Assessment of the Greater Portland Region" from 2015.

share of total imports both by value and weight, totaled $235 million in 2015, up from just $16 million in 2012.[25]

Figure 4.6: Imports by value and weight, 2005-2015



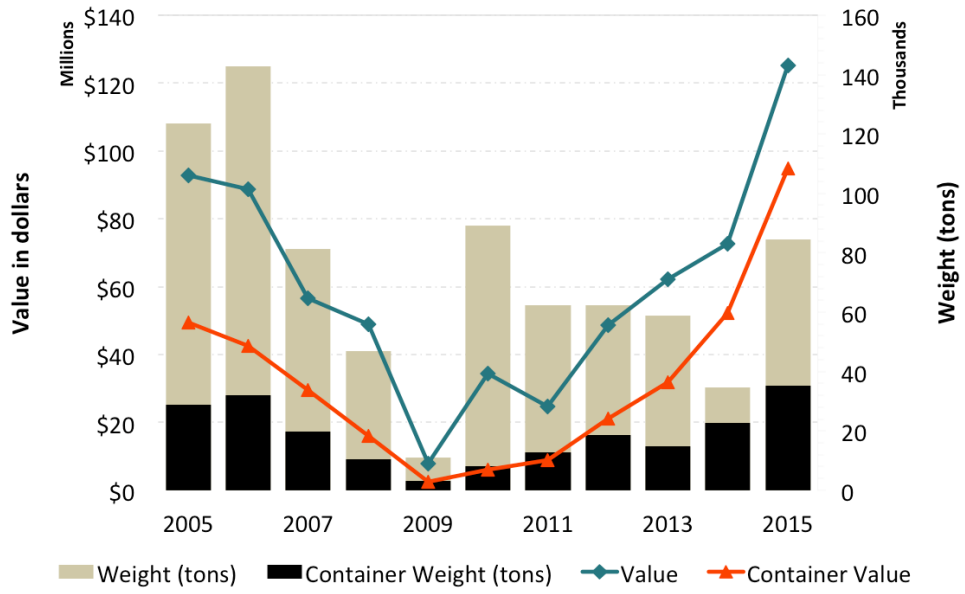
Source: NOEP, US Census Bureau, USA Trade; values in chained 2009 dollars

Exports

Exports have clearly benefited from increased containerized shipping capacity. Although overall exports are much lower in volume and value than overall imports, containerized exports have grown rapidly over the last several years approaching similar levels as containerized imports (Figure 4.7). Containerized export values were just short of $100 million in 2015, up from just $20 million in 2012, while total export value saw proportional increases to $125 million in 2015. This suggests that containerized shipments of exports typically carry higher value products, or at least have in the recent past. Goods are shipped to markets around the world, with top markets for exports in the Netherlands, Iceland, and other northern European Union countries, as well as the Philippines and China.

[25] Values are reported in 'real dollars' as chain-weighted dollars expressed using 2009 as a base year. Chain-weighted dollars are a method for accounting for differences in value that arise as a result of changes in prices (i.e. inflation). The result are annual values that are comparable from year to year and control for differences in value that arise from inflation.

Figure 4.7: Exports by value and weight, 2005-2015



Source: NOEP, US Census Bureau, USA Trade; values in chained 2009 dollars.

As capacities and efficiencies are advanced through developments at the Port of Portland, local and statewide manufacturers may be able to increase production, thereby supporting additional jobs and output. Such indirect impacts of shipping are not captured in the employment estimates of the sector reported here. These indirect impacts can vary significantly depending upon the type of goods manufactured. A recent analysis suggests that the number of containers moving through the IMT will increase by 20 percent each year through 2025, while the percentage of business sourced from Maine companies is expected to grow from 20 percent to 30 percent.[26] The analysis estimates, under a mid-range scenario, that this growth will directly support over 900 additional jobs by 2025 in an array of manufacturing industries. Another estimate provided by the Brookings Institute and cited in another recent study suggests that every $1 million in increased exports supports five manufacturing jobs.[27]

[26] "Economic Impact of the International Marine Terminal Expansion" (2017). Maine DOT, Maine Port Authority, Maine Office of Policy and Management, and Greater Portland Council of Governments.
[27] "An Export Market Assessment of the Greater Portland Region" (2015). Maine Center for Business and Economic Research, University of Southern Maine.

Living Resources

Harvesting of marine living resources, such as fishing, is perhaps the quintessential example of what comprises an ocean economy and is central to the identity of Maine and the Casco Bay region. However, the sector includes the harvesting and cultivation of marine living resources, as well as value-added activities in processing and distribution of those resources (Table 4.8). Despite the importance of this sector to the regional and state brand, Living Resources makes up a proportionally smaller share of the ocean economy (6 percent of GRP), but still contributing $76 million to the economy measured by GRP in 2016.

Over the 10-year period overall jobs in this sector decreased by 16.7 percent (-222 jobs) compared to a 9.2 percent (-52,834) decrease at the national level and 10.1 percent in Maine (-903). Most sector activity is in the harvesting of the natural resources (about 80 percent) primarily lobster and finfish, while aquaculture, a small but growing industry in Casco Bay, does not yet make a significant contribution to employment. Following national trends, fishing employment has declined over the last 10 years as domestic production has fallen because of declines and shifts in US fish stocks. At the same time, US seafood consumption has increased over the period with demand being met via imports. As a result, employment has grown in the value added industries of the supply chain, such as fish processing and distribution.

However, employment estimates provided here likely underestimate the real employment in the sector because most jobs in the living resource sector, specifically in fishing and lobstering, identify as self-employment. Measurement challenges and alternative employment estimates are discussed below.

Table 4.8: Living Resources Summary, 2016

	Employment				Gross Regional Product	
Industry Description	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Sector	Number	Share of Sector
Shellfish Fishing	620	-93	-13%	54%	$46,241,805	61%
Seafood Product Preparation & Packaging	235	42	22%	21%	$12,048,902	16%
Finfish Fishing	164	-114	-41%	14%	$11,741,508	15%
Fish & Seafood Markets	102	-42	-29%	9%	$4,422,325	6%
Aquaculture	18	-16	-47%	2%	$1,558,119	2%
Living Resources Total	**1,139**	**(222)**	**-16%**	**-**	**$76,012,659**	**-**

Source: EMSI, 2017.1 data series & MCBER calculations.

Portland is a regional center for processing and distribution (Fish & Seafood Markets and Seafood Product Preparation & Packaging in Table 4.8) of seafood related products, which supported an estimated 337 jobs in 2016, while the industry increased employment by 22 percent since 2006. Imports of seafood products directly into the region have been on the rise because of recent developments in marine trade at the International Marine Terminal. A proposed cold storage warehouse facility will help to further solidify the region's role in this regard and likely add a number of jobs in the processing and distribution end of the sector in the years ahead.

Average earnings per job in 2016 was $33,144 compared to $37,412 nationally in the sector as a whole. Wages range from a low of roughly $30k to a high of $50k. The highest earning industry is in processing and packaging of seafood products which has also been the only industry that appears to have added jobs over the last 10 years.

Sector Specific Supplemental Data

In addition to the core sector economic measures reported in the previous section, we provide supplemental data on commercial fisheries and aquaculture production in Casco Bay to provide a more detailed representation of the current state of the living resources sector in Casco Bay.

Employment measurement challenges

One of the major challenges with estimating economic activity in the living resources sector is related to estimating the number of jobs in fish harvesting. Traditional employment measures shown in Table 4.8 draw from federal and state data collected from unemployment insurance programs. Workers earning a living through fishing are typically self-employed and are not easily counted in standard employment data. As a result, these estimates under-represent the actual number of people with jobs in fishing industries. Although the estimates reported in Table 4.8 do include a measure of self-employment and estimates the number of fisheries jobs at 784, it is still difficult to accurately capture the full number of jobs. The reader should be aware that employment estimates provided in Table 4.8, which uses the same methods and sources as data reported for the other ocean sectors, may not align with alternative measures reported here.

There are two alternative measures that help to paint a picture of the potential range of jobs in the fishing industry. The first is employment data estimated by NOAA's ENOW data series, which includes an estimate of self-employment in the fisheries sector derived from Census surveys

of self-employment. ENOW data for the living resources sector in Cumberland County estimates self-employment in fisheries at 1,131 jobs in 2014 (Table 4.9 below).[28]

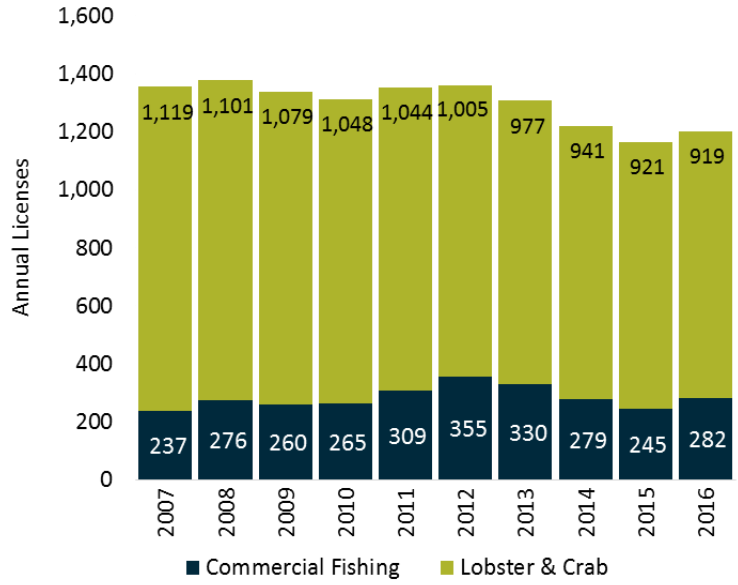
Table 4.9: Living Resources Sector Employment Estimate NOAA ENOW Data, 2014

EMPLOYMENT BREAKDOWN	
Employed	411
Self Employed	+ 720
Employment **Total**	1,131

Source: National Oceanic and Atmospheric Administration, Economics National Ocean Watch

A second source of employment measurement uses commercial fishery licensing data. Figure 4.8 shows the number of commercial licenses located in the Casco Bay region. Total licenses have declined by 200 since 2007, primarily due to drops in the number of lobster license holders, which have declined steadily, albeit slowly, over the last 10 years.

Figure 4.8: Commercial Fishing and Lobster and Crab Licenses, 2016



Source: Maine Department of Marine Resources (DMR), MCBER calculations. Includes all commercial licenses.

[28] This estimate draws upon similar data sources as the EMSI data reported in Table 4.8, including US Census nonemployer data series and the BLS QCEW dataseries.

Licensing can be a gauge of the potential number of jobs in commercial fishing, but it is an imperfect measure for at least two reasons. The first is that not all license holders actively fish or lobster on a frequent or full-time basis or at all. Second, there is no direct link between where the license holder resides and the location of where they fish or lobster. The license holder might reside within the Casco Bay region in Brunswick for instance, but lobster out of Boothbay Harbor. Likewise, while a licensed lobsterman may reside in Harpswell, his traps may be lined outside of Casco Bay.

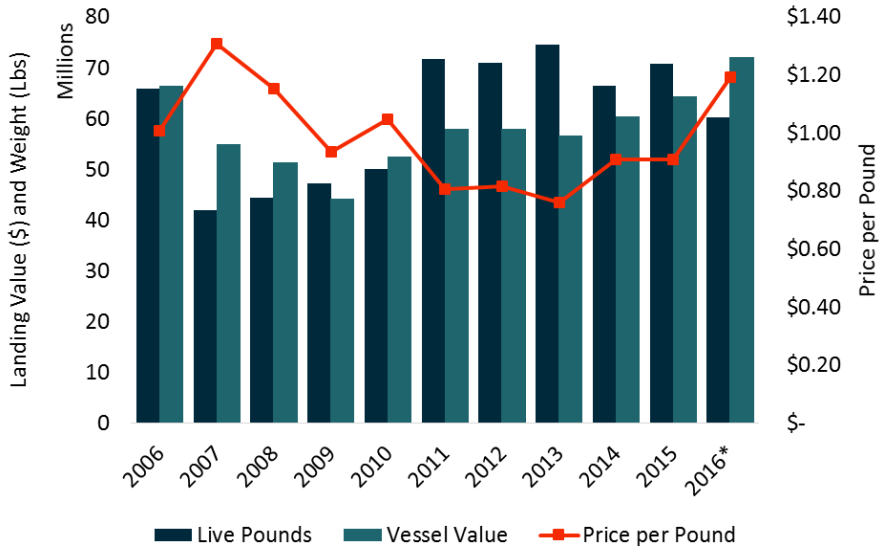
In sum, the actual number of living resource harvesters lies somewhere between these numbers. Despite these data limitations, we can provide a rough sense of the total number of jobs employed in fisheries, and more importantly, use these measures as a baseline to measure changes over time. For purposes of consistency with the other sectors, we used the employment and economic measures in Table 4.8 as indicative of activity in the Living Resources sector.

Fisheries Live Landings [29]

Commercial fisheries landings in the Casco Bay Region (all fisheries tracked by DMR) have undergone significant shifts over the last decade and a half. Commercial landings dropped sharply between 2006 and 2007 by about one third, before leaping back up to about 70 million pounds in 2011 from 50 million pounds in 2010 (Figure 4.9). Landings have fallen in recent years to around 60 million pounds in 2016. However, the total value of landings has risen steadily since 2009 with a sharp increase in 2016. Within the Casco Bay region, landing values increased by 12.7 percent between 2006 and 2016, rising from $66,419,895 to $74,879,490 respectively (in 2016 dollars).

[29] Data reported in this subsection include all live commercial landings provided by the Maine Department of Marine Resources on 5/23/17, reported in aggregate based on a geography that includes ports between Cape Elizabeth and Phippsburg. Landings as reported by dealers are the report of the total number or weight of all marine species captured, brought to shore, and sold (or transferred) to another person or party. Some species groups are grouped with like species for confidentiality reasons. Scallops are reported in meat weights (without shell), all others are live pounds. 2016 data are preliminary and subject to change without notice. Value and total landings are included in the Appendices as well (See Figure A.1). All live landings reported in this subsection are based on these data. For more information on these data visit http://www.maine.gov/dmr/commercial-fishing/landings/historical-data.html.

Figure 4.9: Casco Bay Region Commercial Live Landings (all species), 2006-2016



Source: Maine Department of Marine Resources (DMR); MCBER calculations. Values are in 2016 dollars. [30]

These trends are primarily a result of a changing composition of the fisheries both within the Casco Bay region and the broader Gulf of Maine. The ground-fishing industry, including cod and haddock, has undergone contraction over the last several decades as significant declines in fish stocks and stricter regulations have cut harvests to a fraction of what they were just 10 years ago. However, the lobster fishery has risen significantly.

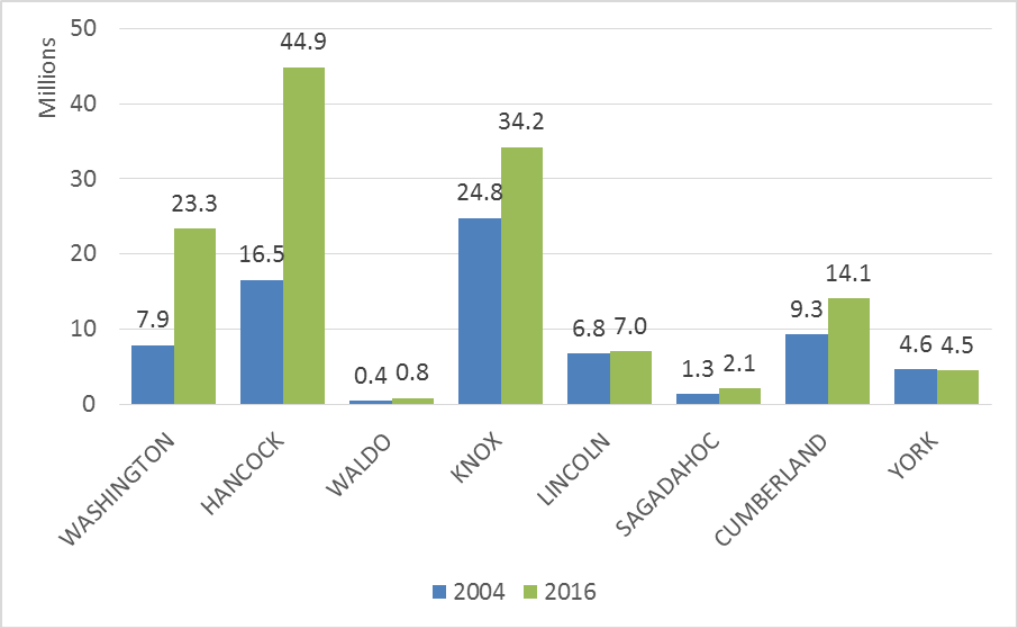
There has been a dramatic shift in the New England lobster fisheries over the last 20 years in which the center of gravity has shifted further east, with Maine capturing virtually all of the benefits. Maine's increased harvest has occurred in tandem with the collapse of a once robust lobster fishery in Connecticut/Long Island Sound and Rhode Island. Massachusetts lobster landings have remained steady, while New Hampshire has experienced an increase. In Maine, statewide landings are at historic levels, in both volume and value. In 2016, landings totaled 130.8 million pounds, up from 71.5 million pounds in 2004. Landed value of lobster statewide has increased by 45 percent over the same period from $367 million in 2004 to $533 million in 2016 (in 2016 dollars). These increases have most dramatically been experienced "Downeast" in Hancock and Washington counties, and to a lesser extent in Waldo County (Figure 4.10). Lobster landings in Cumberland County and the

[30] 2016 data are preliminary and subject to change without notice. Data pulled 5/23/17. Includes ports between Cape Elizabeth and Phippsburg. Landings as Reported by Dealers. Provided by Maine DMR.

Casco Bay region have experienced significant gains over the period as well, rising from 9.3 to 14.1 million pounds (an increase of 52 percent) between 2004 and 2016.

The decline in the southern New England lobster are only one reason for the dramatic increases in lobster harvest in Maine. The shift in lobster populations are thought to be partially a result of the impacts of warming ocean temperatures, as lobsters move northward towards deeper, cooler waters. Still, there is no conclusive agreement on the reasons for the surge in lobster landings in Maine over the last couple of decades. However, there is real concern that the center of the fishery may continue to move further northward and eastward, putting lobster out of reach for more and more New England lobstermen.

Figure 4.10: Casco Bay Lobster Landings by County, 2004 & 2016 (in pounds)



Source: Data from the Maine Department of Marine Resources (2017)[31] Data is based on the period 2004 to 2016 because 2004 was the first year in which reporting of landings by dealers was mandatory and 2016 is the most recent full year of data available.

Aquaculture

Aquaculture refers to the breeding, rearing, and harvesting of aquatic plant and animals and may occur in both fresh and saltwater environments, though much of Maine aquaculture is marine based. Depleted stocks of natural species and growing worldwide demand for protein is driving the

[31] Landings as reported by dealers. 2004 was the first year of mandatory reporting by dealers. 2016 data are preliminary and subject to change without notice.

demand in aquaculture production as a food source. Globally, aquaculture is already a major industry. As a share of total global fish production, aquaculture fisheries grew from 31.1 percent in 2004 to 44.1 percent in 2014, while the value of aquaculture products (both animals and plants) grew from $63 billion in 2004 to $165 billion in 2014 (FOA 2016). 2014 marked the first time aquaculture provided more fish than captured fisheries on record and is only expected to increase as natural fisheries are depleted or affected by ocean conditions.

Maine has a long history of aquaculture beginning in the early 1800's, yet it was not until 1973 when commercial production began to accelerate. In that year the state enacted the Maine Aquaculture Law that set leasing guidelines and standards for private aquaculture producers after which commercial production began to increase. Currently, Maine holds one of the largest marine aquaculture industries in the US. A recent report by the University of Maine Aquaculture Research Institute (ARI) found that the industry contributed $73.4 million dollars directly to the state's economic output and supported 571 jobs, while it supporting another $64 million in indirect output and another 500 jobs through multiplier effects (Cole et al. 2017). There are signs the industry is still young and faces many challenges related to production, such as replicating conditions that are conducive to growth and regeneration, and achieving commercial scale. The UMaine ARI study surveyed 71 aquaculture businesses and found that 39 percent reported no revenues, while 47 percent of revenue was reported as research services. Forty-five percent reported starting operations in the last 5 years, 24 percent of all businesses, in just the last two years.

The rapid expansion of the industry is just as evident in Casco Bay, although aquaculture has not played a significant role in the Living Resources sector in recent years, in part due to water quality challenges and restrictions. Total harvests jumped between 2012 and 2013 and have remained somewhat flat from 2014 to 2015 (Table 4.10).[32] Despite the current relatively low levels of aquaculture production in Casco Bay, the industry is poised for growth, with many small businesses entering the industry; increased demand for its products due to declining natural stocks and increased global demand for seafood; and emerging technologies that are enabling more efficient and profitable production.

[32] This does not include land-based farm-raised salmon and trout which does have a sizeable contribution in economic value, but data are not available beyond 2010 because of confidentiality restrictions. However, the most recent data from 2010 reported that 9 sites produced 24.5 million whole pounds of Atlantic salmon at a value of $73.5 million (nominal $).

Table 4.10: Aquaculture Harvest in Casco Bay, 2012-2015[33]

	2012	2013	2014	2015
Value ($)	$195,293	$659,644	$553,865	$527,193
Pounds	114,584	380,516	276,465	234,673
Price per Pound	$1.70	$1.73	$2.00	$2.25

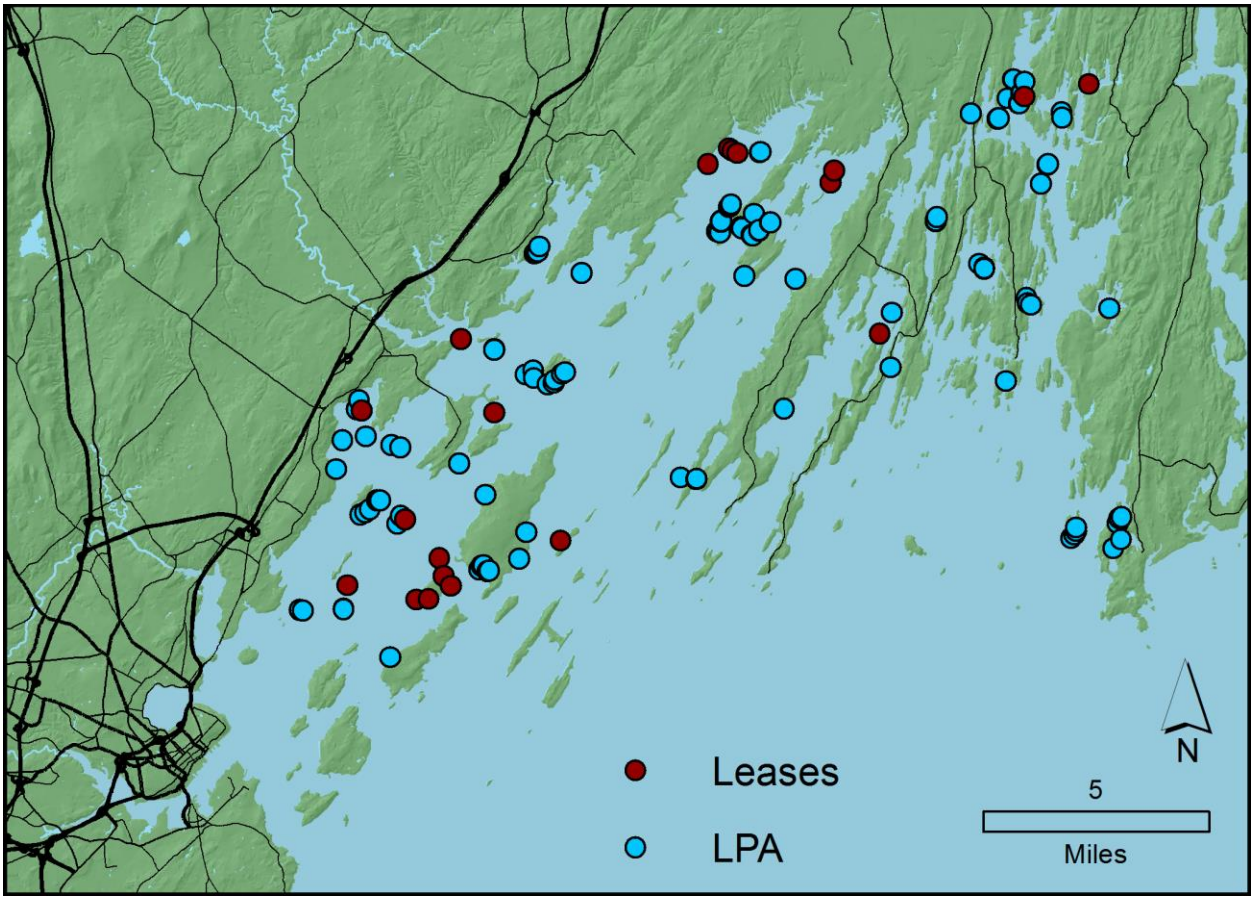
Source: Maine DMR, Aquaculture Division (2017). Data includes harvest value only and does not reflect value-added processing or other components that are reflected in the GRP numbers in Table 4.8.

There are two types of licenses for aquaculture sites; "Active" commercial leases and "Limited Purpose Aquaculture" (LPA) license. According to recent Maine DMR data, there are 19 active commercial leases and 2 applications that are pending in Casco Bay (see Figure 4.11). DMR data lists 15 separate corporations as leaseholders for the 21 commercial lease sites. Of the 21 active commercial leases, there are 15 separate corporations listed as leaseholders, with 6 corporations holding 2 commercial leases.

LPA licenses allow for testing of a site location for commercial production, recreational, or scientific/educational use. However, a majority of sites appear to be used as a testing phase before commercial license is sought and full commercial production at a site may commence. According to Maine DMR data, there are 137 active LPA licenses in total, with123 listing their purpose as "commercial." There are approximately 50 LPA license holders of the 123 LPA licenses in Casco Bay, and another 6 being used for scientific/educational purposes, 2 for recreational purposes, and 3 license holders that listed multiple uses.

[33] Data includes aquaculture leases in Casco Bay, the Cousins River, the Royal River, Presumpscot River, Middle Bay, and Harpswell Sound (limited purpose aquaculture license harvest data was not included). The following species are included in aquaculture harvest figures: American/eastern oyster, blue mussel, European oyster, sea scallop, horsetail kelp, and sugar kelp. American/eastern oyster and European oyster were reported in count but converted to pounds using the standard .28lb/count conversion. Shellfish harvest data only goes back to 2005, however, due to the limited number of growers and confidentiality requirements this data is suppressed for Casco Bay. Additionally, the number of harvesters of each individual species did not meet the DMR's confidentiality requirements and therefore all species harvested from aquaculture sites are combined.

Figure 4.11: Aquaculture Production Locations in Casco Bay



Source: Maine Department of Marine Resources, as of June 7, 2017.

Marine Construction

The marine construction sector makes up a very small portion of the overall ocean economy of Casco Bay totaling just 94 jobs in 2016 and adding about $7.8 million to GRP (Table 4.11). In general, the sector, which consists of such activities as harbor dredging, pier and marine construction, and estuary restoration, derives much of its business from projects sourced with government funding. Given the relatively small scale of the sector in the Casco Bay region, most of the related activity that occurs in the area is likely not supported by local sector businesses, but rather large national and international engineering and construction firms.

Table 4.11: Marine Construction Summary, 2016

	Employment				Gross Regional Product	
Industry Description	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Sector	Number	Share of Sector
Other Heavy and Civil Engineering Construction	85	16	23%	90%	$6,968,320	90%
Oil & Gas Pipeline & Related Structures Construction	9	-	-	10%	$809,493	10%
Marine Construction Total	**94**	25	**36%**	-	**$7,777,813**	-

Source: EMSI, 2017.1 data series; MCBER calculations.

Future growth in the sector may be tied to investments in climate change and sea level rise adaptation, such as raising port related infrastructure (piers), as well as potential for new industries in renewable energy that are growing in the northeastern US. Some of the best offshore wind resources in the US are off the coast of Maine and southern New England. Massachusetts, for instance, has begun an aggressive push to promote offshore wind energy development. The scale of offshore wind facilities provides incentives to locate manufacturing and staging of wind turbine components during construction closer to the wind resource, in this case the Gulf of Maine. Whether Casco Bay will become a center for this activity is uncertain, however, there will likely be opportunities for area firms in this space as the industry takes shape.

Ship and Boat Building

The sector is comprised of two industries differentiated by whether a company's core business is with large marine vessels or smaller recreational or lifestyle vessels. The best way to characterize the make-up of the ship and boat building sector in the Casco Bay region, however, is not clear because of the presence of Bath Iron Works (BIW) in Bath. BIW is one of the largest

employers in the state of Maine, and it lies in a municipality immediately adjacent to the ecological boundary of the Casco Bay watershed.

Under a strict technical definition of the watershed, BIW should not be included in the ocean economy of Casco Bay. However, the economic impact of BIW stretches much farther than its immediate location, providing employment for many residents of the Casco Bay region as well as supporting numerous businesses within the Casco Bay watershed directly and indirectly. Much as ecological boundaries do not adhere to political boundaries, economic boundaries do not adhere to ecological ones. It is important for a clear understanding of the regional ocean economy to consider the impact of one of the region's largest economic actors. Failing to account for BIW's integration with, and impact on, the broader Casco Bay watershed economy would greatly underestimate the ship and boatbuilding sector's role.

This is made more nuanced because of a technical challenge. It is difficult to isolate BIW's economic contribution in the data. The principal economic data on which this report is based is available on a zip code basis. Thus the working definition of the Casco Bay Watershed Region used here is also based on zip codes. Bath and West Bath share the same zip code. The municipality of West Bath lies within the Casco Bay watershed, while Bath does not. As a result, if one chooses to omit Bath, and thus BIW, from the analysis because it lies outside the watershed, one ends up also leaving out West Bath, which is in the watershed.

In order to resolve these challenges, this section reports the economic contribution of the ship and boat building sector of the Casco Bay ocean economy both with and without data from Bath/West Bath. Since BIW is the only ship builder in Bath and West Bath, this is equivalent to reporting the numbers with and without BIW.

Without considering BIW, the ship and boat building sector is very small in the Casco Bay region accounting for just $2.5 million in GRP and employing just 30 workers in 2016 (Table 4.12). This was made up almost entirely of activity in the boat building industry, principally Sabre Yachts.

Table 4.12: Ship and Boat Building Sector Summary, 2016 (omitting Bath Iron Works)

	Employment				Gross Regional Product	
Industry Description	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Sector	Number	Share of Sector
Boat Building	30	11	58%	0%	$2,503,497	99%
Ship Building and Repairing	-	-	-	-	-	-
Ship and Boat Building Total	**30**	**11**	**58%**	**-**	**$2,540,313**	**-**

Source: EMSI, 2017.1 data series & MCBER calculations.

With the addition of Bath/West Bath which includes BIW, the sector as a whole makes a significant contribution to the ocean economy in Casco Bay, accounting for over $533 million in GRP (table 4.13). BIW employed almost 5,800 workers in 2016, up 11 percent from 2006. In addition, a total of 223 jobs were in boat building (193 jobs of which are located in Bath/West Bath). The sector has a long history in Maine. However, given that most ships constructed at BIW are procured by the US federal government, related economic activity tends to ebb and flow with the tide of defense (especially Navy) spending. Although the shipyard was not awarded a recent bid in late 2016 to build a number of ships for the US Coast Guard, reports from BIW leadership suggest the outlook for the shipyard is good in the near term.[34]

Table 4.13: Ship and Boat Building Summary Inclusive of Bath Iron Works, 2016

	Employment				Gross Regional Product	
Industry Description	Jobs 2016	Change (Absolute) 2006-16	Change (%) 2006-16	Share of Sector	Number	Share of Sector
Boat Building	223	9	4%	1%	$14,423,627	3%
Ship Building and Repairing	5,779	573	11%	96%	$518,756,377	97%
Ship and Boat Building Total	**6,002**	**573**	**11%**	**-**	**$533,180,004**	**-**

Source: EMSI, 2017.1 data series & MCBER calculations.

[34] http://www.pressherald.com/2017/01/22/lesko-lessons-learned-from-lost-coast-guard-contract-position-biw-for-better-future/

Offshore Minerals

The offshore minerals sector of the ocean economy includes such activity as offshore oil and gas drilling and industrial sand mining, as well as services that support these types of activity including geophysical engineering and surveying. There is no significant offshore mineral economic activity in the Casco Bay Watershed region. In fact, due to federal confidentiality reporting restrictions, industry level data is suppressed and likely includes no more than a handful of workers. This type of ocean related economic activity is rather specialized and is found in coastal regions with rich offshore resource deposits, generally in oil and gas reserves, such as those in the Gulf of Mexico and the coastal regions of Texas, Louisiana, Alabama, Florida, as well as Alaska.

Other Sectors: Research and Development and Resource Management

The methods developed by NOEP and ENOW to characterize the ocean economy do not track ocean-related research and management. Cumulatively, however, a significant amount of activity takes place that is aimed at understanding the science and management of Casco Bay and the watershed. Most of this activity is not easily parsed in traditional economic data, as it is undertaken through grant and research funding by federal, state, and philanthropic sources. Some of the key institutions that complete such work include institutions of higher education, state and quasi-state agencies, federal agencies, independent research labs and institutes, as well as private sector organizations that focus on the commercialization of ocean research.

Estimation of the economic contribution of these organizations affiliated with Casco Bay and the watershed is difficult. First, not all research dollars are specific to Casco Bay, though the Bay may be included in research over a much broader geographic area, such as the Gulf of Maine. Second, collection of funding and project data is limited to what can be provided by organizations and for a variety of factors is not able to be easily disclosed. Furthermore, funding periods for separate projects are variable and are not easily tallied. However, we have been able to compile a somewhat complete summary of recent or ongoing research activities that take place in or in part of Casco Bay. A summary is included in Appendix B.

Environmental, conservation, and wildlife organizations

Our analysis identified over 30 organizations listed as an environmental, conservation, or wildlife organization located within the Casco Bay Watershed region. The activities of many of these organizations are likely not limited to Casco Bay or the watershed directly and may engage in

activities within the watershed region unrelated to the Bay or may work statewide or nationally in some cases. Still, it is likely that many of these organizations have some connection or relationship to actions that affect the health of the Bay or economic activity related to the Bay.

While not a full representation of the true value, combined these organizations accounted for an estimated $20 million to GRP in 2016 and approximately 330 jobs using traditional economic data. However, many of these organizations draw resources from unpaid volunteers and limited financial resources and the value of services provided is not easily captured by traditional economic data. So the true value of these organizations is likely higher, although it is very difficult, if not impossible, to derive.

Chapter 5. The Economic Effects of Changes in Bay Health

The economic contribution of Casco Bay's ocean and watershed economy is substantial, yet these economic data are based on the existing conditions of Casco Bay and are vulnerable to changes in the health and state of Casco Bay and its watershed. Given the pressures of the built environment and the unprecedented challenges posed by climate change, economic activity associated with Casco Bay will likely be impacted by these changes in the years ahead. Moreover, the interaction among an evolving regional economy and uncertainties of climate change make understanding the threats and opportunities all the more difficult.

This chapter focuses on the likely effect of climate change on the ocean economy sectors: marine transportation, living resources, ship and boat building, and tourism and recreation. We begin with a brief overview of climate change and its expected impacts in the Casco Bay region and the ways in which the marine ecosystem is expected to respond. We then examine the likely effects of anticipated changes on the ocean economy sectors in Casco Bay, given the scientific uncertainty surrounding those predictions. This chapter is not intended to be a detailed comprehensive assessment of the impacts of changes to Bay health and climate change on the ocean economy. Rather its purpose is to provide a general overview of the potential implications and likely directional impacts to the ocean economy sectors resulting from various changes in the health of Casco Bay and the impacts of climate change.

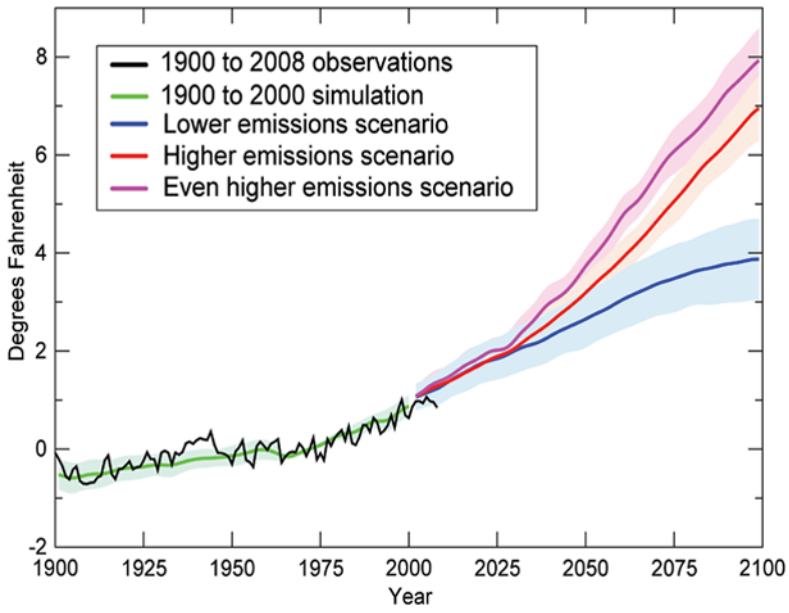
Anticipated Impacts of Climate Change in Casco Bay

The International Panel on Climate Change (IPCC) is the principal source for information on climate change and its likely impacts. Figure 5.1 shows the likely changes in temperature if certain scenarios in the emissions of greenhouse gases to the atmosphere are realized under the most recent IPCC models. Under a "lower emissions" scenario, global temperatures are expected to rise by about 3 degrees Fahrenheit (around 2 degrees Celsius) by the year 2100. Under a "high emissions" scenario, on the other hand, global temperatures may rise by as much as 7 or 8 degrees Fahrenheit (or around 4 degrees Celsius).

Average changes in global temperature can mask significant regional variations. The Gulf of Maine, for example, is one of the fastest warming bodies of water on earth (Pershing, et al., 2015). Climate models predict an increase in temperature in the Gulf of Maine and surrounding regions by 2°C to 4°C by the second half of this century.

In 2014, the report "Climate Trends in the Casco Bay Region" identified seven climate "stressors" that will affect Casco Bay and its watershed in the coming decades (Casco Bay Estuary Partnership, 2015). The stressors include warmer summers; warmer winters; increased variability in precipitation (including the possibility of both increased drought and increased precipitation); along with greater storm frequency and intensity; sea level rise; and ocean acidification. The biological and physical effects of these stressors on the Casco Bay watershed are complex and interdependent, as they are reliant upon the system's capacity to adapt to change. The following discussion of stressors draws from this report, unless a source is otherwise noted.

Figure 5.1: Predicted Temperature Change Under Multiple Emissions Scenarios



Source: (Smith, Reynolds, Peterson, & Lawrimore, 2008).

What can we expect from climate change?

- **Warmer summers / warmer winters**. Most often cited as a result of climate change is an increase in temperature, both during the summer and in the winter. The IPCC (2007), for example, predicts that average air temperatures across Maine will rise between 3 and 5 degrees Fahrenheit.[35] The number of extremely hot days (days above 90 degrees) is expected to increase, while the number of days below 0 are expected to decrease. However, most

[35] Refers to emission scenario A2 in the 2007 IPCC Climate Change assessment. This data is referenced in Fernandez et al (2015).

models indicate that the change will be driven by higher daily lows in both summer and winter, rather than higher daily highs. Observed temperatures over the past several years in Portland have been consistent with that.

- **Increased precipitation, as well as increasing storm intensity and frequency**. Records indicate that average annual precipitation has increased about 9 percent over the last century, mainly during the spring and fall. Total annual rainfall is predicted to increase by an additional 7 to 14 percent by the end of this century. Moreover, the number of high-intensity rain events, defined as two-inch or greater rainfall in a 24 hour period, has nearly tripled since the 1940's. The combination may lead to increased river flow and runoff into Casco Bay, increasing the probability of water pollution and toxic algal blooms. Increased rainfall increases polluted runoff ("stormwater") from urban and suburban landscapes and contributes to "combined sewer overflow" (CSO) events. Many of the older sewer lines in our region carry both human wastes and runoff, and the sewer system and waste treatment facilities have limited capacity to handle significant amounts of rainfall. During heavy rainfall "much of the rainwater runoff, including raw sewage and industrial waste water, is diverted by overflow pipes directly into the ocean to prevent an overwhelming burden on sewage treatment plants." (Friends of Casco Bay, 2016) Raw sewage and pollutants released into the bay can close shellfish flats, and in areas where people swim, can increase risk of waterborne diseases (Horton et al. 2014). Such risks are only expected to increase in both frequency and intensity and help justify the investments in wastewater, stormwater, and CSO infrastructure that have been made and are still needed.

- **Increased drought**. Although a prediction of increased drought seems to contradict the bullet point above, both can occur as a result of climate change. A shift towards fewer, more intense storms can increase the probability of extended periods without significant rainfall. Despite increased rainfall during the spring and fall, the northeast is seeing drier growing seasons, exacerbated by reduced snowpack in the winter (and hence, reduced groundwater recharge). This trend is expected to continue.

- **Rising sea levels**. The Maine Geological Survey estimates that sea level in Casco Bay may rise by 2 to 4 feet by the end of the century, depending upon location and carbon emissions, and could rise much more if ice sheets in Greenland or West Antarctica melt substantially or

the Gulf Stream weakens ((Slovinsky and Dickson, 2014; Casco Bay Estuary Partnership, 2015). Sea level in the Northeast has risen an average of one foot since 1900, exceeding the global average of 8 inches (Horton, et al., 2014), but abrupt changes in the rate of sea level rise may exacerbate that trend: in Portland, for example, sea level rose at a rate of 2.5 inches per year during the 2009-2010 period (U.S. Department of Homeland Security, 2016). Within the Casco Bay Region, the Portland and South Portland Waterfronts, as well as the Bayside and East Bayside areas of Portland are anticipated to be significantly impacted by sea level rise.

- **Ocean Acidification**. Ocean acidification is the phenomenon through which increased carbon dioxide emissions result in changing acidity of water (both freshwater and saltwater). The ocean acts as a "global sink" for carbon; some estimates suggest that the ocean has absorbed approximately 25 percent of anthropogenic carbon dioxide emissions, although others suggest the rate is as high as 90 percent. Moreover, local factors could temporarily increase ocean acidification in coastal waters through increased eutrophication, "upwelling" of carbon-rich waters, and increased urban run-off during high precipitation events. Although there are no time series measuring pH for the Gulf of Maine, one estimate indicates that surface ocean pH in the region has decreased by 0.1 units since the 1980s, and may decline by an additional 0.3-0.4 units by 2100 (Gulf of Maine Council on the Marine Environment, 2010).

Physical Effects of Climate Change on Marine and Coastal Ecosystems and Living Resources in Casco Bay

Marine ecosystems (including oceans, estuaries, and salt marshes) are expected to be affected by climate change in various ways. Perhaps most obvious is the fact that, as the region's waters warm, the distribution of species within the Bay will shift. Temperature is a dominant factor in species' growth, development, and ultimate survival, and thus a major factor in their spatial distribution (Gulf of Maine Council on the Marine Environment, 2010). Scientists at the Northeast Fisheries Science Center and others report that over the past twenty years, thermal habitat between 5-15°C (the preferred range for many Gulf of Maine species) along the Northeast shelf of the US has been declining. The ideal habitat for fish that prefer cooler waters, like cod, haddock, redfish, plaice, and pollock, may shift to higher latitudes or to deeper waters (Kleisner, et al., 2017). At the

same time, the "thermally appropriate" habitat for lobster may actually increase in the Gulf of Maine, while habitat for species previously rare in Maine waters, such as longfin squid, may become more prevalent (Woodward, 2017).[36]

Moreover, some species (including the iconic lobster) can hit a "stress threshold," where prolonged exposure to warmer water can create difficulties with immune systems and increase vulnerability to disease (such as shell disease in lobster), impede reproduction, and harm respiratory systems (Greenhaigh, 2016). But predicting how a certain species will react to climate change is difficult precisely because of the interactions between several different factors. Temperature is only one of them. Predator-prey dynamics; ocean acidification; and invasive species and disease are also of concern.

Many species have evolved a precise relationship between the lifecycles of predators and prey. Climate change can disrupt these complex interspecies relationships, triggering significant impacts on populations of individual species or on ecosystem structure (Gulf of Maine Council on the Marine Environment, 2010). One study found that long-term trends in estuarine water discharge, air temperature and salinity had resulted in changes in the timing of key lifetime events, such as spawning and recruitment (i.e., survival to adulthood) (Chevillot, et al., 2017). Such changes can put predator and prey out of synch, affecting population sizes and persistence. Nesting seabirds, for example, are likely to do poorly if their eggs hatch before the fish and crustaceans they rely on to feed their chicks are available. Climate change may also disrupt inter-specific relationships by separating predator and prey in space. While the habitat of a certain species may shift due to warming waters, the habitat of their prey (or other organisms on which they depend) may shift elsewhere, or shift not at all, severing ecological linkages.

Ocean acidification can negatively affect the shells of creatures that produce shells from calcium carbonate, such as clams, mussels, shrimp, scallops, and sea urchin. Moreover, an increase in acidity may lead to a decrease in growth rate for many of these species, meaning that not only might these species become more vulnerable to predation, but they also may see a reduction in size. In addition, if species take longer to reach maturity, they will remain vulnerable to predators for a longer period. At the same time, there is some evidence that lobster and the blue crab may respond to acidification by developing harder shells (Madin, 2010).

[36] Note that the predicted increase in the thermally appropriate lobster habitat does not necessarily imply that the population of lobster would increase. Temperature is only one factor affecting species growth and distribution.

Increased precipitation can bring more urban runoff and hence more pollution to Casco Bay, increasing the possibility of harmful algal blooms (HABs) and further stressing sea life. The most widely known HAB in Maine is known a "red tide." Under red tide conditions, high amounts of a toxin can be present in shellfish tissue, putting people who eat tainted shellfish at risk of suffering from Paralytic Shellfish Poisoning, or PSP. In May of 2017, clam flats from Harpswell to Old Orchard Beach were closed due to the threat posed by red tide (Hoey, 2017).

Finally, climate change may open new pathways by which invasive species may be introduced to Casco Bay. According to the Invasive Species Advisory Committee at the US Department of the Interior, "invasive species share traits that may allow them to capitalize on the impacts of global climate change including fast growth, rapid reproduction, and the ability to survive in a wide range of environmental conditions… Consequently, a decline in cold-affinity or even 'typical' resident species and an increase in warm-affinity residents can be expected, which will change species proportions as well as community structure and dynamics" (Invasive Species Advisory Committee, 2010). One prominent recent example is the green crab, which invaded much of Casco Bay in 2012 to 2013, wreaking havoc on eel grass, mudflats, and shellfish. While it is difficult to pin any particular event like this on climate change, rather than shifts in oceanographic or climatological cycles, the warming trend in Casco Bay may provide openings for non-native species to exploit (Woodward, 2015).

The economic effects of these stressors add another layer of complexity and uncertainty, as they depend upon the economy's ability to respond and adapt to the physical changes wrought by climate disruption, as well as human actions to mitigate and prepare for climate change. Climate-related economic uncertainty is in addition to business cycle fluctuation typical of most economies, which undergo periods of expansion and contraction.

Economic Effects of Climate Change on the Ocean Economy

Most sectors of the ocean economy will be affected by climate change in some way. Climate change could disrupt the living resources sector in obvious ways, through direct impacts of changes to Bay health, including those caused by or exacerbated by climate change. Yet this sector makes up a small (albeit socially and culturally important) percentage of the overall ocean economy. Tourism and recreation on the other hand, which may be more resilient to changes in Bay health, could experience the largest overall impacts (whether positive or negative), simply because the sector is so

large. Furthermore, costs associated with sea level rise will affect not only ocean-related sectors, but have impacts across the entire economy.

Living Resources

It is generally not possible to develop a robust mechanistic model of how each stressor accompanying climate change will affect individual species, due to the multiple feedback loops and uncertainties. The Organization for Economic Cooperation and Development (OECD), for example, identifies four sources of uncertainty in predicting the economic impacts of climate change: observational uncertainty, where the current state of the ecological system is unknown; model uncertainty, in that the economic and ecological models are not perfect; process uncertainty, where there is a lack of understanding of the links between the ecology and the economy; and policy uncertainty, where scientific and economic information and advice are inadequately applied. These uncertainties combine to make predicting the economic effects of climate change on a certain species or the region as a whole difficult.

Scientists at the National Oceanic and Atmospheric Administration (NOAA) and others recently published an article evaluating the biological sensitivity, climate exposure, and potential for change in species distribution for several species of marine vertebrates and invertebrates (Hare, et al., 2016). Biological sensitivity is an assessment of the species' "intrinsic resilience to change," while climate exposure "includes factors that have the potential to affect productivity or distribution of a species (or population) in a given region" (Hare, et al., 2016). The results for several of species of commercial significance to Casco Bay are listed in Table 5.1.

Table 5.1: Selected Commercial Species Sensitivity to Changes in Bay Health

Species	Biological Sensitivity	Climate Exposure	Potential for Change in Species Distribution	Overall Directional Effect in the Northeast Atlantic Region
Alewife	High	Very High	Low	Negative
American Eel	Moderate	Very High	High	Neutral[37]
American Lobster	Moderate	High	High	Neutral[38]
Atlantic Cod	Moderate	High	High	Negative
Atlantic Salmon	Very High	Very High	Moderate	Negative
Atlantic Scallops	High	Very High	Moderate	Negative
Bloodworm	High	Very High	Low	Negative
Blue Mussel	High	Very High	Moderate	Negative
Northern Shrimp	High	High	High	Negative
Oysters	High	Very High	Moderate	Negative
Softshell Clam	High	Very High	High	Negative
Winter Flounder	High	Very High	High	Negative

Source: Adapted from (Hare, et al., 2016).

A quick glance at the table indicates that almost all of the marine species of commercial importance to Casco Bay are vulnerable to the effects of climate change, with the possible exception of American lobster and American eel. It is likely, therefore, that the landed price of each species will increase as a result of falling supply, all else being equal. However, a rise in price does not necessarily translate into an increase in revenue for the fishery. That depends upon how consumers respond to changes in the price. If consumers continue to pay the higher price without much of a drop-off in demand, revenue for the fishery as a whole may not be affected. However, if consumers switch to a different species of fish, or another source of protein altogether, revenue may decrease as demand and/or prices fall. It should go without saying that a total collapse of a species and fishery, such as that which results from major structural changes in the coastal ecosystem, would result in significant revenue and job loss.

The other side of the profit equation is costs. If fish species are negatively impacted by climate change, then the effort needed per ton of fish caught will increase, as fishermen may have to go farther afield or search in new locations for their catch. This translates into an increase in labor, fuel, and refrigeration costs, and may lead to the necessity for the fishing fleet to refit their boats.

[37] There is much uncertainty surrounding this determination.
[38] Lobster populations have declined in the southern part of the Northeast Atlantic, while increasing in the northern part.

Fuel already consumes about 40% of a lobsterman's revenue, up from 10 to 15% a decade ago (Smith 2010). The increasing climate variability may also necessitate the investment in more safety gear, and lead to an increase in insurance premiums (Hanna, 2011).

The structure of the industry is likely to change as well. Larger, more mobile boats, and those with more access to financial capital and substitute fisheries, will fare better under climate change than smaller, less well-equipped, less flexible fishers. This has implications for equity in the region, as existing inequalities are likely to increase. Finally, the existing processing infrastructure may need to adjust or change completely, as fisheries in the area transition towards other species (Hanna, 2011).

Effect of Climate Change on Other Marine-Related Industries

Marine Transportation

The greatest impacts of climate change on the shipping industry are the increase in strong weather patterns, ocean temperature, and sea level rise. With the rise in ocean temperature and the rapid melting of the polar ice cap, new shipping lanes in the Arctic may become navigable during the summer months. NASA estimates that the Arctic is warming at a rate of almost twice the global average, and points out that the past thirteen years (from 2002 to 2015) yielded the thirteen smallest recorded winter maximums for sea ice (Viñas, 2016).

This has implications for Maine, as in Senator Angus King's words, "It's 10 days shorter from Asia to Europe through the Arctic than through the Panama Canal. And the first port on the [US] East Coast for ships coming from Asia is Maine" (Struzik, 2016). The southern route of the Northwest Passage, for example, has been navigable every summer since 2007, whereas the northern route has been open for six of the past nine summers (Gass, 2016). However, due to the risks and uncertainties involved, using the Northwest Passage is unlikely to become a common practice for several decades.

Increased frequency and intensity of hurricanes could lead to disruptions in ships' routes and delays in passage and ship arrival (Wright, 2013). The alteration of routes will lead, in turn, to increased fuel and labor costs, and may cause ripple effects throughout the economy. Some storms may cause more severe coastal flooding, which when combined with rising sea levels, may make some ports dangerous to enter.

The most significant impacts on the marine transportation sector, and in fact the broader coastal watershed economy, will likely result from sea level rise, which presents significant

implications for coastal shipping, storage, and other transportation infrastructure, much of which is vulnerable to increases in water levels. Nearly every gallon of gas that arrives in Maine by sea passes through the Port of Portland. Port infrastructure facilities, in addition to passenger and recreational transport facilities, will need to be restructured over time to adapt to rising water levels, and may include more flexible seaside structures or in some cases relocating facilities away from the shore completely. However, the latter is less an option for infrastructure critical to the movement of goods from sea to land.

Infrastructure improvements and adaptation will need to be addressed by the marine construction sector. So while the marine transportation sector may be negatively impacted by sea level rise, the marine construction sector will likely experience growth from increased demand for port and coastal infrastructure adaptation to sea level rise. However, given the regionally specialized nature of the marine construction sector and minimal presence of the sector in the Casco Bay region, it is unclear to what extent the marine construction sector located in the Casco Bay region will be the beneficiary of sector increases.

Shipping and boatbuilding

Rising seas are likely to provide the principal impacts to the ship building industry. Most large ship facilities, such as BIW, are located only a few feet from the water, although BIW is numerous miles upriver and may not be as impacted as ocean side facilities. While dry dock facilities are often used for construction and launching, related facilities (e.g., engineering, design, fabrication and assembly) that are on land may need to move to higher ground adding significant costs and challenging an already competitive industry.

However, the changing climate may call for the construction of new ships built to endure the special challenges that will arise. For example, Maine's Senator Angus King has been raising the possibility of a growing need for more heavy-duty ships equipped to ply shipping routes in the Arctic. However, Dirk Lesko, president of BIW, says that building icebreakers would be a significant technological shift from their current product (naval destroyers) (Miller, 2017). Moreover, some shipbuilders - and regulators - are calling for the use of more environmentally-friendly materials and fuels, to help reduce greenhouse gases and mitigate climate change (OECD Council Working Party on Shipbuilding, 2010).

Tourism and recreation

Tourism and recreation together make up the largest share of both employment and GRP in the Casco Bay ocean economy. However, despite awareness of climate change and its potential impact on these sectors, the economic effects have not been well-studied. One way to examine the probable impacts of climate change on tourism-related industries is by considering whether each industry is likely to be sensitive to climate-related factors, and assessing whether those traits are expected to affect demand or supply, and in a positive or negative direction (Shaw & Loomis, 2008).

The tourism and recreation activities in the Casco Bay region most likely to be affected by climate change include beach-going and recreational fishing, but other areas are likely to be altered as well, as shown in Table 5.2. We provide a brief discussion of the likely impacts on beach-going and recreational fishing to provide a general sense of the logic in Table 5.2.

Table 5.2: Directional Impacts on Tourism and Recreation Activities

Activity	Features Sensitive to Climate Change (Likely Directional Effect on Demand or Supply)
Boating	Temperature (+) Sunshine (+) Precipitation (-) Water pollution from urban runoff (-) Extreme weather events (-)
Beach-going	Temperature (+) Sunshine (+) Precipitation (-) Beach erosion (-) Water pollution from urban runoff (-) Extreme weather events (-)
Recreational Fishing	Temperature (+) Sunshine (+) Water pollution from urban runoff (-) Species availability (-)
Bird / Animal Watching	Temperature (+/-) Sunshine (+) Precipitation (-) Species availability (?)

Source: Adapted from (Shaw & Loomis, 2008).

Beach-going

Beach-going is likely to be affected positively by increased temperatures across the Casco Bay region, but negatively by beach erosion. While much of Maine's iconic rocky shoreline is relatively immune to beach erosion, the Maine Geological Survey has expressed concerned about erosion of the shoreline in York and Cumberland Counties, where sandy beaches are the most prevalent (Maine Coastal Program, 2007). However, almost all major beaches in Southern Maine are located outside of Casco Bay, with the exception of Willard Beach in Southern Portland and the East End beach in Portland. Both beaches are low lying, and thus likely to be vulnerable under a

one-half meter rise (2 feet) rise in sea levels. Also of concern is the vulnerability of transportation infrastructure along the Maine coast – if beach access roads are affected by rising sea level and increased storm surge, tourists may experience delays, which could affect their overall experience (e.g. Southern Maine Planning and Development Commission, nd).

Water quality may be affected by climate change, as mentioned above. If increased eutrophication and increased urban runoff lead to more toxic algal blooms or bacteria, it could result in beach closures – leading to decreases in both municipal and local business revenues – however most visitors to the Willard and East End beaches are local residents who would likely substitute any beach related spending elsewhere in the local economy. Moreover, a recent study in California used the "cost-of-illness" method to determine the economic impact of hospital visits and lost income brought about by diseases related to swimming in polluted water. The study determined that water-borne illnesses brought about by swimming in contaminated water cost the regional economy at least $21 million a year (Dwight, Fernandez, Baker, Semmenza, & Olson, 2004).

Recreational fishing

Marine recreational fishing will be affected in a similar manner to the commercial fishing industry which will largely depend on the impact of saltwater species population and distributional impacts. Decreased abundance of recreational fisheries or fisheries that have shifted to deeper waters further from shore will certainly add costs to charter and non-charter recreational excursions, including both realized costs (fuel) and opportunity costs from alternative fishing locations or recreational opportunities. Still, the magnitude of impacts may not be as significant as in commercial fisheries since there is enjoyment gained from simply 'being on the water'.

Much like the distribution of cool thermal habitat for saltwater fisheries, the spatial distribution of suitable habitat for cold freshwater fisheries is projected to contract over time, as air temperatures and the timing and intensity of precipitation vary along with climate change. These climate alterations will result in changes in groundwater recharge, stream discharge, snowpack, and evaporation, further changing the hydrogeologic cycle (Jones, et al., 2012). By using a model of fish thermal habitat and projected temperature increases as a result of climate change, Jones et al. were able to model how the distribution of habitat suitable for coldwater fisheries (principally trout and salmon in Maine) is expected to change over the next 80 years. While the projections were done at a national level, results nonetheless show that Maine is projected to experience almost a complete loss

of coldwater-suitable habitat by 2100 in all but the most optimistic of climate scenarios (Jones, et al., 2012).

Chapter 6. Summary and Conclusion

Casco Bay clearly plays a critical role in the regional economy and is inarguably a primary reason for the historic geographic significance of Portland and the region as an economic engine of Maine. The purposes of this analysis were:

1. to determine the market-value of economic activity linked to Casco Bay;
2. to assess economic implications of changes in Bay health, especially those associated with climate change; and
3. to establish a framework for continued monitoring and tracking of the health of the ocean economy.

In sum, Casco Bay is responsible for over $704 million in direct economic activity supporting over 18,500 jobs in the region and another 5,700 indirectly. Tourism and recreation make up the vast majority of jobs, while ship building, marine transportation, and living resource extraction and processing are all important sectors. The beauty of Casco Bay also plays a key role in attracting and retaining skilled workers to the region that are greatly needed to support other key industries in the region. The Bay is undoubtedly central to the greater Portland region's brand, while the upper watershed supports a robust seasonal recreation and vacation destination.

What lies ahead for Casco Bay and the regional economy inextricably linked to it? Global economic forces and a changing industrial composition are placing a greater value on urban areas with access to high quality of life and rich natural amenities (Moretti 2012). The greater Portland Casco Bay region will likely experience some of these pressures, with a growing population. Still, people are moving towards urban regions, especially those that are on the coast and that are rich in amenities. Casco Bay and its watershed are part of a complex urban region that will continue to grow, although differently than in the past. Balancing these changes while supporting a growing ocean economy provides great opportunities for the region, but is not without challenges.

Given the uncertainty presented by climate change and other environmental stressors, the impacts on ocean dependent economies are not easily discerned, but will likely take multiple directions and will affect communities that depend on those industries differently. The living resources sector is likely to have the greatest near-term vulnerability, though what could be trouble for one species could be a gift for another. Continued research on species and coastal ecosystems will help us better anticipate both direction and magnitude of impacts. Small island communities and

parts of northern Bay communities, such as Harpswell, have local economies that are more heavily dependent on natural resources and are thus most vulnerable to changes in marine resources.

Tourism and recreation may be less impacted than living resources as a percentage but it is the largest ocean sector and may exhibit the largest overall impacts, either positive or negative. For instance, longer warm seasons could attract more tourists for longer stretches of the year, though greater precipitation may keep people away. However, the greatest implications of climate change will likely come from sea-level rise which will have far greater impact in terms of costs on other ocean economy sectors, the broader regional economy, and the built environment (Colgan et al, 2017).

Continued monitoring can be simply carried out using the framework established in this report. The methods used are based on consistent and reliable data sources that are not expected to substantially change in the foreseeable future. The working economic definition (the ocean economy) that underlies the core of this report can be carried forward, while allowing for slight adjustments as necessary. These definitions have the added advantage of being tied to standard methods, allowing the Casco Bay economy to be easily compared to the economy of other coastal, marine, or estuarine regions.

There are several additional indicators not discussed in this report that can be considered when assessing the overall health of Casco Bay's ocean economy. Based on an adaptation of a recent report by the Island Institute and Natural Resource Defense Council (2014), the following additional indicators should be considered in future updates of this study:

- Landed value of shellfish and other species
- Proportion of state GDP in each sector
- Number of licenses for different industries
- Percentage of employment in at-risk industries
- Population trends in species (including age / size)
- Effort needed for harvest
- Timing of spawning and recruitment
- Absence / presence of invasive species and disease
- Width of beaches
- Visitation counts at beaches
- Mean high water mark

To the extent that consistent data does exist, incorporating these measures into the periodic economic check-up could be useful, as they can be strong indicators of emerging trends or challenges. Furthermore, with the uncertainty of implications presented by climate and ocean change, it will be important to tie economic indicators directly to changes in the conditions or health of the resource.

The full value of Casco Bay is difficult to measure and extends far beyond that which can be measured by the traditional economic means that are the focus of this analysis. One recommendation for future consideration is to establish nonmarket based values that can be tied to functioning of Bay ecosystem services and values that people place on Casco Bay. The more policymakers, business leaders, and the public understand just how vital a role the Bay plays in the region's prosperity, the more likely actions will be aligned in the best interest of the resource.

The health of Casco Bay is vital to our economy. Climate change and other stressors jeopardize that economic activity. Even beyond the effects outlined here, an unhealthy bay can imperil the health and the well-being of the population that chooses to call Casco Bay home. As our economy shifts from a goods-focused economy to a service-oriented one, the condition and vitality of the Bay and the ecosystems it supports are crucial to attracting and retaining the necessary high-skilled workers demanded of the broader economy. Part of the Casco Bay region's appeal is its ocean economy: its fishing, boat building, and shipping industries, not to mention its beaches and outdoor-related tourism. The health of Casco Bay itself is an important economic resource, deserving our protection.

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APPENDIX A

Table A.1: Zip Code Definitions of the Casco Bay Watershed

Zip Code	Town	County
04210	Auburn	Androscoggin
04003	Bailey Island	Cumberland
04530	Bath	Sagadahoc
04217	Bethel	Oxford
04009	Bridgton	Cumberland
04011	Brunswick	Cumberland
04093	Buxton	York
04107	Cape Elizabeth	Cumberland
04015	Casco	Cumberland
04017	Chebeague Island	Cumberland
04019	Cliff Island	Cumberland
04021	Cumberland Center	Cumberland
04110	Cumberland Foreside	Cumberland
04222	Durham	Androscoggin
04105	Falmouth	Cumberland
04032	Freeport	Cumberland
04033	Freeport	Cumberland
04034	Freeport	Cumberland
04038	Gorham	Cumberland
04039	Gray	Cumberland
04079	Harpswell	Cumberland
04040	Harrison	Cumberland
04050	Long Island	Cumberland
04055	Naples	Cumberland
04260	New Gloucester	Cumberland
04057	North Bridgton	Cumberland
04267	North Waterford	Oxford
04097	North Yarmouth	Cumberland
04268	Norway	Oxford
04066	Orrs Island	Cumberland
04270	Oxford	Oxford
04108	Peaks Island	Cumberland
04562	Phippsburg	Sagadahoc
04101	Portland	Cumberland
04102	Portland	Cumberland
04103	Portland	Cumberland
04104	Portland	Cumberland
04109	Portland	Cumberland
04112	Portland	Cumberland
04122	Portland	Cumberland
04123	Portland	Cumberland
04124	Portland	Cumberland
04069	Pownal	Cumberland
04071	Raymond	Cumberland
04029	Sebago	Cumberland
04106	South Portland	Cumberland
04116	South Portland	Cumberland
04084	Standish	Cumberland
04231	Stoneham	Oxford
04088	Waterford	Oxford
04530	West Bath	Sagadahoc
04092	Westbrook	Cumberland
04098	Westbrook	Cumberland
04062	Windham	Cumberland
04096	Yarmouth	Cumberland

Table A.2: Zip Code Definitions of the Casco Bay Ocean Economy (Shore Adjacent)

Zip Code	Town	County
04003	Bailey Island	Cumberland
04530	Bath	Sagadahoc
04011	Brunswick	Cumberland
04107	Cape Elizabeth	Cumberland
04017	Chebeague Island	Cumberland
04019	Cliff Island	Cumberland
04021	Cumberland Center	Cumberland
04110	Cumberland Foreside	Cumberland
04105	Falmouth	Cumberland
04032	Freeport	Cumberland
04033	Freeport	Cumberland
04034	Freeport	Cumberland
04079	Harpswell	Cumberland
04050	Long Island	Cumberland
04066	Orrs Island	Cumberland
04108	Peaks Island	Cumberland
04562	Phippsburg	Sagadahoc
04101	Portland	Cumberland
04102	Portland	Cumberland
04103	Portland	Cumberland
04109	Portland	Cumberland
04078	South Freeport	Cumberland
04106	South Portland	Cumberland
04116	South Portland	Cumberland
04530	West Bath	Sagadahoc
04096	Yarmouth	Cumberland

Data source methodology notes

Economic Modeling Specialists (EMSI) data source: 2017.1 includes QCEW (Quarterly Census of Employment and Wages) Employees, Non-QCEW Employees, and Self-Employed. EMSI industry data have various sources depending on the class of worker. (1) For QCEW Employees, EMSI primarily uses the QCEW with supplemental estimates from County Business Patterns. (2) Non-QCEW employee data are based on a number of sources including QCEW, Current Employment Statistics, County Business Patterns, Bureau of Economic Analysis (BEA) State and Local Personal Income reports, the National Industry-Occupation Employment Matrix (NIOEM), the American Community Survey, and Railroad Retirement Board statistics. (3) Self-Employed and Extended Proprietor classes of worker data are primarily based on the American Community Survey, Nonemployer Statistics, and BEA State and Local Personal Income Reports. Projections for QCEW and Non-QCEW Employees are informed by NIOEM and long-term industry projections published by individual states.

Table A.3: Industry employment and growth by major sector for CBWR, 2016

NAICS	Industry	2016 Jobs	% of Total Jobs 2016	10-Year Change (06'-16')	5-Year Change (11'-16')	2016 Concentration
62	Health Care and Social Assistance	34,193	15.6%	10.7%	5.9%	1.26
44	Retail Trade	25,890	11.8%	-11.4%	1.1%	1.14
90	Government	24,280	11.1%	-13.7%	-4.0%	0.73
72	Accommodation and Food Services	18,778	8.6%	13.3%	8.2%	1.02
31	Manufacturing	16,941	7.7%	-7.6%	7.3%	0.98
54	Professional, Scientific, and Technical Services	13,116	6.0%	13.5%	6.1%	0.95
52	Finance and Insurance	12,637	5.8%	-4.5%	-2.2%	1.49
56	Admin., Support, Waste Mgmt. & Remediation Services	12,478	5.7%	21.9%	4.3%	0.92
23	Construction	10,999	5.0%	-16.6%	1.6%	0.94
81	Other Services (except Public Administration)	10,335	4.7%	14.3%	8.9%	0.99
61	Educational Services	7,715	3.5%	39.0%	21.9%	1.39
42	Wholesale Trade	7,506	3.4%	-4.0%	13.5%	0.90
48	Transportation and Warehousing	6,819	3.1%	39.2%	10.0%	0.92
55	Management of Companies and Enterprises	3,921	1.8%	83.7%	29.6%	1.28
71	Arts, Entertainment, and Recreation	3,743	1.7%	12.1%	16.9%	1.02
53	Real Estate and Rental and Leasing	3,623	1.7%	-10.9%	2.6%	1.01
51	Information	3,532	1.6%	-28.7%	-2.4%	0.87
11	Crop and Animal Production	1,725	0.8%	0.2%	8.6%	0.64
22	Utilities	367	0.2%	-32.3%	-28.0%	0.48
21	Mining, Quarrying, and Oil and Gas Extraction	46	0.02%	3.7%	-14.8%	0.05
		218,644	**100%**	**1.4%**	**4.8%**	

Source: EMSI, 2017.1; MCBER calculations. Concentration is measured by location quotients relative to the state of Maine. Typically values greater than 1 suggest an industry is more concentrated than the state and values below 1 suggest an industry is less concentrated.

A closer look at more detailed industry definitions provides a more complete picture of the regional industry strengths in the Casco Bay region. Table A.4 shows the most significant industries in terms of employment size and specialization in the region, measured as a location quotient relative to the US.[39] The industries in Table A.4 are more detailed than those shown in Table A.3 and Figure 2.3 of the report and are based on three digit NAICS definitions, rather than two digit broad sectors. For instance, NAICS industries 316 and 336 both fall within manufacturing sector (NAICS 31-33), while NAICS 524 falls within Financial Activities (NAICS 52).

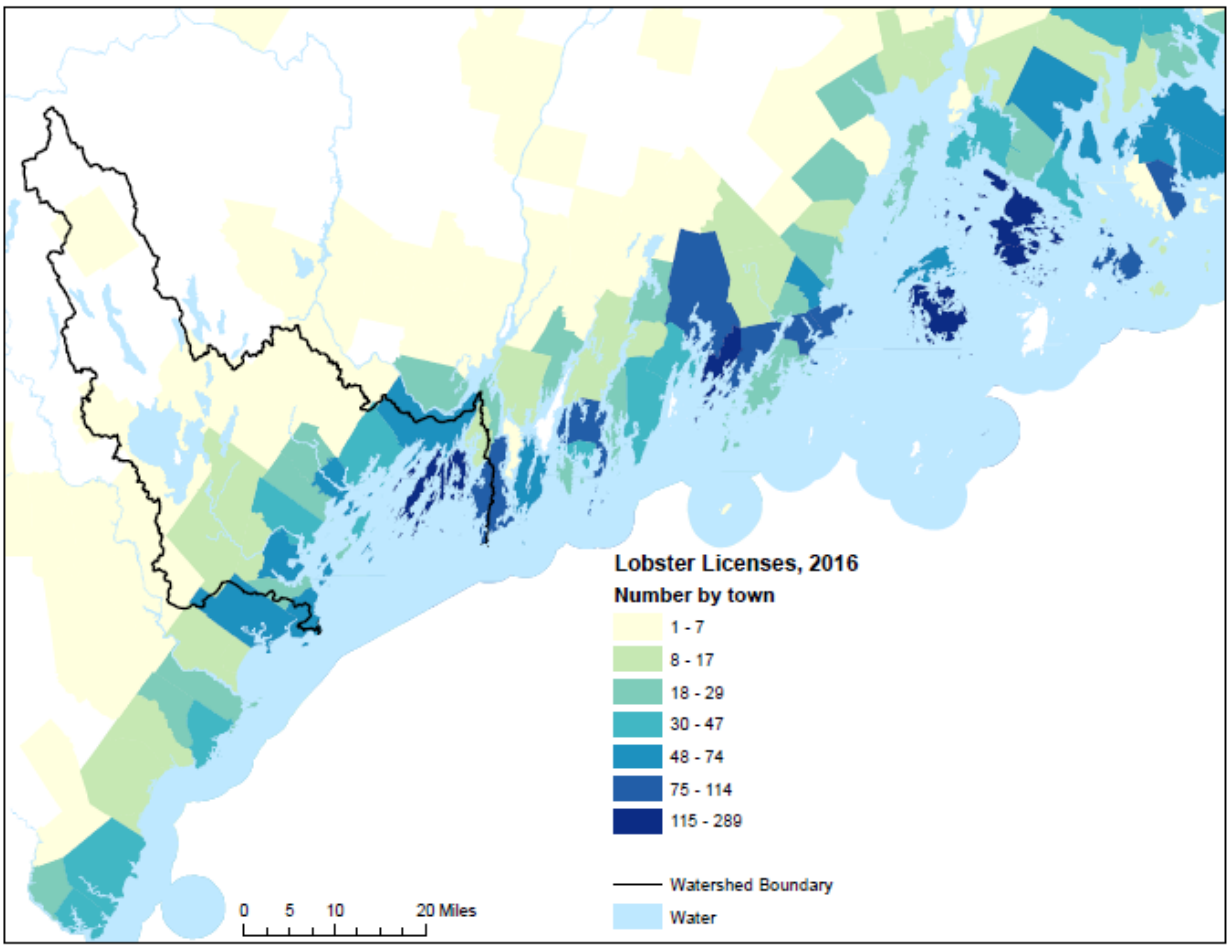
Table A.4: Detailed Industry Employment and Concentration Relative to the US in the Casco Bay Region, 2016

NAICS	Industry	2016 Jobs	10-Year Change (06'-16')	5-Year Change (11'-16')	2016 Concentration
114	Fishing, Hunting and Trapping	800	-20.9%	0.1%	14.84
316	Leather and Allied Product Manufacturing	584	127.2%	72.3%	13.99
336	Transportation Equipment Manufacturing	6,101	11.9%	13.4%	2.70
524	Insurance Carriers and Related Activities	7,725	-2.8%	-0.5%	2.24
454	Nonstore Retailers	1,797	-54.6%	-18.1%	1.99
322	Paper Manufacturing	1,008	-34.3%	-13.4%	1.96
493	Warehousing and Storage	2,364	102.2%	-0.6%	1.94
622	Hospitals	10,638	19.8%	5.9%	1.57
623	Nursing and Residential Care Facilities	6,704	7.7%	-1.2%	1.46
611	Educational Services	7,715	39.0%	21.9%	1.39
532	Rental and Leasing Services	1,049	-15.7%	-7.5%	1.36
445	Food and Beverage Stores	5,762	4.0%	7.1%	1.33
448	Clothing and Clothing Accessories Stores	2,600	-0.6%	7.0%	1.33
721	Accommodation	3,554	9.2%	11.5%	1.32
451	Sporting Goods, Hobby, Musical Instrument, and Book Stores	1,222	-33.0%	-0.9%	1.31
453	Miscellaneous Store Retailers	1,729	-16.6%	-5.5%	1.30
551	Management of Companies and Enterprises	3,921	83.7%	29.6%	1.28
444	Building Material and Garden Equipment and Supplies Dealers	2,258	-9.5%	8.1%	1.26

Source: EMSI, 2017.1; MCBER calculations. Concentration is measured by location quotients relative to the state of Maine. Typically values greater than 1 suggest an industry is more concentrated than the state and values below 1 suggest an industry is less concentrated.

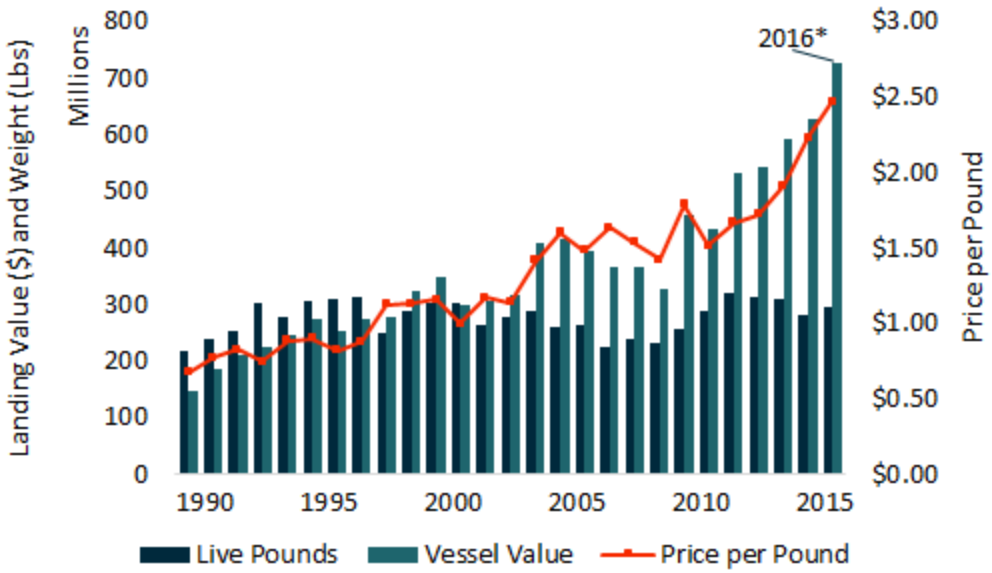
[39] Industries included are at the 3-digit NAICS sector level and were screened using criteria of greater than 400 jobs and deemed to be concentrated/specialized in the region indicated by a location quotient greater than 1.20.

Figure A1: Lobster and Crab Licenses by Municipality, 2016



Source: Maine DMR pulled on 5/23/17.

Figure A.2: Maine Commercial Landings by Vessel Value, Weight (lbs.) and Price per Pound, 1990-2015



Source: Data downloaded from DMR website on 3/35/17. Note: *2016 data are preliminary. Reporting requirements for different species varied from year to year. In nominal dollars.

APPENDIX B

Overview of research and development activity related to the Casco Bay watershed

This section provides an overview of Casco Bay related research and development (and educational) activity. Due to challenges in collecting data on research funding, we are not able to provide a complete total. However, we do provide a sense of the funding levels, when available, and the staff supported by specific projects.

Applied Research – Ecosystems and Monitoring Surveys

Gulf of Maine Research Institute (GMRI) - *Casco Bay Aquatic System Survey (CBASS)*

- Approximately $100k/year for a 10-year time period (2015 to 2025).
- As of 2017, this project reportedly supports 6 scientists and students positions per year.

Started in 2015, the Casco Bay Aquatic System Survey (CBASS) is a 10-year project where researchers are monitoring near shore fisheries ecosystems around the Casco Bay. This project is internally funded with private sources at variable amounts averaging about $100k per year. According to GMRI, approximately half a dozen scientists and students contribute to the effort each year, particularly during the summer field season when many of the sampling activities are happening.

Source: GMRI and GMRI website.

Department of Marine Resources (DMR) - *Lobster Research, Monitoring, and Assessment Program; Maine Sea Scallop Research and Survey Reports*

- Both Lobster and Scallop work amounts to roughly $140k per year and supports about 5 full-time staff.

  Lobster: The four primary monitoring programs included in the Lobster project, along with their yearly funding (approx.) and number of supported staff is detailed below:

  - Roughly $135k/year for the region.
    - The Sea Sampling Program - $30k/year
    - Ventless Trap Survey - $30k/year
    - American Lobster Settlement Index - $5k/year
    - Maine-New Hampshire Inshore Trawl Survey (Ground fish)- $70k/year for region ($350k/year total)
  - Five staff supported, as listed on DMR website (biologist, coordinators, marine resource specialist and lead sampler).

  Scallops: Maine Sea Scallop Research and Survey Reports.
  - Roughly $1 - 5k for the region ($5-15k total)

Source: Carl Wilson, Director of DMR and DMR website.

University Research

In 2015, Maine EPSCoR at the University of Maine received a "five year, $20 million grant from the National Science Foundation to establish the Sustainable Ecological Aquaculture Network (SEANET) and

will build a network of interdisciplinary researchers along the coast of Maine to help advance sustainable ecological aquaculture (SEA) and support marine STEM sciences in Maine's K-12 curricula."
It is estimated that the Casco Bay region, 1 of 6 bioregions in Maine, will receive roughly $3.4M SEANET grant funds during the five-year period. These dollars are distributed to various universities including University of New England, University of Maine System (UMaine and University of Maine Machias) and fund a number of Casco Bay related projects.

University of Maine (Darling Center)

Two major efforts are going on in Casco Bay. The first, which is funded by Casco Bay Estuary Partnership, is called "Assessing Casco Bay's nutrient sources, cycles and impacts: Improving Casco Bay loading estimations." By Damian Brady and Sean Smith.

- Casco Bay Estuary Partnership Fellowship – 9/1/2016-8/31/2017, $20,000 graduate stipend (Designed the first National Estuary Program Casco Bay Estuary Partnership Fellowship for the University of Maine). This is funding a graduate student named Whitley Gilbert to quantify nitrogen loading.

The second, called the "Sustainable Ecological Aquaculture Network (SEANET)," works in 6 sites along the coast, including Casco Bay. SEANET is a $20 million National Science Foundation (NSF) grant and quantifying how much of it is in Casco Bay is very difficult. UNE's Dr. Carrie Byron is also doing SEANET work in Casco Bay.

- Buoy Monitoring Program and Transect Sampling, supporting approximately 5 internships in the summer of 2017.

Source: Damian Brady, May 2017.

University of Maine at Machias (UMM)/ Downeast Institute (UMM's Marine Science Field Station)

For 2014, 2015 and 2016, total research funding amounted to $722,500. This funding supported 3 fulltime positions at UMM's Marine Science Field Station as well as contracted services from Stewards of the Sea LLC. Of the $722,500, Stewards of the Sea received between $90,000 - $195,000 during the three year period.

Research in-and-around the Harraseeket and Fore Rivers began in May 2014 and 2015 using funds generated from the Maine Economic Improvement Fund (MEIF) - Small Campus Initiative; NOAA - Saltonstall-Kennedy; the Broad Reach; Sea Pact; and the US Fish & Wildlife Service via the Department of Environmental Protection (DEP). The work has focused on examining various field techniques to improve soft-shell clam management ranging from how to keep predators from consuming shellfish to the effects of ocean acidification on soft-shell clam recruitment. The following bullet points break down funding by source:

- $350,000 - MEIF
- $250K – NOAA
- $90,000 - Sea Pact (non-profit) for applied research
- $25,000 - Broad Reach (non-profit) for applied research
- $7,500 - DEP

Supported with those funds:

- 3 fulltime positions
- Contracted services of a group of "clammers" who formed a business called Stewards of the Sea LLC. Stewards of the Sea LLC received between $30,000 - $65,000 per year for the period 2014-2016 for their services. In 2014 funds were administered through the Casco Bay Estuary Partnership. The 2015 study was funded by the University of Maine at Machias and the Downeast Institute (Beal, 2017; Downeast Institute, 2017).

Source: Brian F. Beal, Professor of Marine Ecology and Director of the Marine Field Station (2017); Downeast Institute website (2017). Note: Some of the details of the work through 2015 is on the web site for the Downeast Institute (UMM's Marine Science Field Station): http://www.downeastinstitute.org/freeport.htm and http://www.downeastinstitute.org/webhannet-and-fore-river-studies-(2014-and-2015).htm.

University of New England (UNE): Center for Excellence in the Marine Sciences

Assistant Professor, Dr. Carrie Byron and Assistant Research Scientist, Adam St. Gelais are working on two major projects (without formal titles) along with several smaller projects. Major funders include National Science Foundation EPSCoR SEANET (roughly $3.4M project) and Northeast Sustainable Agriculture Research and Education (SARE) as well as UNE (amount unknown).

- Matt Moretti received funding from SEANET for research equipment on his farm ($8k).
- Dr. Byron and USM partner, received approximately $2,000 for project specific supplies. Dr. Byron is working with Karen Wilson from University of Southern Maine and Matt Moretti of Bangs Island Mussels on a food web study that integrates various analysis methods for kelp.
- Mr. Gelais is working on integrating histological analysis on bivalve tissues and environmental data to examine environmental variability in tissue condition.

Several graduate and undergraduate students from UNE are leading or assisting aspects of this integrated project. For the kelp and bivalve work in Casco, that includes 2 Professors, 1 PhD student, 3 MS students, and 4 undergrad students.

In addition to the work mentioned above, Assistant Research Scientist, Adam St. Gelais along with PhD student Gretchen Grebe are working with two seaweed farms in Casco Bay: Ocean's Balance and Casco Bay Kelp. This work is focused on kelp morphology, ecosystem services as it pertains to nutrient remediation, and aquaculture engineering. As part of this project they have worked through Ocean's Balance and previously the Island Institute, on seaweed farming outreach projects with students on Long and Chebeague Islands.

Mr. Gelais is also working with small oyster growers in the Brunswick and Harpswell area in a comparison of the performance of different grow out methods and the tradeoffs with view-scape impacts and other user conflicts.

- Supported Staff: Adam St. Gelais, Dr. Carrie Byron, Gretchen Grebe (PhD student), several graduate and undergraduate students from UNE.
  - 2 Professors
  - 1 PhD student
  - 3 MS students
  - 4 undergrad students

- *External Staff/Partners:* Karen Wilson from University of Southern Maine, Matt Moretti of Bangs Island Mussels, Ocean's Balance, Casco Bay Kelp, Island Institute.

Source: Via email from Adam St. Gelais and Dr. Carrie Byron, (April, 2017).

Education and Research

Southern Maine Community College (SMCC)

SMCC runs a number of education-related research projects. All of SMCC's research effort occurs through teaching and student projects. Covered topics include:

- Water quality in the Portland Ship Channel, annual Fall survey
- Subtidal fish populations near the SMCC campus, annual
- Isolation of marine bacteria and bacteriophage, ongoing
- Lobster shell disease, intermittent
- Monitoring invasive invertebrates, ongoing
- Sonar mapping of eel grass, intermittent current drifter studies

Source: Via email from Brian Tarbox, Marine Lab at SMCC (April, 2017).

Other Research and Education (Casco Bay related)

Bigelow Laboratory for Ocean Sciences

Dr. Nichole Price, Senior Research Scientist and Director of Center for Venture Research on Seafood Security, is working with the Island Institute on a project looking at the impact of seaweed aquaculture on pH. The project is related to ocean acidification and climate change.

Saint Joseph's College of Standish Maine

Mark Green is a marine science professor at Saint Joseph`s College in Standish who works on marine geochemistry, ocean acidification, climate change impacts on marine ecosystems; and aquaculture techniques and production. In 2006, Green received a $419,000 National Science Foundation grant for research on two commercially valuable clam species in Casco Bay. The three-year grant supported fieldwork along the shoreline in Freeport and South Portland. Green also carries out research at Sebago Lake.

Source: Mark A. Green summary via Saint Joseph's College website, https://www.sjcme.edu/About-Us/Contact-Directory/Mark-A_-Green/. Last accessed on 6.16.2017.

Bates College of Lewiston, Maine

Dr. Beverly Johnson, Professor of Geology at Bates College, has been working on a research project, titled *Coastal blue carbon; changes in baseline conditions in Gulf of Maine coastal ecosystems over the last 4,000 years*, which is focused on coastal ecosystem restoration and climate change mitigation. According to the Bates website (2017) a number of students are working on related research projects, and some of the data generated by these projects have been used in the Manual for Measuring Coastal Blue Carbon, a resource generated by Johnson, and others members of the Blue Carbon Scientific Working Group and distributed globally.

Source: Beverly Johnson summary via Bates College Website, http://www.bates.edu/geology/facultystaff/beverly-johnson-2/current-research/. Last accessed on 6.16.2017.

New England Ocean Cluster (NEOC)

The NEOC promotes networks and relationships among businesses and entrepreneurs in the marine industry. Efforts include the New England Ocean Cluster House (NEOCH), which is an innovation hub and

incubator, located in Portland, for companies that draw on the ocean as a resource for their products, services, and ideas.

Source: www.newenglandoceancluster.com.

Maine Technology Institute (MTI) Grants - Agriculture, Aquaculture, Fisheries and Food Production

MTI has funded various projects including the following:

Grant Recipient	Project
Focus Maine	Aquaculture and Agriculture initiative
Maine Sustainable Agriculture Society	Sustainable Year-Round Agriculture (SYRA) Cluster Initiative
Coastal Enterprises Inc.	Maine Scallop Aquaculture knowledge transfer and equipment demonstration project
	Underutilized Shellfish Products feasibility study
Gulf of Maine Research Institute	Sustainable Seafood cluster initiative
Bigelow Laboratory for Ocean Sciences	Maine Algal Cluster planning effort

Source: Maine Technology Institute.