Edible Seaweed Market Analysis

ISLAND INSTITUTE

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Courtesy: Atlantic Sea Farms and the New England Ocean Cluster

In partnership with Pentallect and EPR

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Opposite page: *Photos depicting all stages of the edible seaweed aquaculture industry*
Top row: seeding lines in the fall and premature kelp "seedlings" in the early winter
Middle row: kelp harvest in the spring
Bottom row: kelp processing and a chickpea seaweed salad

Introduction

Purpose of the Market Analysis

The Island Institute and its constituents have identified edible seaweed aquaculture as a growth industry that presents Maine participants with the potential to expand within the profitable domestic marketplace. To further analyze and evaluate this opportunity, the Island Institute engaged two experienced consulting organizations, Pentallect Inc. and Economic & Policy Resources Inc. (EPR), to complete a comprehensive Edible Seaweed Market Analysis (ESMA) report on the edible seaweed opportunity for Maine stakeholders.

The ESMA report is designed to be a critical resource for stakeholders associated with the Maine seaweed aquaculture industry and creates a framework, including identification of the size and nature of the current and future opportunity and an assessment of the requirements for success, for Maine island and coastal communities interested in participating in the edible seaweed aquaculture marketplace.

Scope of Work

The ESMA report includes a number of critical strategic elements, including:

- High level understanding of the size and scope of global and domestic markets for edible seaweed
- Profiling factors that influence domestic production of edible seaweed
- Providing data and insight in order to determine Maine's production capacity to participate competitively in the domestic edible seaweed market
- Preparing a detailed economic impact analysis that addresses the market potential, or likely development path, for edible seaweed for Maine's statewide and local economies and its stakeholders

Methodology

To complete this research report and economic impact study, Pentallect and EPR conducted extensive research and analysis including: web-based research; reviews of publications and reports; on-site and telephone interviews with over 25 edible seaweed harvesters, processors, researchers and industry experts in Maine, Alaska, New England, California, and the Pacific Northwest; and interviews with retailers and operators within primary channels. See the following section and footnotes throughout the report for sourcing information.

Executive Summary

Maine's edible seaweed aquaculture industry is in its relative infancy, with a limited set of harvesters and processors investing to build capacity, develop products, establish distribution channels, and create consumer demand. There is significant interest among existing and potential new entrants to expand Maine's farmed edible seaweed industry infrastructure and scale. This report documents the size and nature of the opportunity over a fifteen-year planning horizon, identifies the requirements for success, and estimates the potential economic impact of the farmed edible seaweed industry on Maine participants and the state's overall economy.

Aquaculture-sourced edible seaweed represents a sustainable growth opportunity for Maine industry participants if sufficient infrastructure and demand creation capabilities can be developed to support continued investment in harvesting capacity. The research indicates that the best estimate projections for Maine farmed edible seaweed production will grow an average of 12% – 15% annually over the planning horizon, representing an incremental 2.7 million wet pounds of market opportunity by 2035, or more than 3 million total wet pounds. High-end projections suggest that the Maine farmed edible seaweed industry could reach almost 6 million wet pounds by 2035.

Growing and harvesting the primary farmed edible seaweed species (sugar/skinny kelp and alaria) is a relatively low cost, easily implementable process that can deliver supplemental revenue and asset utilization. For most harvesters that lack processing capabilities, edible seaweed provides supplemental revenue rather than their primary source of revenue.

The annual revenue potential for harvesters varies significantly depending on lease acreage and processing practices. Harvesters without processing capabilities can expect to realize approximately $0.40 – $0.70 per wet pound for bulk unprocessed seaweed. For these harvesters, securing access to processing capabilities prior to initiating the growing process, either via established contracts with processors or investing in first stage processing (typically drying) capabilities, is critical to success. Maine infrastructure requirements to support continued growth include:

- Expanded processing capacity
- Value-added product development
- Distribution network expansion
- Brand building/consumer awareness

Generally, Maine's established edible seaweed processors are in the best position to invest in these infrastructure elements given their scale, product development capabilities, and established, although still relatively under-developed, distribution networks.

1. Global Market Analysis

1.1 Global Market Overview

The global seaweed market is large, diverse, and growing. Key global seaweed market dynamics include:

- 80 billion pounds of worldwide production across all end-product applications (food and non-food)
- 8% – 10% annual global growth rate due to population growth in high consumption countries, increased market penetration of less developed countries, end-product innovations, and growth of plant-based diets and product solutions, especially in Western countries
- Numerous species and end product applications—food-related products account for the significant majority of end products
- Almost exclusively reliant on aquaculture, or farmed, production to meet global demand
- The majority of both production and consumption is driven by a set of Asian countries, although demand is increasing across the globe, including in the United States

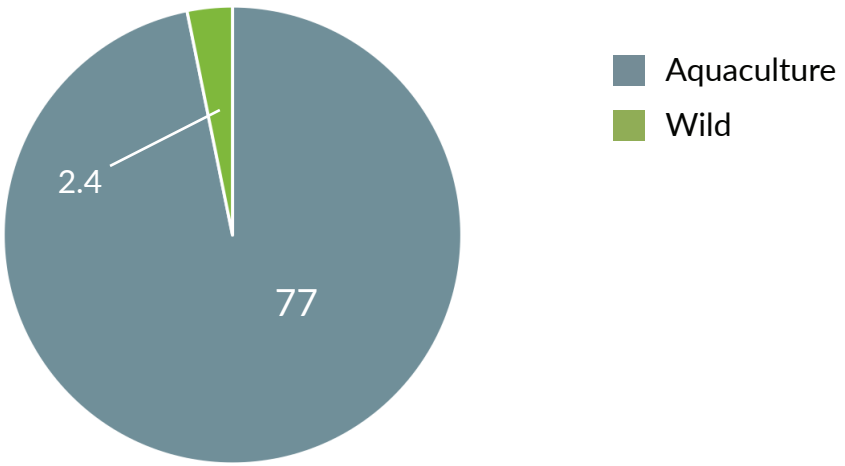
The global annual seaweed harvest represents almost 80 billion pounds

1.2 Global Market Size

The global annual seaweed harvest represents almost 80 billion pounds (36 million metric tonnes), with a harvest value of approximately $6 billion USD across all species and end-product formats.

Aquaculture-sourced seaweed accounts for almost 97% of global supply, or an estimated 77 billion pounds.

Figure 1A: Global Status of Seaweed Production – Weight (billions of pounds)

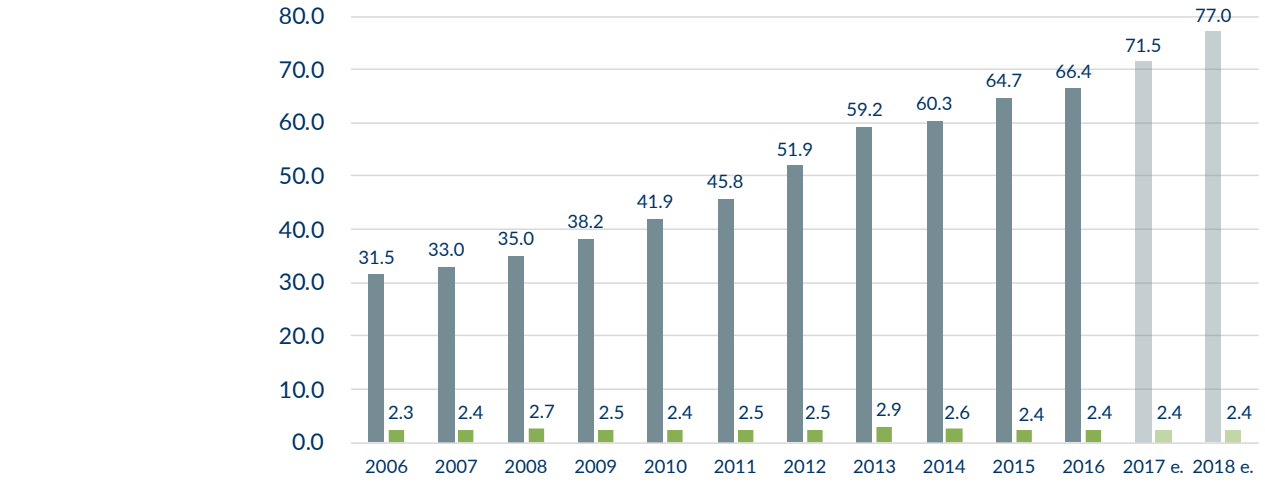


Source: Food and Agriculture Organization of the United Nations (FAO); Globefish Research Programme; The Global Status of Seaweed Production, Trade and Utilization; Volume 124; 2018; Pentallect research

1.3 Global Market Growth

Aquaculture-sourced seaweed products have driven overall global industry growth, while wild production has plateaued.

Figure 1B: Global Growth of Seaweed Production – Weight (billions of pounds)



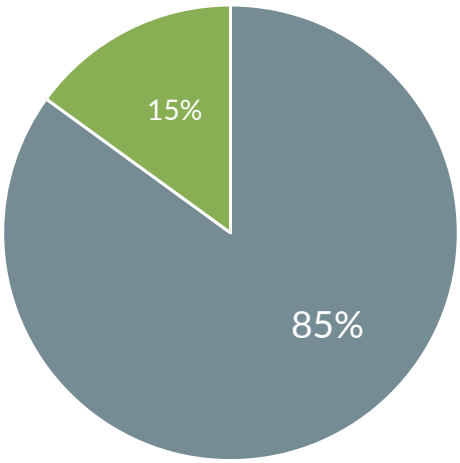
Source: Food and Agriculture Organization of the United Nations (FAO); Globefish Research Programme; The Global Status of Seaweed Production, Trade and Utilization; Volume 124; 2018; Pentallect research

Average Annual Growth
Aquaculture: 7.7%
Wild: 0.3%
Total: 7.3%

1.4 Edible Seaweed Global Market Share

Food products for human consumption represent an estimated 85% of total global seaweed production, including finished products and ingredients for beverages, nutritional products, food production, etc. For aquaculture-sourced seaweed, human food products account for more than 90% of production.

Figure 1C: Seaweed Market Share – Percent Weight



Human consumption
- Consumer Food Products
- Thickening Agents
- Clarifying Agents

All other uses
- Fertilizers
- Animal Feed
- Pharmaceuticals
- Cosmetics
- Biofuel

Source: Food and Agriculture Organization of the United Nations (FAO); Globefish Research Programme; The Global Status of Seaweed Production, Trade and Utilization; Volume 124; 2018; Pentallect research

1.5 Leading Global Producers

Global seaweed production is heavily oriented toward Asian/Pacific Rim countries, which account for over 99% of global production. The North American seaweed harvest accounts for less than one-tenth of one percent of total global seaweed production.

Figure 1D: Relative Production by Region (2016)

Region	Weight (MT[1])	Percent of Global Production
Asia/Pacific Rim	29,891,000	99.47%
Africa	136,000	0.45%
South America	15,000	0.05%
All other	8,000	0.03%
Global	30,050,000	

1. Metric "tonnes" are equivalent to 1.10231 U.S. tons or 2,204.6 pounds
Source: Food and Agriculture Organization of the United Nations (FAO); The State of the World Fisheries and Aquaculture; 2018

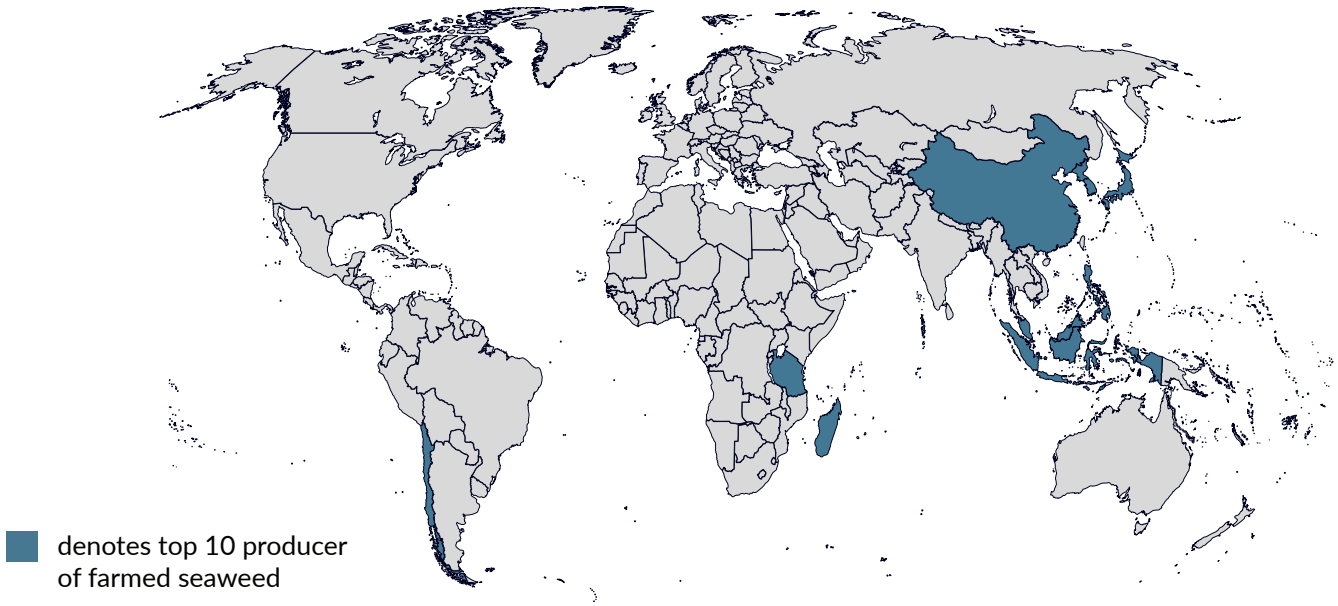
The top 10 leading global farmed seaweed producers account for more than 99% of total production. Global production is heavily concentrated within China and Indonesia, which collectively represent over 86% of total production.

Figure 1E: Global Leading Farmed Seaweed Producers (2016)

Country	Rank	Weight (wet MT[1])	Market Share	
China	1	14,387,000	47.9%	} 86.6%
Indonesia	2	11,631,000	38.7%	
Philippines	3	1,405,000	4.7%	
South Korea	4	1,351,000	4.5%	
North Korea	5	489,000	1.6%	
Japan	6	391,000	1.3%	
Malaysia	7	206,000	0.7%	
Tanzania	8	119,000	0.4%	
Madagascar	9	17,000	0.1%	
Chile	10	15,000	<0.1%	
All other		40,000	0.1%	
Global		30,050,000		

1. Metric "tonnes" are equivalent to 1.10231 U.S. tons or 2,204.6 pounds
Source: Food and Agriculture Organization of the United Nations (FAO); The State of the World Fisheries and Aquaculture; 2018

Figure 1F: Global Leading Farmed Seaweed Producers Map (2016)



1.6 Global Exports – Seaweed for Human Consumption

The majority of seaweed for human consumption exports are concentrated among four countries in Asia, which represent more than 90% of all export volume. Indonesia alone accounts for almost 58% of total seaweed for human consumption exports.

Figure 1G: Leading Global Exporters – Seaweed for Human Consumption (2016)

Country	Rank	Weight (MT[1])	Market Share	
Indonesia	1	100,972	57.8%	} 76%
South Korea	2	31,719	18.2%	
China	3	14,721	8.4%	
Japan	4	14,620	8.4%	
Malaysia	5	2,224	1.3%	
United Kingdom	6	1,496	0.9%	
South Africa	7	1,299	0.7%	
United States	8	1,132	0.6%	
France	9	991	0.6%	
Chile	10	748	0.4%	
All other		4,690	2.7%	
Global		174,612		

1. Metric "tonnes" are equivalent to 1.10231 U.S. tons or 2,204.6 pounds

Source: Food and Agriculture Organization of the United Nations (FAO); Global Seaweed Production Report; 2018

1.7 Global Imports - Seaweed for Human Consumption

China and Japan are the largest importers of seaweed for human consumption, representing more than 71% of all import volume. Note: Countries may import and/or export seaweed for further processing.

Figure 1H: Leading Global Importers – Seaweed for Human Consumption (2016)

Country	Rank	Weight (MT[1])	Market Share	
China	1	146,028	58.1%	} 71.2%
Japan	2	32,989	13.1%	
Taiwan	3	16,229	6.5%	
North Korea	4	12,159	4.8%	
United States	5	8,560	3.4%	
United Kingdom	6	5,922	2.4%	
Thailand	7	4,554	1.8%	
Norway	8	4,125	1.6%	
France	9	3,482	1.4%	
Russia	10	2,506	1.0%	
All other		14,715	5.9%	
Global		251,269		

1. Metric "tonnes" are equivalent to 1.10231 U.S. tons or 2,204.6 pounds
Source: Food and Agriculture Organization of the United Nations (FAO); Global Seaweed Production Report; 2018

While the United States is in the top 10 countries for both exports and imports, the U.S. is a relatively small player in the global marketplace, accounting for less than 1% of global exports and 3% of global imports of seaweed for human consumption.

2. U.S. Domestic Market Analysis

2.1 U.S. Edible Seaweed Market Overview

The United States edible seaweed market has relied heavily on imported products to meet demand. Domestic harvesting, processing and distribution infrastructures, and demand creation capabilities are in their relative infancy and production levels have only begun to accelerate within the past two years. Key domestic edible seaweed market dynamics include:

- More than 95% of current edible seaweed products are imported.
- Domestic edible seaweed aquaculture production has increased significantly since 2017, with Maine and Alaska accounting for the majority of growth and overall market share.
- Total domestic edible seaweed production (farmed and wild) is estimated to be slightly less than 1 million pounds wet harvest, with farming accounting for approximately three-quarters of current supply and growing.
- Interest in farming/harvesting, represented by lease applications and increased output, has increased significantly in the primary growing markets (particularly Maine and Alaska).
- The majority of edible seaweed growers are also professionally engaged with other seafood-related commercial activities (fishing, lobstering, shellfish aquaculture, etc.).
- Processing infrastructure remains limited to a small set of processors in the primary markets. Ensuring sufficient capacity and access to first- and/or second-stage processing will be critical to the long-term growth prospects for the domestic edible seaweed farming industry.
- Seed availability can be a limiting factor for harvesters that do not have contracts with processors, as the majority of seed spools are currently sourced by a small set of processors. There are opportunities to increase seed supply through both the existing processors and, potentially, other organizations involved with seaweed aquaculture (laboratories, universities, etc.). While some of the leading processors provide seed to their contracted growers, non-contracted growers, in particular, must ensure access to processing capabilities.
- Domestic processors of sugar/skinny kelp and alaria and a small amount of regional species (dulse, laver, etc.) have primarily focused their product development efforts on value-added products, in dried and wet formats, for snacking, appetizers/meal accompaniments, condiments, salad components, beverages, and seasonings.
- Domestic processors have largely avoided competing with lower-priced, more commoditized imported products that are primarily designed for Asian markets, sushi applications in restaurants, and grocers and health/natural foods stores. Product differentiation from imported items will be critical to achieving sustained success for the domestic edible seaweed industry, unless more cost-effective solutions are developed via exploration of lower-cost regional species and/or significant efficiencies of scale can be achieved in harvesting and processing to reduce product costs.
- U.S. consumers source the majority of edible seaweed volume via Asian ethnic markets, specialty stores (health/natural foods), Asian-menu restaurants, and grocery chain sushi franchises. Secondary channels include: fine dining restaurants, foodservice operations at colleges and universities, and select seafood restaurants.

More than 95% of current U.S. edible seaweed products are imported

2.2 Total U.S. Edible Seaweed Market Size

The total domestic edible seaweed market is approximately 16 million pounds dry weight. Imported products represent almost all of the current domestic edible seaweed supply (more than 98%).

Figure 2A: U.S. Edible Seaweed Market Size (2019)

Source	Estimated Dry Pounds[1]
Net Imports[2]	16,000,000
Domestic Aquaculture	55,000 – 60,000
Domestic Wild	30,000 – 35,000
Total	**16,085,000 – 16,095,000**

1. Total U.S. imports (19 million lbs.) less FAO-sourced exports (-2 million lbs) less 5% estimated further processing yield loss (-1 million lbs.). Includes both wet and dry formats, although the majority of imports are dried product formats, and the imported volume may include some packaging weight, so the imported volume may be slightly overstated. Domestic wet harvest estimates are adjusted for a 10:1 dry yield to enable direct volume comparisons.
2. It is important to note that some of the imported volume is further processed within the U.S., which will result in volume losses during the further processing cycle.

Source: Food and Agriculture Organization of the United Nations (FAO); Global Seaweed Production Report; 2018; Pentallect research.

2.3 U.S. Edible Seaweed Imports – Primary Countries

The leading U.S. sources of imported edible seaweed, in dollar value, are China and South Korea which collectively account for over one-half of total U.S. edible seaweed imports.

Figure 2B: U.S. Import Providers – Seaweed Fit for Human Consumption (2016)

Country	Rank	Weight (MT[1])	Value ($USD)
Iceland	1	2,543	$2,973,000
China	2	1,815	$19,572,000
Canada	3	1,555	$7,788,000
South Korea	4	1,144	$11,964,000
Philippines	5	591	$3,218,000
United Kingdom	6	432	$2,548,000
Japan	7	211	$5,095,000
Chile	8	103	$1,264,000
Taiwan	9	41	$179,000
India	10	26	$551,000
All other		99	$730,000
Total		8,560	$55,882,000

1. Metric "tonnes" are equivalent to 1.10231 U.S. tons or 2,204.6 pounds
Note: Relative differences in values per ton among U.S. import countries are due to variations in species and product format mix.
Source: Food and Agriculture Organization of the United Nations (FAO); Global Seaweed Production Report; 2018

2.4 Domestic Edible Seaweed – Wet Pound Harvest

The U.S. edible seaweed wet, or non-processed, harvest is an estimated 850,000–925,000 pounds, or the equivalent of almost 100,000 dry pounds. Farming accounts for more than 65% of domestic volume.

Figure 2C: U.S. Edible Seaweed Harvest (2019)

Source	Estimated Wet Pounds	Equivalent Dry Pounds[1]
Aquaculture	550,000 – 600,000	55,000 – 60,000
Wild	300,000 – 350,000	30,000 – 35,000
Total	**850,000 – 950,000**	**85,000 – 95,000**

1. One dry pound is roughly equivalent to ten wet pounds.

Source: Pentallect Inc.; EPR research

2.5 Primary Domestic Harvest Regions – Edible Seaweed

Maine and Alaska are the leading domestic edible seaweed producers, accounting for more than 85% of total U.S. supply.

The seaweed industry infrastructures have significant differences between Maine and Alaska. Alaska has substantial potential lease acreage, and harvesters have access to seafood processors for first-stage processing to stabilize the seaweed for final stage processing. However, the Alaskan supply chain typically requires harvested seaweed to be transported via water to consolidation points and then shipped to the Pacific Northwest or other U.S. West Coast locations for further processing. Maine harvesters have more direct overland access to Maine-based further processors, and the Maine seaweed industry has a shorter supply chain to traditional food and retail industry distribution channels.

Figure 2D: Estimated U.S. Edible Seaweed Weight by Region (Wet Lbs.)

Region	Farmed	Wild	Total	Equivalent Dry[1]
Maine	325,000	230,000	555,000	55,000 – 60,000
Alaska	180,000 – 200,000	<10,000	200,000 – 220,000	20,000 – 22,000
Other Northeast (CT, RI, MA, NH, NY)	10,000 – 20,000	<10,000	15,000 – 30,000	1,500 – 3,000
Other West (CA, OR, WA)	30,000 – 50,000	50,000 – 70,000	80,000 – 120,000	8,000 – 12,000
All Other	<10,000	<10,000	<20,000	<2,000
Total	550,000 – 600,000	300,000 – 325,000	850,000 –950,000	85,000 – 95,000

1. One dry pound is roughly equivalent to ten wet pounds.

Source: Pentallect Inc.; EPR research

2.6 Historic Growth

The domestic edible seaweed harvest has grown significantly in recent years, with a five-fold annual increase in the spring 2019 farmed harvest—particularly in Maine and Alaska. Despite the accelerated growth of the developing industry, the U.S. farmed edible seaweed industry has not yet achieved scale or diversity of species and remains in its infancy.

Figure 2E: Estimated Farmed Edible Seaweed Harvest by Year (Wet Lbs.)

Source	2015	2016	2017	2018	2019
Maine	15,000	24,000	45,000	54,000	325,000
Alaska	Not Available	Not Available	Not Available	30,000	180,000 – 200,000
All Other	10,000 – 15,000	10,000 – 20,000	15,000 – 30,000	20,000 – 40,000	45,000 – 75,000
Total	25,000 – 30,000	30,000 – 40,000	60,000 – 75,000	100,000 – 125,000	550,000 – 600,000

Source: Pentallect Inc. and EPR research; Maine DMR

2.7 Primary Species – U.S. Farmed Edible Seaweed

Sugar/skinny kelp (Saccarina latissimi) is the primary domestically grown edible seaweed species, although more harvesters are experimenting with additional species for various end-product applications (dulse, laver, etc.).

Figure 2F: Leading U.S. Farmed Edible Seaweed Species

Species	Estimated Market Share
Sugar/Skinny Kelp *(Saccharina latissimi)*	75% – 80%
Alaria/Winged Kelp *(Alaria esculenta)*	10% – 15%
Dulse *(Palmaria palmata)*	<10%
All Other *Digitata (Horsetail Kelp), Kombu, Nori/Laver, etc.*	<10%

Source: Pentallect Inc. research; Maine DMR.
Note: Reporting confidentiality practices limit species volume information.

2.8 U.S. Market Segmentation – Leading Channels

The largest channels for edible seaweed are Asian restaurants and Asian markets, which primarily utilize imported products. Health and natural food stores, foodservice establishments (primarily fine dining restaurants and colleges and universities), and select grocery chains are the primary current channels for domestically-produced edible seaweed products. Over time, it is anticipated that edible seaweed products will achieve more mainstream channel penetration as traditional supermarkets and grab and go venues (convenience stores, workplace dining, micro markets, etc.) will most likely embrace edible seaweed products due to their perceived healthy positioning (clean labels, locally sourced, potentially organic, etc.) and the growing consumer interest in plant-based meal and snack solutions.

Figure 2G: Leading U.S. Channels for Edible Seaweed Products

Channel	Number of Locations	Primary Product Source: Imported	Primary Product Source: Domestic	Estimated Market Share
Foodservice				
Asian Restaurants	64,000	✓		25%
Independent Fine Dining Restaurants	17,800	✓	✓	5%
Colleges/Universities	4,500	✓	✓	3%
Independent Seafood Restaurants	6,800	✓		<2%
All Other Foodservice	670,000+	✓		
Retail				
Health/Natural Foods	3,500	✓	✓	15%
Asian Markets	8,000+	✓		30%
Grocery–Sushi Franchises	7,000	✓		10%
All Other Retail Grocery	30,000+	✓		10%

Source: Pentallect Inc. research

A spool of kelp seed

2.9 Pricing / Value Chain – Realized Value

The nascent U.S. edible seaweed industry lacks an established pricing structure, and there are significant variations in the value realized by value chain participants.

Growers can expect to pay approximately $100 per 200 ft. seed spool of sugar kelp from a nursery if they do not have a contract with a processor for their harvest volume. Growers that contract with further processors that offer nursery services may receive discounted seed pricing or free seed supplies in exchange for a volume commitment at an established price that reflects the seed cost to the processor. The typical harvest yield on a seed spool is three to six pounds. of seaweed per foot, or 600 – 1,000 lbs. per spool potential. This equates to an average seed cost of $0.10 – $0.17 per harvested wet pound.

Growers of sugar/skinny kelp can expect to receive approximately $0.40 – $0.70 per wet pound for their harvest. Growers that complete the first stage processing to dry the seaweed can expect to receive $6.00 – $8.00 per dried pound. Note: it typically requires approximately 10 pounds of wet seaweed to yield one dry pound. Organic products can achieve a 30% – 50% premium, although pricing varies and not all processors utilize organic products.

The value realized by final stage processors that produce end consumer/customer products varies significantly based on finished product formats.

Figure 2H: Realized Value of Edible Seaweed Products

Product	Typical Value	Reported Range
Seed/Nursery		
Sugar Kelp	$100 per 200 ft. spool	$90 – $120
Organic Sugar Kelp	$150 per 200 ft. spool	$110 – $200
Alaria	$100 per 200 ft. spool	$110 – $130
Organic Alaria	$175 per 200 ft. spool	$150 – $200
Grower/Harvester Stage		
Wet Sugar Kelp/Alaria	$0.40 – $0.70 / lb.	$0.26 – $1.00 / lb.
Wet Organic Sugar Kelp/Alaria	$0.60 – $1.00 / lb.	$0.50 – $2.00 / lb.
First Stage Processed – Dry		
Sugar Kelp/Alaria	$6.00 – $8.00 / lb.	$3.00 – $10.00 / lb.
Organic Sugar Kelp/Alaria	$9.00 – $12.00 / lb.	$8.00 – $16.00 / lb.
Second Stage Processed – Finished Products		
Sugar Kelp/Alaria	Wide Variation: $10.00 – $50.00+ /lb.	
Organic Sugar Kelp/Alaria		

Source: Pentallect Inc. research

2.10 Brand Building

Given the nascent position of the domestic edible seaweed marketplace, it will be critical for industry participants to build awareness of the availability, benefits, and differentiating characteristics of domestically-sourced edible seaweed. This awareness building process must address both company-specific brands as well as create awareness of, and interest in, domestic edible seaweed as a category. When considering opportunities to build brand awareness of the domestic edible seaweed category, including Maine-sourced products, there is value in reviewing the brand building practices of other relevant categories. For the purposes of this exercise, this report outlines the brand building practices of Alaska Salmon, Maine Lobster, and Iceland Atlantic Cod.

While the brand building strategies of these three examples differ, general similarities, or common practices, include:

- Industry participant brand building funding via license surcharge fees (Maine) or ex-vessel value taxes (Alaska)
- State funding support (Alaska)
- Communication of high quality products from sustainable, clean water sources (Maine, Alaska, and Iceland)

An overview of each is on the next page.

Alaska Salmon

- Alaska Seafood Marketing Institute (ASMI) is responsible for increasing the value of Alaska seafood via branding campaigns, collaborative marketing programs, technical support, and education and advocacy, among other responsibilities.
- ASMI's efforts are funded by a 0.5% marketing tax on ex-vessel value (landed), USDA funding to support export growth, and matching funds from the State of Alaska.
- Brand building/marketing tools include: brand and species insights and merchandising tools for retailers, and consumer trend data, staff training, recipes, and promotional programs for foodservice customers.
- ASMI's funding is approximately $10 million ($9 million in 2016).

Maine Lobster

- The Maine Lobster Marketing Collaborative is the primary brand building entity for the Maine lobster industry.
- The Marketing Collaborative is funded by lobster license surcharges paid by industry participants. The surcharges vary by type of participants, with lobster harvesters typically paying $31.25 – $93.75 depending on their size; wholesalers paying $250 and processors paying $1,000 – $4,000.
- The Marketing Collaborative promotes the Maine lobster brand in the media.
- The Marketing Collaborative's brand building funding is approximately $2 million.

Iceland Atlantic Cod

Iceland has successfully built brand awareness of their Atlantic Cod as being a high-quality industry leader through a number of efforts that differ from Alaskan Salmon and Maine Lobster.

- Focus on freshly caught, high-quality cod products caught by hook rather than nets.
- Established a quota system to manage supply that tends to keep product availability limited and margins relatively high for participants.
- Ability to leverage fresh products via Iceland's proximity to major U.S. and European markets in contrast to other global competitors that must rely on frozen products due to supply chain lengths.

2.11 Edible Seaweed Growth Factors

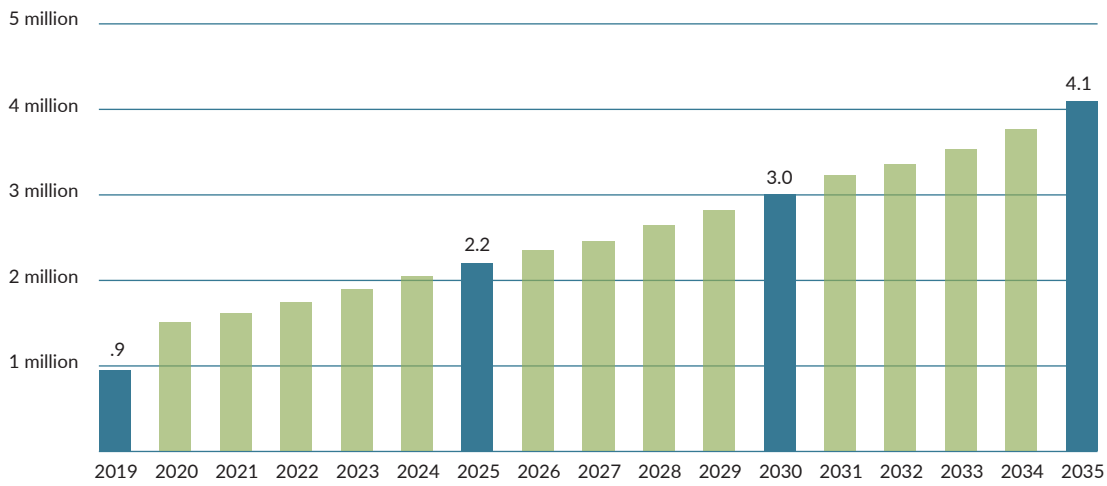
There are a number of factors both supporting the growth of the domestic edible seaweed market and potentially limiting its expansion. In general, the positive forces outweigh the potential constraints, and demand for domestically produced products is projected to grow an average of more than 7%-9% annually through the 2035 planning horizon.

Growth Drivers	Potential Constraints
• The barriers to entry (capital, training, etc.) for growers/harvesters are low. • Nascent domestic production infrastructure in a relatively high-volume, expanding category represents a growth opportunity for domestic participants assuming sufficient infrastructure development. • Lease capacity is available in key growth regions. • Fresh, sustainable, nutrient-rich, plant-based product positioning is on trend with consumer preferences. • There are ancillary environmental benefits—carbon reduction, shellfish aquaculture water quality, etc. • Opportunity exists for integration with shellfish/seafood aquaculture for space and asset utilization. • Industry utilizes the shoulder season and generates revenue for seafood businesses. • Domestic products have greater quality control and a shorter supply chain relative to imported products. • In instances where water quality is not satisfactory, seaweed can absorb toxins. Maine water quality represents a potential competitive advantage that could be leveraged via marketing and positioning.	• The lease application process can be complicated and lengthy. • The current processing infrastructure is limited and requires scaling up to support industry growth. Prior to committing to harvest seaweed, growers must have processing plans or contracts in place to ensure a source for their supply. • Effective, scalable product development is required to drive edible seaweed industry growth. Getting the product right is required for success. • End market demand creation needs to be further developed to build consumer awareness and purchase. Final stage processors are currently in the best position to build awareness and create demand. It is challenging for harvesters to create demand and source sufficient customers to sell their inventory on an individual basis. • Foreign processors are well-established, large-scale, formidable competitors; domestic producers must differentiate with value-added products, as they currently lack the scale and resources to compete directly on price with imported products. • There is a relative lack of species diversity to-date; potential opportunity to expand offerings. • Distribution networks are relatively under-developed and need to be built out to support expansion.

2.12 Domestic Edible Seaweed Growth Projections

To address growing consumer demand, the "best estimate" forecast for domestic edible seaweed production is that capacity will more than double over the next five years and will more than quadruple over the planning horizon, equating to over four million wet pounds annually by 2035.

Figure 2I: Domestic Edible Seaweed Growth Projection (Millions of Wet Lbs.)



Source: Pentallect Inc. research.
Production estimates are based on Pentallect Inc. research with edible seaweed processors, retailers and foodservice operations.

Growth estimates are derived from projected harvest and processing capacity expansion to address growing market demand for domestically-sourced products. Given that the U.S. currently imports the equivalent of approximately 150 million wet tons of edible seaweed (note: U.S. imports are primarily dried formats, so actual converted import volume is approximately 16 million lbs.), domestic production will still account for less than 2% of total U.S. consumption. The research indicates that there may be additional upside to the growth projections if processors develop a broader assortment of consumer-relevant products, invest to build demand at the retail, foodservice, and consumer levels, and expand distribution systems.

The farmed edible seaweed sector will drive the majority of domestic production expansion as harvesting capacity and processing infrastructure are projected to expand to meet growing demand for domestically produced products.

Figure 2J: Domestic Edible Seaweed Harvest Projections

	Volume, Wet Lbs.			Average Annual Growth	
Source	2019	2025	2035	2019 - 2025	2019 - 2035
Farmed	575,000	1,790,000	3,730,000	20.8%	12.4%
Wild	325,000	365,000	410,000	2.0%	1.4%
Total	**900,000**	**2,155,000**	**4,140,000**	**15.7%**	**10%**
			Total (weighted avg)		

Source: Pentallect Inc. research.

2.13 Product Formats

Value-added edible seaweed products will account for more than 80% of projected domestic production growth over the 2035 planning horizon.

Domestically-produced dry low-value-added products' volume will more than double over the planning horizon, although the domestically-sourced dry low-value-added categories' market share will shrink to a projected 24% in the expanding marketplace as U.S. producers primarily focus on value-added products rather than competing directly with lower-priced, less value-added imported products.

Figure 2K: Domestic Edible Seaweed Harvest Projections By Product Format

	Volume, Wet Lbs.				Average Annual Growth		
Source	2019	2025	2035		2019 - 2025	2019 - 2035	
Dry Low Value Added[1]	405,000	775,000	995,000		11.5%	5.8%	
Dry Value Added[2]	225,000	630,000	1,435,000		18.7%	12.3%	} 82% of growth
Wet Value Added[3]	270,000	750,000	1,710,000		18.5%	12.2%	
Total	**900,000**	**2,155,000**	**4,140,000**	Total (weighted avg)	**15.7%**	**10.0%**	

Descriptors:
1. Flakes, ground, chopped/whole leaf, etc.; 2. Snacks, bars, seasonings, pastas, etc.; 3. Frozen for sides & salads, sauces, condiments, pickled, etc.
Note: Gross harvest equivalent, excludes trim and other losses during processing.

Source: Pentallect Inc. research

Courtesy: Atlantic Sea Farms and the New England Ocean Cluster

3. Maine Market Position, Future Outlook, and Requirements for Success

3.1 Maine Edible Seaweed Market Overview

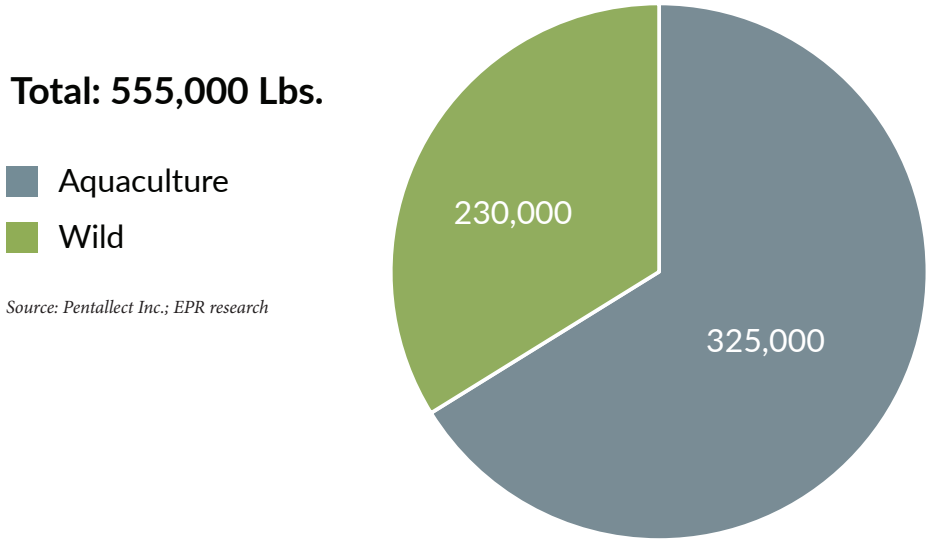
Maine is the domestic edible seaweed harvest leader, accounting for approximately 55% of total harvest volume (farmed and wild) and approximately 60% of total farmed edible seaweed. While Maine leads the nation in edible seaweed harvest volume, similar to the overall domestic marketplace, the industry is still in its relative infancy in the state. With farmed edible seaweed, there has been significant growth in raw supply from harvesters in the past two years and processing capacity has generally managed to keep up with increased supply. Expanding processing capacity, ensuring harvester access to processors, and developing differentiated, consumer-relevant products will be critical to Maine's ongoing edible seaweed industry.

3.2 Maine Edible Seaweed Market Size and Structure

Volume – Farmed and Wild

Maine produced an estimated 555,000 lbs. total wet harvest in 2019. Farmed operations accounted for approximately 60% of Maine's 2019 harvest, with the balance being wild-sourced.

Figure 3A: Maine Edible Seaweed – Farmed and Wild 2019 Estimate (Wet Lbs.)

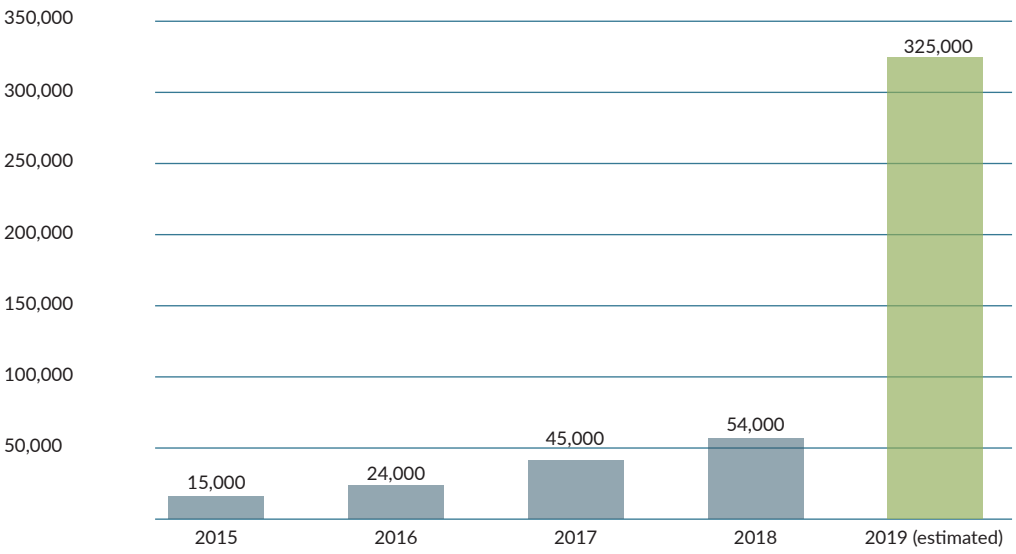


Source: Pentallect Inc.; EPR research

Farmed Edible Seaweed Historic Growth

Farmed seaweed volume has grown significantly within the past three years, with 2019 estimated harvest volume at approximately 13 times that of 2016 levels.

Figure 3B: Maine Farmed Edible Seaweed Harvest by Year (Wet Lbs.)

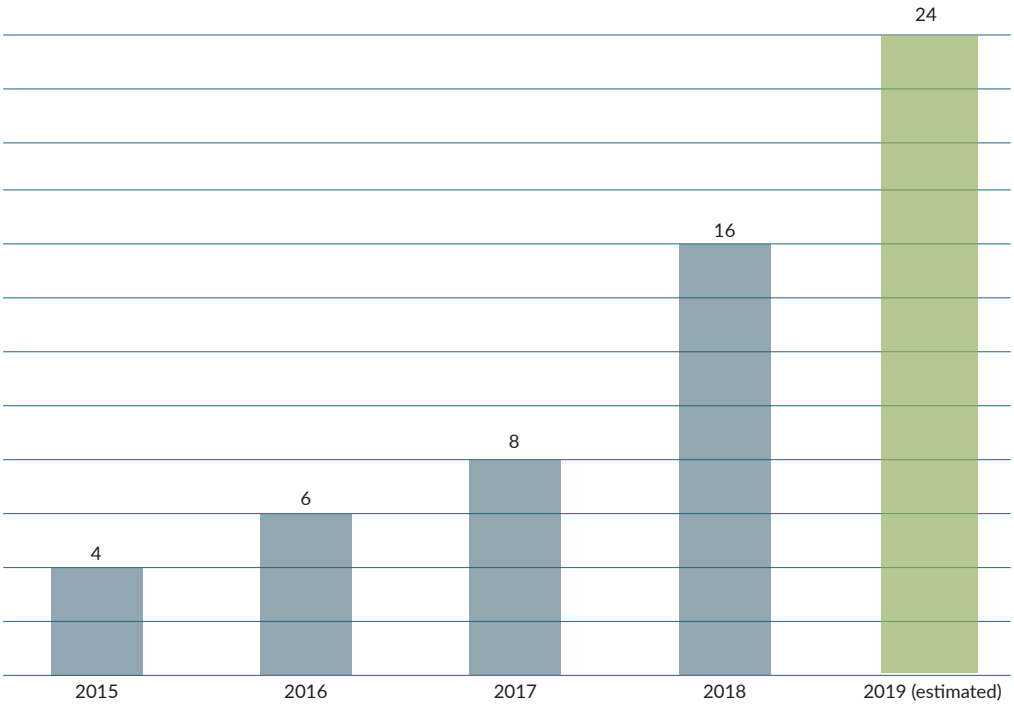


Source: Maine DMR; Pentallect Inc. research, EPR research

Harvester Dynamics

Maine's farmed edible seaweed growth has been fueled by a limited group of processors that has expanded capacity and invested in product development and demand creation activities to varying levels. While the existing Maine edible seaweed processing infrastructure is limited, recent growth has supported an associated increase in the number of growers/harvesters and their associated acreage.

Figure 3C: Maine Farmed Edible Seaweed – Number of Harvesters by Year



Source: Maine DMR, Pentallect research, EPR research

Seed Supply

While there is generally sufficient seed supply to meet existing harvester demand, the seed nursery infrastructure will need to expand to meet expected growth, particularly for harvesters that do not have contracts with seed-supplying processors and those located further Downeast, which is farther away from the primary seed sources. Much of the available seed supply is provided by seaweed processors to both contracted and independent growers. The contracted growers typically establish a harvest price with the processors that accounts for the upfront seed supply.

There is a relatively limited set of five edible seaweed processors that produce finished end products in Maine with established scale.

Processor Dynamics

Maine's edible seaweed processing infrastructure consists of both first-stage and second-stage processing. First-stage processing is where the wet seaweed is either dried, often by harvesters, or blanched and frozen in preparation for further processing into finished products. Second-stage processing typically entails either wet or dry seaweed conversion into consumer-ready products, or dried bulk seaweed grinding into ingredients for consumer products.

For fresh or frozen seaweed formats, the harvested seaweed must be rapidly processed into finished products and distributed, or blanched and frozen in bulk form as raw material inventory to extend the production timetable for further processing. Blanching and freezing enables processors to extend the production cycle well beyond the brief harvesting season.

Currently, there is a relatively limited set of five edible seaweed processors that produce finished end-products in Maine with established scale. Some of these processors have their own growing operations and others contract with independent growers to provide raw or first-stage processed (dried) edible seaweed. Cumulatively, these processors account for an estimated 80%+ of total current Maine-based edible seaweed processing capacity. As wild rockweed harvesting may be constrained by recent legal rulings, there could be potential for additional first-stage drying capacity of edible farmed seaweed at these rockweed processing facilities. In order to process edible seaweed, rockweed processors may need to modify some of their operations to produce food-grade products. This potential opportunity has not been explored by the authors of this report.

Atlantic Sea Farms, based in Saco, Maine, processes Maine seaweed into a variety of value-added products.

Courtesy: Atlantic Sea Farms and the New England Ocean Cluster

Maine's primary edible seaweed processors include:

- Atlantic Sea Farms / Ocean Approved — atlanticseafarms.com
- Maine Coast Sea Vegetables – primarily wild harvest — seaveg.com
- Ocean's Balance — oceansbalance.com
- Springtide Seaweed — springtideseaweed.com
- Vitamin Sea Seaweed — vitaminseaseaweed.com

Given the limited existing set of edible seaweed processing options, new growers must have a well-defined plan for processing their harvest to ensure a viable business model—either by contracting with existing processors or building their own processing capabilities.

3.3 Organics

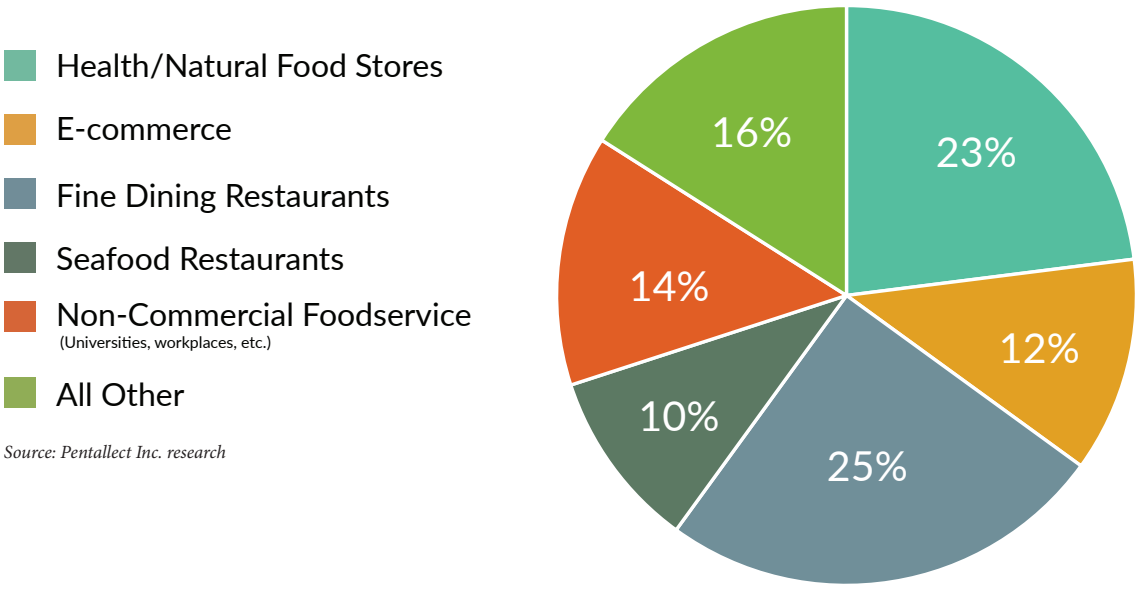
While organic products have been a growth driver in certain product categories, the Maine edible seaweed industry processors are split regarding organic products' strategic role in their product offerings. Proponents cite the growth of organic products in the U.S., the healthier halo, and higher price point associated with organic products. Others express concern that ocean-based products cannot truly be labeled organic due to the uncontrollable nature of open water contents and that the organic licensing requirements are not justified given the incremental costs and operational restrictions associated with organic labeling. Another potentially limiting factor is the fact that organic seeds are approximately 50% – 100% more expensive than non-organic due to a longer growing cycle and other organic product requirements. See the Appendix for an overview of the Maine Organic Farmers & Gardeners Association (MOFGA) organic practice standards for edible seaweed.

The other primary farmed seaweed producing state, Alaska, has relatively rigid organic certification requirements and the harvesters/processors have not pursued organic product options to date. At this time, organic Maine farmed edible seaweed products are viewed as a potential differentiator, but not a requirement, for success. Harvesters and processors need to assess the role of organic in their growth strategies, including evaluating the cost implications relative to the market potential, to make their own determinations regarding evolving to an organic product positioning.

3.4 Market Segmentation

The majority of Maine-produced edible seaweed from both wild and farmed sources is currently sold through a relatively balanced set of foodservice and retail channels, with specialty retail (natural/health foods, including Whole Foods) and fine dining restaurants accounting for approximately one-half of total volume. Maine's farmed edible seaweed is believed to skew more toward the foodservice channel given the farmed participants' finished product formats and distribution networks. It is anticipated that edible seaweed products will eventually expand penetration within traditional grocery and immediate consumption channels (convenience stores, workplaces, colleges and universities, etc.).

Figure 3D: Maine Edible Seaweed – Primary Market Segments



Source: Pentallect Inc. research

3.5 Competition

As noted in this report, imported products account for approximately 99% of total U.S. consumption. Given this dynamic, Maine edible seaweed producers' primary competition from a market share perspective is seaweed producing countries that export to the U.S. These high-volume imported products are typically low-cost dried, minimal value-added products for Asian-menu restaurants, ethnic specialty stores, and grocery sushi station operations. Among these countries, South Korea in particular has been focused on the U.S. market and has established processing facilities in North America. It is anticipated that exporters to the U.S. will increasingly attempt to evolve product offerings to meet U.S. consumer preferences in an effort to offer more mainstream products to increase market penetration.

While the majority of competing edible seaweed volume is imported, Maine seaweed producers often compete more directly with other health-oriented products for consumer purchase, retail shelf space, and foodservice menu presence. Examples include natural/organic vegetable-based snacks, condiments (salsas and dips), seasonings and flavorings, salads, and leafy vegetables (kale and spinach), etc. Domestically, Alaska is the second largest harvesting area for farmed edible seaweed, with Alaska's farmed edible seaweed harvest at approximately one-half the volume of Maine's farmed harvest. While also in its infancy with a small set of current harvesters and processors, Alaska edible seaweed market participants have identified edible seaweed as a growth market and are exploring opportunities to expand harvesting and processing capacity. Alaskan harvesters' ready access to seafood processors for first-stage processing creates a potential advantage relative to Maine harvesters' currently limited processing options; however, Alaskan harvesters' distance from further processing facilities, primarily in southern Alaska and the Pacific Northwest, and general reliance on water transportation rather than highways to transport products from harvest areas create some unique challenges for Alaska's nascent edible farmed seaweed industry that Maine participants do not face to the same degree. It is anticipated that both Alaska and Maine will continue to lead U.S. farmed edible seaweed market growth.

It is anticipated that both Alaska and Maine will continue to lead U.S. farmed edible seaweed market growth.

3.6 Value-Added Differentiation

Given the challenges associated with competing directly with low-cost, minimally processed imported products, Maine edible seaweed producers' greatest potential for profitable growth requires the development of differentiated, value-added, consumer-relevant products that will enable Maine producers to continue to expand their penetration of existing and new markets and channels.

Most of the Maine processors offer value-added products and continue to update their offerings. Developing products with broad consumer appeal and high volume potential will be critical to building market share. Effective product development will require transforming consumer and foodservice customer insights into scalable product innovations. Many processors that have failed to achieve scale have not adequately defined their end markets or have not developed compelling products for their customers, resulting in ineffective allocation of resources and limited demand for their products. Constant innovation will be important to maintain a differentiated position from imported products. A list of relevant consumer trends that edible seaweed producers have an opportunity to address is included on the following page.

Relevant Consumer Food Trends	
• Natural; clean ingredient labels • Sustainable • Locally/U.S. sourced • Snacking/on-the-go consumption	• Organic • Plant-based products • Limited/reduced packaging • Healthy without sacrificing taste • Ethnic/global menu experimentation

Examples of Existing Value-Added Products	
Wet Products	Dried Products
• Salsas • Sauces • Pickled stipes • Seaweed salads/sides—bulk and smaller portions	• Pastas • Snack bars/chips • Seasonings/flakes • Flavored products

3.7 Value Chain/Economics

In general, the Maine edible seaweed farming value chain mirrors overall U.S. dynamics identified in the Domestic Market section of the report (see section 2.9 on page 15). Given the relatively limited set of Maine industry participants and the need to maintain confidentiality, U.S. value chain dynamics are used in this report to provide a representative overview of Maine value chain dynamics. (Figure 2H repeated below)

Product	Typical Value	Reported Range
Seed/Nursery		
Sugar Kelp	$100 per 200 ft spool	$90 – $120
Organic Sugar Kelp	$150 per 200 ft spool	$110 – $200
Alaria	$100 per 200 ft spool	$110 – $130
Organic Alaria	$175 per 200 ft spool	$150 – $200
Grower/Harvester Stage		
Wet Sugar Kelp/Alaria	$0.40 – $0.70/lb.	$0.26 – $1.00/lb.
Wet Organic Sugar Kelp/Alaria	$0.60 – $1.00/lb.	$0.50 – $2.00/lb.
First Stage Processed – Dry		
Sugar Kelp/Alaria	$6.00 – $8.00/lb.	$3.00 – $10.00/lb.
Organic Sugar Kelp/Alaria	$9.00 – $12.00/lb.	$8.00 – $16.00/lb.
Second Stage Processed – Finished Products		
Sugar Kelp/Alaria	Wide Variation: $10.00 – $50.00+ /lb.	
Organic Sugar Kelp/Alaria		

Source: Pentallect Inc. research

3.8 Maine Future Growth Outlook

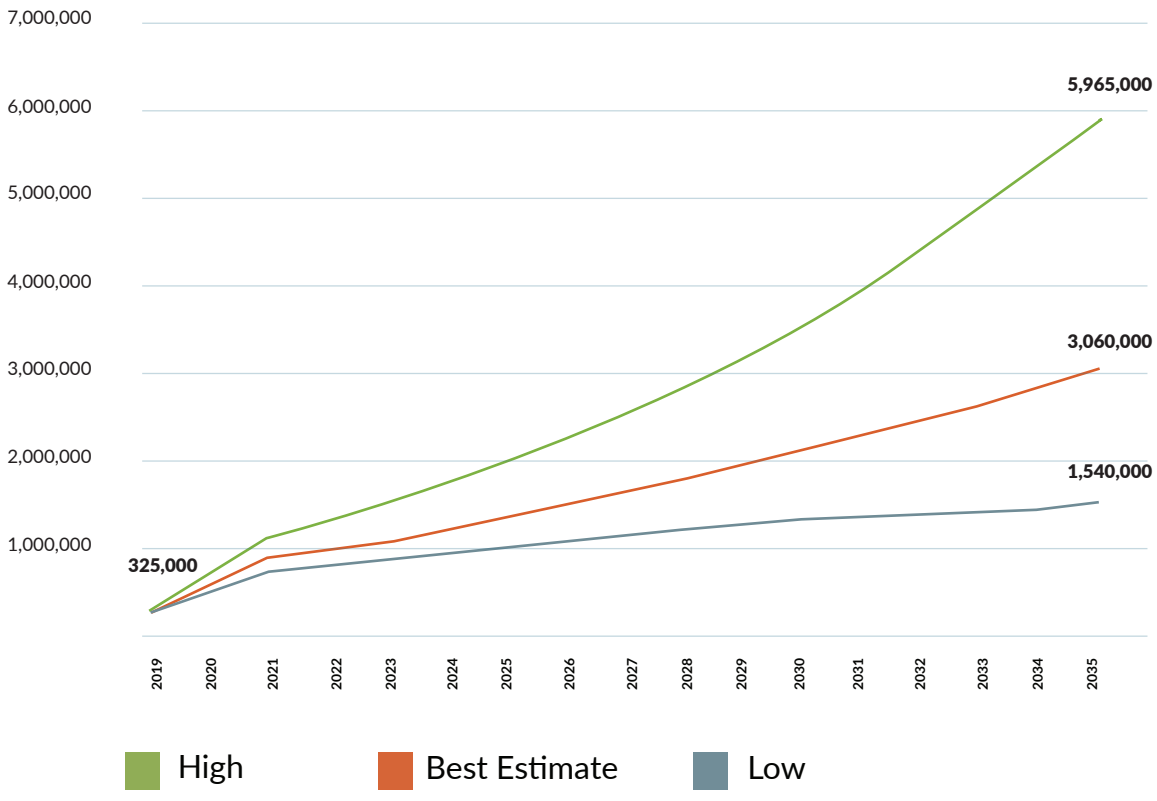
Volume Growth

Consumer demand for Maine-sourced edible seaweed will continue to grow, per the domestic market growth findings of this report. As a market leader, the Maine-farmed edible seaweed industry is well-positioned to capitalize on this growth. The Maine future growth outlook scenarios assume that both Maine harvester and processor capacity will expand, and that Maine processors will continue to develop innovative products, to meet increased consumer demand.

The level of growth and scale achieved by Maine participants will define the amount of operating efficiencies that can fuel investment in product innovations, enable Maine processors to compete more effectively with imported products, build expanded distribution networks, and create increased demand for Maine edible seaweed.

The best estimate growth projection for Maine-produced farmed edible seaweed over the planning horizon is that Maine will produce approximately 3 million wet pounds by 2035, with a range from 1.5 million lbs. on the low end to almost 6 million wet lbs. as a high growth scenario. The 3 million pound best estimate projection is a production-based scenario derived from growth assumptions related to Maine's harvesting and processing capacity expansion. The 6 million pound high growth projection is a consumer demand-based scenario that assumes Maine's processors accelerate capacity growth, effectively develop new products, and expand distribution across consumer channels.

Figure 3E: Maine Farmed Edible Seaweed – Volume Growth Scenarios (Wet Lbs,)

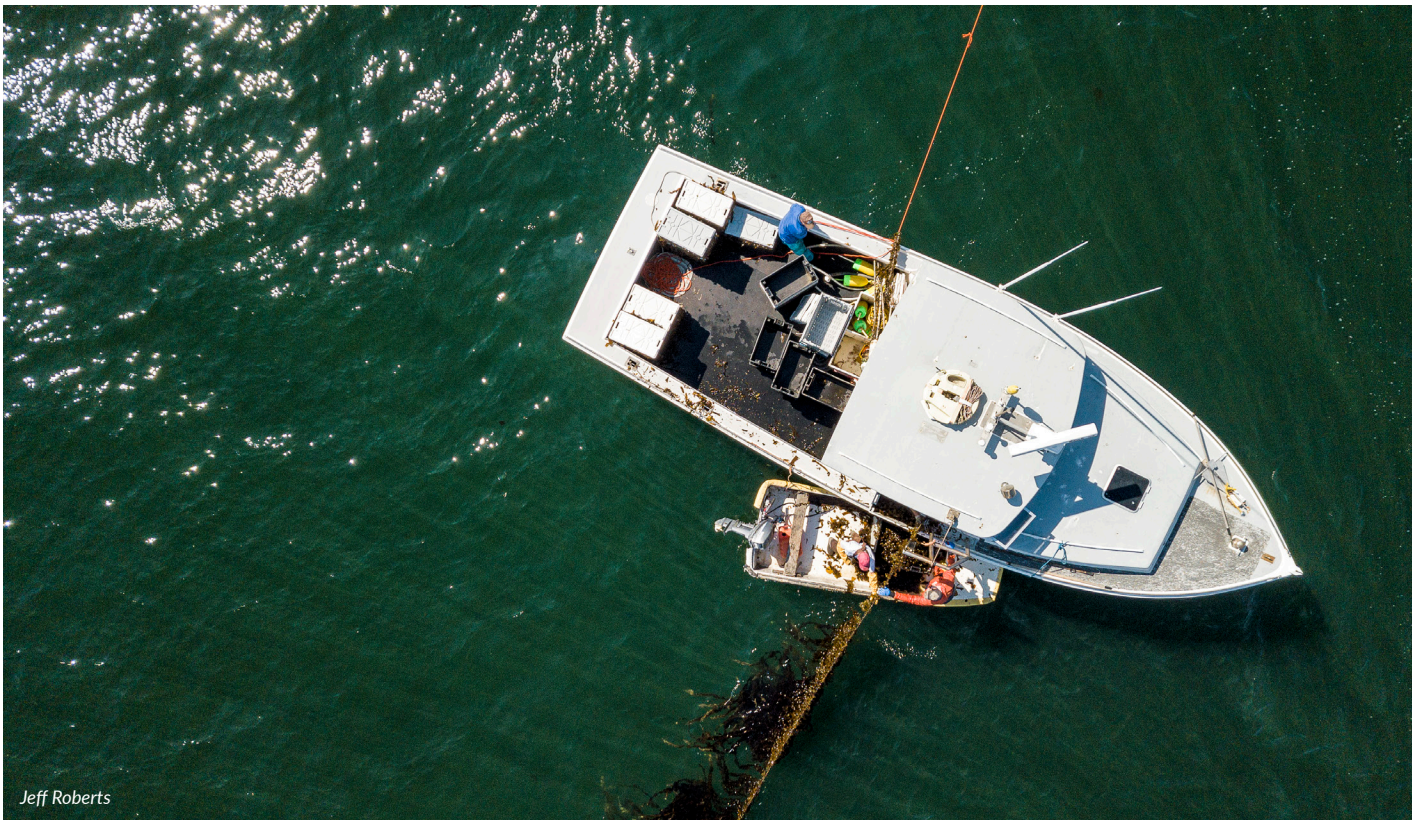


Source: Pentallect Inc. research

Volume Growth Scenario Assumptions

The volume growth scenarios were developed by evaluating a combination of factors including: historic and projected future domestic demand growth, lease applications and potential incremental lease capacity, current processor dynamics, short-term and longer term potential for new processing capacity, required investment in new product development and distribution, and processing growth potential for other domestic geographies, particularly Alaska. A summary of growth scenario assumptions follows:

- Low Growth Scenario (+8% – 10% average annual growth): Assumes continued rapid capacity expansion through 2022 and then eventual growth constraints of harvester and/or processing capacity expansion limitations, potentially exacerbated by accelerated capacity growth in other producing regions, particularly Alaska. Increased imports of value-added products could also stifle Maine growth if Maine processors cede innovation leadership. Assumes that, on average, Maine grows at the same pace as the overall domestic marketplace.
- Best Estimate Scenario (+12% – 15% average annual growth): Assumes continued capacity expansion at diminishing rates over the planning horizon. Harvesters and processors continue to ramp up capacity; followed by gradually decelerating growth over the planning horizon. Assumes sustained investment in capacity expansion and increasing competitive advantages of scale.
- High Growth Scenario (+15% – 20% average annual growth): Assumes Maine secures the domestic market leadership position for capacity, product innovation, distribution expansion, and demand creation. This leadership position would enable Maine to expand market share well beyond "fair share" to achieve above-market rate growth.



Jeff Roberts

Pricing Trends

Given the relative infancy of the Maine farmed edible seaweed industry, pricing trend projections are derived from both seaweed market analysis research and theoretical comparisons to other traditional food category dynamics. Maine farmed edible seaweed harvest pricing is projected to decline approximately -$0.15/wet lb. over the planning horizon as additional U.S. capacity is developed and domestic processors compete for distribution and market share. Given the anticipated emphasis on value-added products, overall Maine pricing is projected to remain well above lower value-added product pricing sourced from both domestic and imported suppliers.

Pricing Scenario Assumptions

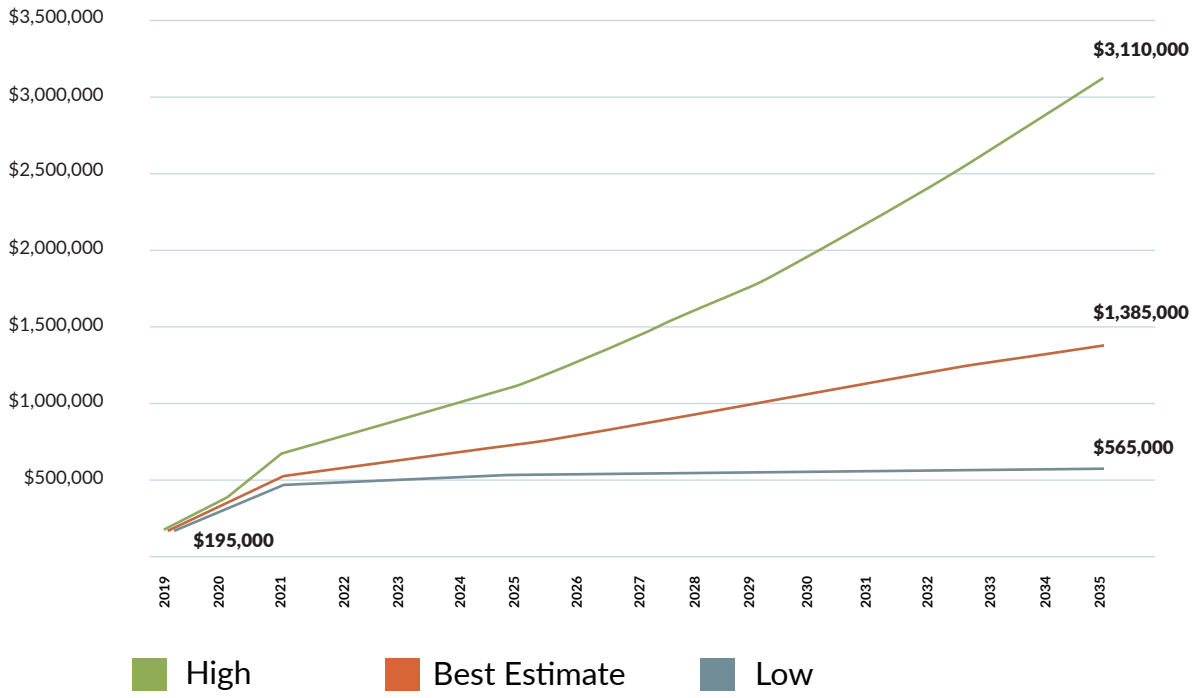
A key assumption within the pricing scenarios is that, as domestic production increases, more harvesters and processors enter the farmed edible seaweed space, and international competitors develop value-added products that are more closely aligned with U.S. consumer expectations, domestic pricing will decline at relatively modest levels. This pricing dynamic is common in most industries when supply expands rapidly to catch up to increased demand and producers compete for market share. A related trend across the domestic food production industry is that increases in further processing and marketing costs have outpaced increases in payments received by harvesters/farmers, so that the harvesters/farmers' share of the value chain has continued to decline moderately over the past four decades. While the research indicates that harvest values per pound will decline over time, the decline is relatively modest and Maine harvesters are projected to realize approximately 50% – 100% greater equivalent prices than typical imported products at the end of the planning horizon.

- Current 2019 dollar equivalent (excluding inflation).
- Low Pricing Scenario (-3.5% avg. annual decline after 2021): Significant capacity growth in both Maine and other regions, primarily Alaska, depresses pricing to 25% premium over lower cost imports ($0.30/lb. equiv.) = $0.37.
- Best Estimate Pricing Scenario (-2% avg. annual decline after 2021): Domestic expansion leads to pricing at 50% premium over lower cost imports ($0.30/lb. equiv.) = $0.45. Primary Maine processor focus on value-added products.
- High Pricing Scenario (-1% avg. annual decline after 2021): Modest price declines as Maine processors create a differentiated market position via continued innovations and distribution expansions.

Maine Harvester Equivalent Value Projections

Given the identified volume and pricing scenarios over the planning horizon, Maine farmed edible seaweed harvest value (projected annual volume x price) is anticipated to grow by over $1 million to exceed $1.3 million annually by 2035, with a range of more than $560,000 on the low end and more than $3 million on the high end. Maine edible seaweed processed product value will also increase approximately six to eight times current levels depending on finished product formats.

Figure 3F: Maine Farmed Edible Seaweed – Harvester Value Scenarios



Source: Pentallect Inc. research

3.9 Strategic Fit and Implications

As a "start-up" leader in the emerging U.S. edible seaweed marketplace, Maine participants are well-positioned to leverage their nascent farming infrastructure and Maine's inherent location, fisheries/shellfish infrastructure, water quality, and brand equity advantages to secure a major role in the U.S. marketplace. To ensure sustained success, Maine farmed edible seaweed participants must leverage their advantages and build capabilities to address primary challenges.

Maine Farmed Seaweed Competitive Advantages

- Established Expertise

  In a new, developing market, Maine's relatively small, yet growing group of edible seaweed industry participants in many ways represents the leading edge of domestic seaweed farming. This group of participants has already established raw material growing/harvesting operations, processing and product development capabilities, distribution networks, customer relationships, and initial brand building initiatives that can serve as the foundation for growth. While still in its early life cycle stages, with most of the aforementioned elements requiring further development, the Maine edible seaweed industry participants have gained relevant experience to support sustained growth.

- Water Quality

  Maine's coastal communities have direct access to the cold, clean waters that are optimal for edible seaweed farming. As the world's oceans warm, more southerly U.S. locations will experience greater challenges and fluctuations with edible kelp yields and product quality. Maine's seaweed industry will be less impacted by rising ocean temperatures, as the state's waters are projected to remain relatively cold enough to support seaweed farming.

- Fishery/Shellfish Infrastructure & Seasonality

  With approximately 4,500 lobster harvesters and another 1,500+ other seafood harvesters (shellfish, finfish, etc.), Maine has a well-established infrastructure of boats, equipment, and experienced on-water people to capitalize on seaweed farming's seasonal alignment with the primary fisheries' shoulder seasons, as seaweed seeds are typically "planted" in October/November and harvested in April/May when the primary fisheries are less active.

- Brand Equity

  The edible seaweed industry benefits from the strong Maine brand halo that has primarily been built upon Maine's reputation for best-in-class lobsters, high quality seafood, pristine coastline, and fresh, sustainably produced products. Maine's brand equity is a particular advantage for Maine-produced edible seaweed items relative to imported products that require long supply chains and largely unknown quality control mechanisms.

- Proximity to Major Markets

  Maine is well-positioned to efficiently reach leading markets in the East, as well as national markets. Portland is within 500 miles of four of the top 10 U.S. metropolitan areas based on population. This ensures both strong relatively local demand for Maine edible seaweed, and also provides an efficient supply chain, particularly through Boston and New York, to other markets.

- Lease Site Availability

  Maine has significant capacity to expand aquaculture lease acreage. Currently Maine's combined aquaculture industry, across all seafood and seaweed species, accounts for approximately 1,500 acres of space out of a total state coastline acreage of approximately 3 million acres. It is important to note that much of the three million total acres may not be available to aquaculture due to near-shore structural dynamics as well as concerns among certain shoreline and fisheries constituents that aquaculture operations may interfere with their commercial or recreational activities. Despite the need to manage aquaculture lease acreage expansion within the context of overall constituent concerns, there remains sufficient upside for lease site expansion to support significant seaweed farming growth acceleration in Maine.

Maine Farmed Seaweed Primary Challenges

- Processing Capacity

  In order to support growth, it will be critical to balance grower capacity with processing capacity. This will require either assured harvester access to Maine's limited processor set via expanded harvester-processor contracts, development of additional processing facilities to support non-contracted growers, or both. The existing processor set will also likely need to expand capacity, either via increased harvest season capacity or through new technologies or operational approaches to extend the processing season. New entrants into the edible seaweed harvesting business must establish processing plans prior to initiating the growing process.
- Product Development

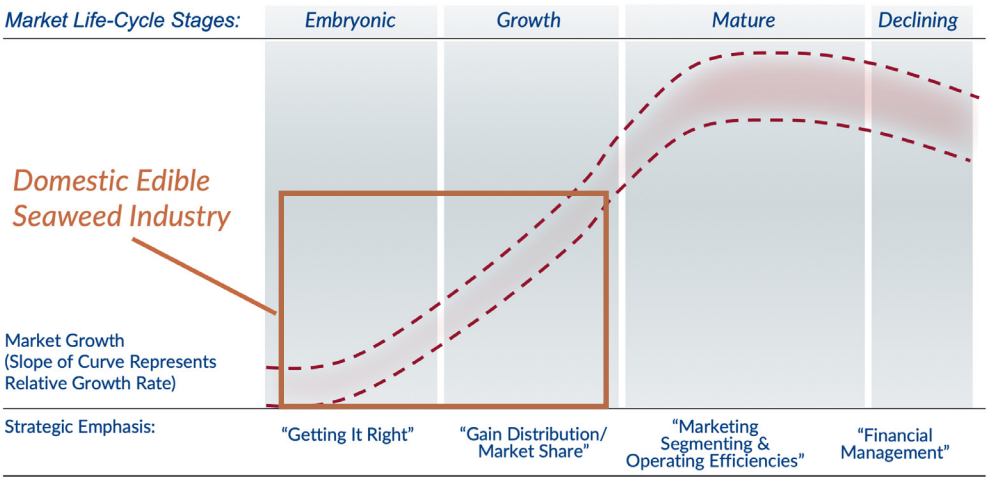
  Developing consumer/customer relevant value-added products is critical for sustained success, as it will be extremely challenging, if not impossible, for Maine producers to compete directly against low cost, more commoditized imported products.
- Demand Creation

  While edible seaweed is a growth category, household penetration, retail ACV (all-commodity volume), foodservice menu frequency, and e-commerce product velocity are relatively under-developed. Given the Maine edible seaweed industry's relative infancy and lack of scale, it is not currently practical or economically viable to invest in many of the traditional demand creation marketing and advertising activities.

  The most effective focus at this stage of the industry's development is on securing in-store placements and merchandising/sampling support to encourage trial and build market penetration; and maintaining robust websites to inform and incent consumers to purchase—either via the website or at identified retailers. As distribution and market penetration expands, Maine participants will be in a position, either independently or via cooperative marketing programs, to invest more heavily in traditional marketing activities (advertising, merchandising, etc.).
- Distribution Network

  Domestically produced edible seaweed is a relatively new category. As with any category in the development stages of the product life cycle, the industry's focus must be on "getting the product right" and building market access via an established distribution network.

Figure 3G: Maine Farmed Edible Seaweed Within the Market Lifecycle



Source: The Hale Group, Ltd.

To varying degrees, Maine's existing edible seaweed processors have begun to build distribution networks to bring finished products to market. To date, the distribution focus has primarily been on broadline foodservice distributors (Sysco, Gordon Food Service, etc.) and health/natural foods distributors and retailers (UNFI, Whole Foods, etc.), website-based e-commerce and, to a lesser degree, direct to foodservice operators. Maine's processors utilize a combination of direct customer engagement and contracted third-party sales agencies to expand distribution and gain market access. To support growth, the existing distribution networks will need to be expanded to increase market penetration, particularly within specialty and traditional grocery retail that account for the majority of edible seaweed volume.

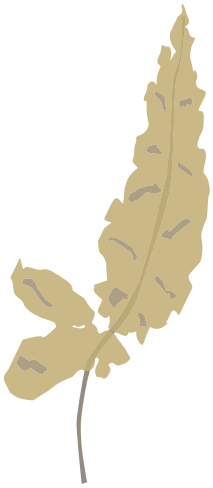
Courtesy: Atlantic Sea Farms and the New England Ocean Cluster

SECTION

2

Maine Economic Impact Study

Prepared by EPR
Economic and Policy Resources



4. Maine Economic Impact Study

4.1 Introduction and Overview

The gathering and farming of seaweed is a significant and growing industry worldwide as seaweeds have multi-purpose uses: food for human and animal consumption, fertilizer, medicinal products, additives, bioremediation, and biofuels. The use of seaweeds has a long-established history in many Asian and European countries; the rest of the world has more recently recognized the unique nutritional and health benefits of seaweeds. In the United States, the cultivation of seaweed—particularly edible seaweeds—is a relatively novel activity throughout much of the coastal zone. Seaweeds, or macroalgae, are nutrient rich, require relatively few inputs for growing, and thrive in the upwelling tidal zone along the coasts of the United States.

Due to the substrate, enormous tidal range, and varying climate, the coast of Maine has one of the most productive seaweed growing regions in the world.

Seaweeds are plant-like marine organisms that generally live attached to rock or other hard materials in coastal and maritime areas. They can be categorized into three distinct groups, based on their prominent color: brown algae (Phaeophyta); red algae (Rhodophyta); and green algae (Chlorophyta). Naturally grown seaweeds are also referred to as wild seaweeds, in contrast to those seaweeds that are cultivated or farmed.

Maine's 5,400-mile mainland and island coastline along the Gulf of Maine supports an extensive biodiversity of nearly 350 species of seaweed: 131 red species (e.g., dulse, Irish moss, laver); 127 brown species (e.g., kelps, rockweed, bladderwrack, wormweed); and 88 green species (e.g., sea lettuce).[1] Due to the substrate, enormous tidal range, and varying climate, the coast of Maine has one of the most productive seaweed growing regions in the world.

Seaweeds in Maine have been harvested for food, fertilizer, medicinal, and industrial uses for hundreds of years. Some 11 species have been harvested commercially in the past, including: dulse (*Palmaria palmata*); sugar kelp (*Saccharina latissima*)[2]; horsetail kelp or digitata (*Laminaria digitata*); alaria or winged kelp (*Alaria esculenta*); rockweed or knotted wrack (*Ascophyllum nodosum*); bladderwrack (*Fucus vesiculosus*); sea lettuce (*Ulva lactuca*); laver (*Porphyra umbillicalis*); Irish sea moss (*Chondrus crispus*); and wormweed (*Ascophyllum nodosum*). A number of species, notably sugar kelp, dulse, alaria, laver, and Irish moss have formed the nucleus of a cottage industry of harvesting, drying, and selling wild seaweed for food.

The majority of Maine's current seaweed harvest is wild and utilized for mostly non-food purposes. Contract harvesters gather seaweed from beds in remote bays during low tides for major buyers-processors located in Maine and elsewhere.[3,4] Nine-tenths of the wild harvest is rockweed; collected largely for use as fertilizer.

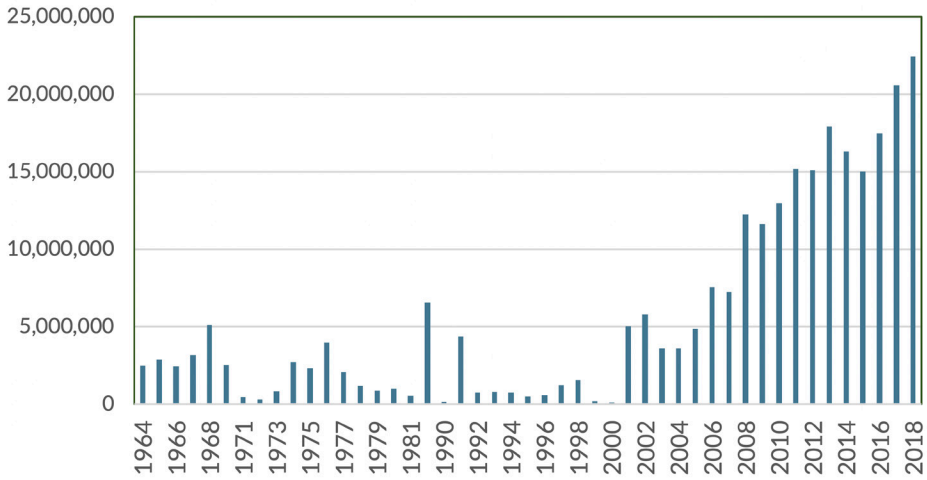
1. Crawford, Stephen. *The Macroalgae Industry in Maine.* University of Maine. Maine/New Hampshire Sea Grant Program. October 1991.

2. A variant of sugar kelp that is cultivated and not typically found in the wild is "skinny kelp" (*Saccharina latissimi* forma *angustissima* or *Saccharina angustissima*). In this report, skinny kelp is combined with sugar kelp, under the latter label.

3. A variety of harvesting methods are used, including hand, knife, rake, mechanical, and diver.

4. These major seaweed processors are North American Kelp and Ocean Organics, both located in Waldoboro; and Acadian Seaplants, Limited with processing facilities in Nova Scotia. FMC Corporation, with its Rockland processing facility, is the only company in the U.S. that produces food-grade carrageenan--a seaweed extract used in food and personal care products such as almond milk, tofu, shampoo, and toothpaste (the bulk of the raw resource, however, is imported from the Philippines).

Figure 4A: Maine Seaweed – Annual Landings (Wet Lbs.)



Source: Maine Department of Marine Resources

The focus of this economic study is on the nascent segment of edible seaweed in Maine.[5] Little research has been completed on assessing the market for edible seaweed in Maine. Market assessments are oriented toward demand; this addendum assesses the adequacy of the supply response—both current and anticipated—to meet the burgeoning domestic demand for edible seaweed. Production activities surrounding the harvesting of wild and farmed seaweed for processing into edible seaweed products form the basis for assessing this sector's contribution to the Maine economy.

After a brief examination of the two major segments of edible seaweed within the context of a value-chain approach, an economic contribution analysis is presented of the edible seaweed sector in coastal Maine. With the seaweed production season recently completed, 2019 is the selected year for the economic analysis of edible seaweed. 2019 marks a substantial growth surge from the recent trend[6] for the sector, particularly in farmed seaweed, and is deemed to be more characteristic of the edible seaweed sector in Maine.

Though related to the same fishery resource, the particular approach here is that wild seaweed and farmed seaweed represent two different segments of the edible seaweed sector in Maine. Wild seaweed still comports of its earlier cottage industry background, comprised mostly of vertically-integrated home-based micro-processors/businesses. Imbedded within these businesses are all of the production activities from harvesting and drying to milling/processing and packaging edible seaweed products. Wild seaweed harvesting is classified as a different economic activity—hunting and gathering—than its aquaculture cousin of farmed seaweed.[7] For edible seaweed processing activities, though sourced differently, both wild and farmed are classified as seafood product processing.[8] All of the wild-based seaweed processors utilize dry-based technologies in their production; farm-based seaweed processors employ either wet-based or dry-based production practices.

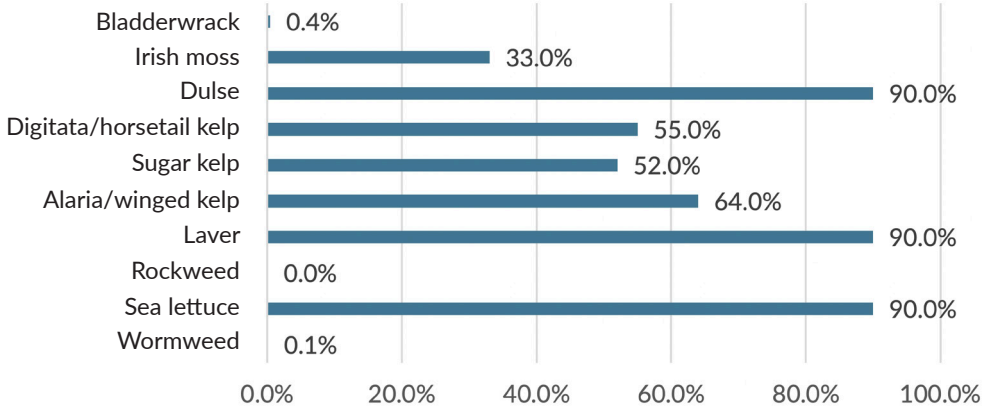
5. While most seaweed species are technically edible, all of the ten principal species with commercial harvests can be categorized as edible. Edible seaweed is also called "sea vegetables."
6. Deemed a "hockey stick" growth perspective, 2018 is the inflection year after which production turned sharply upward.
7. All economic activities are organized in a type of economic taxonomy on the basis of similar production processes or similar products produced or similar markets. The standard taxonomy utilized in the United States is the North American Industrial Classification System (NAICS). Wild seaweed harvesting is classified under "hunting and gathering" (NAICS 11421) or under "other marine fishing" (NAICS 11419). Farmed seaweed is classified under "other aquaculture" (NAICS 112519). No further distinction is made with these growing/harvesting segments as to their markets vis-à-vis edible or non-food.
8. Edible seaweed processors are classified under the broad "catch-all" category of "seafood product preparation and packaging" (NAICS 31171). This industry comprises establishments engaged in canning, smoking, salting, drying seafood; eviscerating fresh fish; shucking and packing fresh shellfish; processing marine fats and oils; and freezing seafood. [Even "floating factory ships" engaged in the processing of seafood into canned and frozen seafood products are included in this industry.]

4.2 Edible Seaweed in Maine

Wild Edible Seaweed

Seaweed production for edible uses is comprised of both wild and farmed (cultivated) harvests. Until recently, all of seaweed harvested for edible uses in Maine was obtained from the wild resource. For over 50 years in Maine, the wild harvest seaweed fishery has been operating at a relatively small scale. This wild seaweed fishery produces high-value food, supplements, and extracts from a wide array of species. Seaweed landings data obtained from the Maine Department of Marine Resources (DMR), however, does not distinguish seaweed harvests by ultimate or final use, such as food. Thus, wild-based seaweed harvests for edible use have been estimated based on a survey of wild seaweed processors and secondary information. Of the 10 seaweed species in Maine with commercial harvests, edible uses range from less than one tenth of a percent for rockweed, bladderwrack, and wormweed to 90% for dulse, laver, and sea lettuce. Most of the wild harvest for edible uses is in the brown algae species of kelp—nearly eight out of every 10 wet pounds harvested are either sugar kelp, alaria, or digitata. Red algae species of dulse, Irish moss, and laver garner about 13% of the wild edible harvest. Wild harvest of green algae species of sea lettuce represents a modest (less than a percent) share.

Figure 4B: Maine Seaweed Species – Edible Share of Wild Harvest (Wet Lbs.)



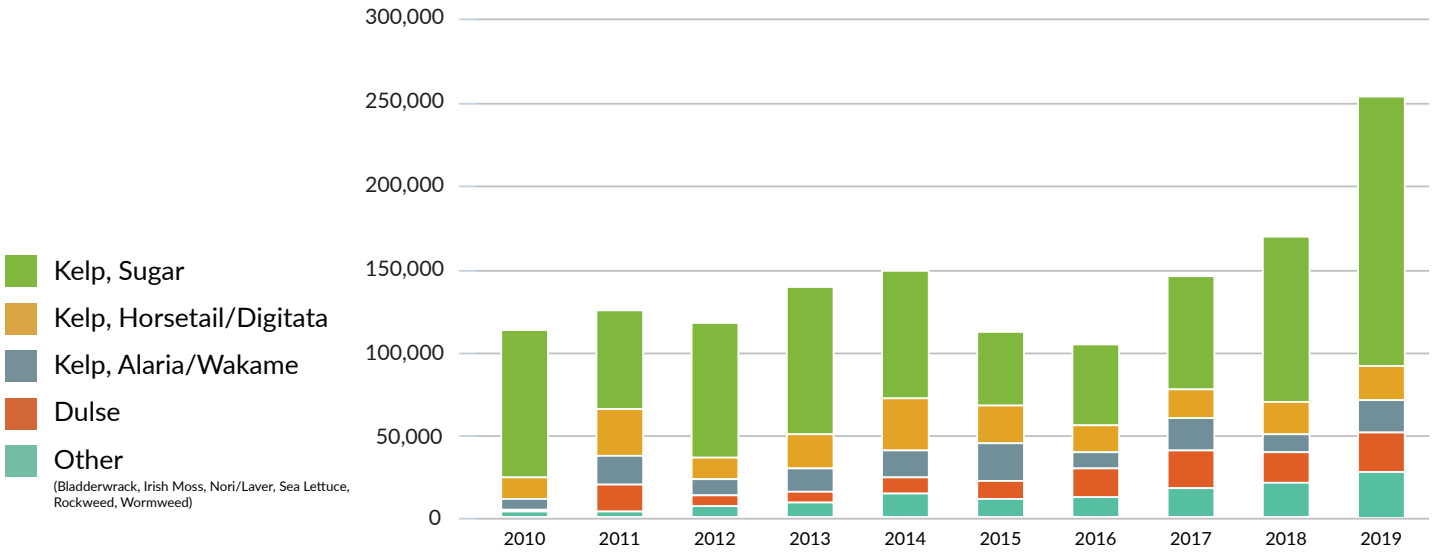
Source: Maine DMR. Wild—estimated, EPR. 2019, estimated based on surveys.

Since 2010, annual wild harvests have more than doubled from about 84,000 wet pounds to an estimated over 230,400 wet pounds in 2019. Over the last three years, annual growth rates in wild edible seaweed harvests have averaged around 30%. Much of the growth has been generated by increased preference for such species as sugar kelp, dulse, laver, Irish moss, and sea lettuce. With respect to the production (or "farm-gate") value, the 2019 wild harvest of 230,445 wet pounds is valued at $105,177, with the estimated dried-equivalent value of production is $264,670.[9]

9. Based on a wet-dry pound ratio of 10.1 to 1; with an average market value of $0.46/wet pound and $11.60/dry pound (2019 dollars).

Wild harvest season varies by seaweed species; wild plants are typically harvested by hand at low tides between March and October.[10] Gathering of wild seaweed occurs along the entire mainland and island coastline in Maine. Prominent areas of commercial wild harvests for edible seaweed are in the Downeast region (Hancock and Washington Counties) and in the south (Lincoln, Sagadahoc, and Cumberland Counties).[11]

Figure 4C: Annual Maine Edible Wild Seaweed Harvest by Species (Wet Lbs.)



Source: Maine Department of Marine Resources

Most people engaged in wild harvesting are contract-harvesters—seasonal part-time workers under such agreement conditions as price and volume and seaweed quality with a buyer (usually a local edible seaweed processor). For instance, a contract between a wild harvester and an edible seaweed company stipulates the price and quality standards for volume of delivered harvest by species (typically dried). Of the 174 harvesters of wild seaweed reported by Maine DMR for 2018, about 18 harvesters sell their harvests to five edible seaweed buyers. For 2019, of an estimated 180 harvesters of wild seaweed, there are 20 harvesters engaged in harvesting edible seaweed.[12] The estimated gross income payment per harvester is $13,233; equivalent to each harvester's share of total farm gate value of wild edible seaweed. Production-related costs for the harvester are minimal.[13] Typically, a harvester gathering wild seaweed in low-tides will log between 40-60 days during the season from mid-April to early October.

10. Bladderwrack, kelp horsetail/digitata, rockweed, and wormweed are harvested year-round.
11. The geography of edible seaweed harvests is estimated, based on approximate harvest zones surrounding the locations of prominent buyers of edible seaweed.
12. These harvesters are estimated to reside in the aforementioned approximate harvest zones.
13. As referenced earlier, some harvesters are in fact owner/operator of their respective wild processing enterprise. Other harvesters are engaged in gathering wild seaweed for other (non-edible) processors.

Wild seaweed harvests are then delivered to about five buyers for further drying, milling, processing, and packaging of edible seaweed products. These edible seaweed processors[14] distribute their products—via wholesale and retail channels to customers inside and outside of Maine. Their estimated 2019 total employment is around 30 workers (sole proprietors/partners and wage & salary). Gross sales of Maine wild edible seaweed products are estimated at $3.53 million.

In summary, the 2019 key economic results for wild edible seaweed are listed below.

Figure 4D: Maine Seaweed – Annual Wild Landings (Wet Lbs.)

Activity	2019 Summary Results
Wild Seaweed Harvest	**Metrics**
Wild edible harvest	230,445 wet pounds 22,816 dry pounds
Value of wild harvest	$105,177 wet-based $264,670 dry-based
Harvesting employment	20 wild harvesters
Value of harvest per worker	$13,233 gross income payment
Wild Seaweed Processing	**Metrics**
5 processors	30 proprietors / workers $3.53 million gross sales

Source: Maine Department of Marine Resources
Estimates by EPR and Pentallect

14. All of these five edible seaweed processors have a web/internet presence: Maine Coast Sea Vegetables (Hancock), Atlantic Holdfast Seaweed Company (Deer Isle), Ironbound Island Seaweed (Winter Harbor), Maine Seaweed (Steuben), and Vitamin Sea (Scarborough).

4.3 Farmed Seaweed in Maine

2009 marked the beginning of seaweed aquaculture in Maine, with Ocean Approved, LLC[15] of Portland (Casco Bay) having the first successful commercial kelp farm in the United States.[16] Seaweed aquaculture has the advantage of occurring during the winter months, which is "off-season" for the lobster fishery as well as recreational boating; and consists of simple submerged long-line systems on a lease site issued and managed by the Maine Department of Marine Resources (DMR).[17] A decade later, there are now dozens of farmed seaweed operations on leased sites within the coastal waters of Maine.

Maine DMR issues three types of aquaculture leases/licenses applicable for seaweed cultivation: Experimental or "Limited Purpose" Leases, Standard Leases, and Limited Purpose Aquaculture Licenses.

Experimental or "Limited Purpose" Leases

Experimental leases are relatively small in size (up to four acres) and short in duration (three years). The lease application fee is $100. Experimental leases were designed to allow for commercial and/or scientific research on sites before a longer or larger lease is needed. According to DMR, these leases are granted with fewer application requirements and do not require the same level of review as standard leases. Experimental leases cannot be renewed unless for continued scientific research. A limited purpose lease for commercial research expires at the end of the three-year period, upon which the leaseholder may apply for a standard lease. As of 2019, there are 10 active experimental leases for the culturation of seaweed,[18] with a combined total of 23.6 acres. In addition, there are at least another 16 experimental leases (totaling 63.0 acres) pending for seaweed aquaculture under current review by DMR.[19] Most of these experimental leases—active and under review—are situated in waters along the southern coast and the Midcoast.

Figure 4E: Experimental Limited Purpose Leases by County

	Active		Applied - Under Review	
Coastal County	Number	Acreage	Number	Acreage
York	0	0.00	1	4.00
Cumberland	4	10.67	5	19.80
Sagadahoc	1	3.51	0	0.00
Lincoln	5	9.38	1	4.00
Knox	0	0.00	8	31.19
Waldo	0	0.00	0	0.00
Hancock	0	0.00	0	0.00
Washington	0	0.00	1	4.00
Total	10	23.56	16	62.99

Source: Maine Department of Marine Resources, 2019

15. Now Atlantic Sea Farms.
16. A prior commercial seaweed farm in Maine (focused on growing laver) began in the early 1990s but soon after went under.
17. In 1973, the Maine Legislature passed a set of aquaculture laws designed to manage a fledgling industry. The Legislature authorized the Department of Marine Resources to issue leases on state-owned waters to private interests for the purpose of conducting aquaculture activities.
18. DMR allows for multiple aquaculture activities on individual leases. For instance, of these 10 current experimental leases half of the leases are growing other species besides seaweed, such as oysters, mussels, clams, and scallops.
19. A site visit by DMR is necessary to approve the lease. An adjudicated hearing is required if the DMR receives three or more letters from interveners.

Standard Lease

Standard leases are larger in size (up to 100 acres) and longer in duration (up to 20 years) than experimental leases. A standard lease application process is rigorous, includes an adjudicated hearing, and the application fee is $1,500. Applicants for standard leases must attend a pre-application hearing and share a draft application with the DMR. A public scoping session must be held with the host municipality prior to submitting a final lease application for DMR review. Applicants also are required to obtain a permit from the US Army Corps of Engineers and must alert the U.S. Coast Guard to ensure that the lease site is included in any navigational updates. Standard leases can be renewed, transferred to another party, or expanded. As of 2019, there are 12 active standard leases that include the culturation of seaweed[20], for a combined total of 65.4 acres. In addition, there are at least another five standard leases (totaling 47.4 acres) pending for seaweed aquaculture under current review by DMR. Acreage under active and intended leases are divided between the southern coast, Midcoast, and Downeast regions.

Figure 4F: Standard Leases by County

	Active		Applied - Under Review	
Coastal County	Number	Acreage	Number	Acreage
York	0	0.00	0	0
Cumberland	5	11.09	2	20.34
Sagadahoc	0	0.00	1	2.99
Lincoln	2	15.35	0	0.00
Knox	3	0.99	1	4.00
Waldo	0	0.00	0	0.00
Hancock	2	37.94	1	20.00
Washington	0	0.00	0	0.00
Total	12	65.38	5	47.33

Source: Maine Department of Marine Resources, 2019

20. As in experimental "limited-purpose" leases, DMR allows for multiple aquaculture activities to occur on individual leases. Of the twelve active standard leases, seven leases have additional aquaculture activities (e.g., oysters, clams, mussels, scallops) besides seaweed.

Limited-Purpose Aquaculture (LPA) License

This licensing program provides applicants with the opportunity to obtain a one-year renewable license to rear specific species using particular gear types that cover no more than 400 square feet (less than one-hundredth of an acre). Given the license is specific to certain gear and certain species in a small area, LPA licenses are typically approved without the extensive review required for either an experimental or standard lease. An individual is allowed to apply for a maximum of four LPAs per year and can supervise up to 12 LPAs. As with any license, the state reserves the right to revoke issuance or decline renewal of the license should the holder fail to comply with requirements.

The intention of this program—initiated at the suggestion of shellfish growers—is to streamline the permitting process so that growers can "test the water" at different locations prior to applying for a lease, experimental or standard. There are currently 187 LPAs issued to 49 different holders for seaweed aquaculture with a grand total of 1.7 acres of leased sea land. All of these LPAs are situated along the entire "kelp highway" of the Maine coast. Licenses are granted for multiple purposes, from primarily scientific and educational to recreational and commercial; more than three-fourths of all LPAs are for commercial interests. Moreover, more than half of the seaweed licenses issued are for multiple fisheries—mussels, oysters, clams, and scallops.

Figure 4G: Limited Purpose Aquaculture (LPA) Licenses by County

Coastal County	Number	Acreage
York	3	0.03
Cumberland	52	00.45
Sagadahoc	8	0.07
Lincoln	22	0.19
Knox	34	0.30
Waldo	8	0.07
Hancock	35	0.32
Washington	25	0.23
Total	187	1.66

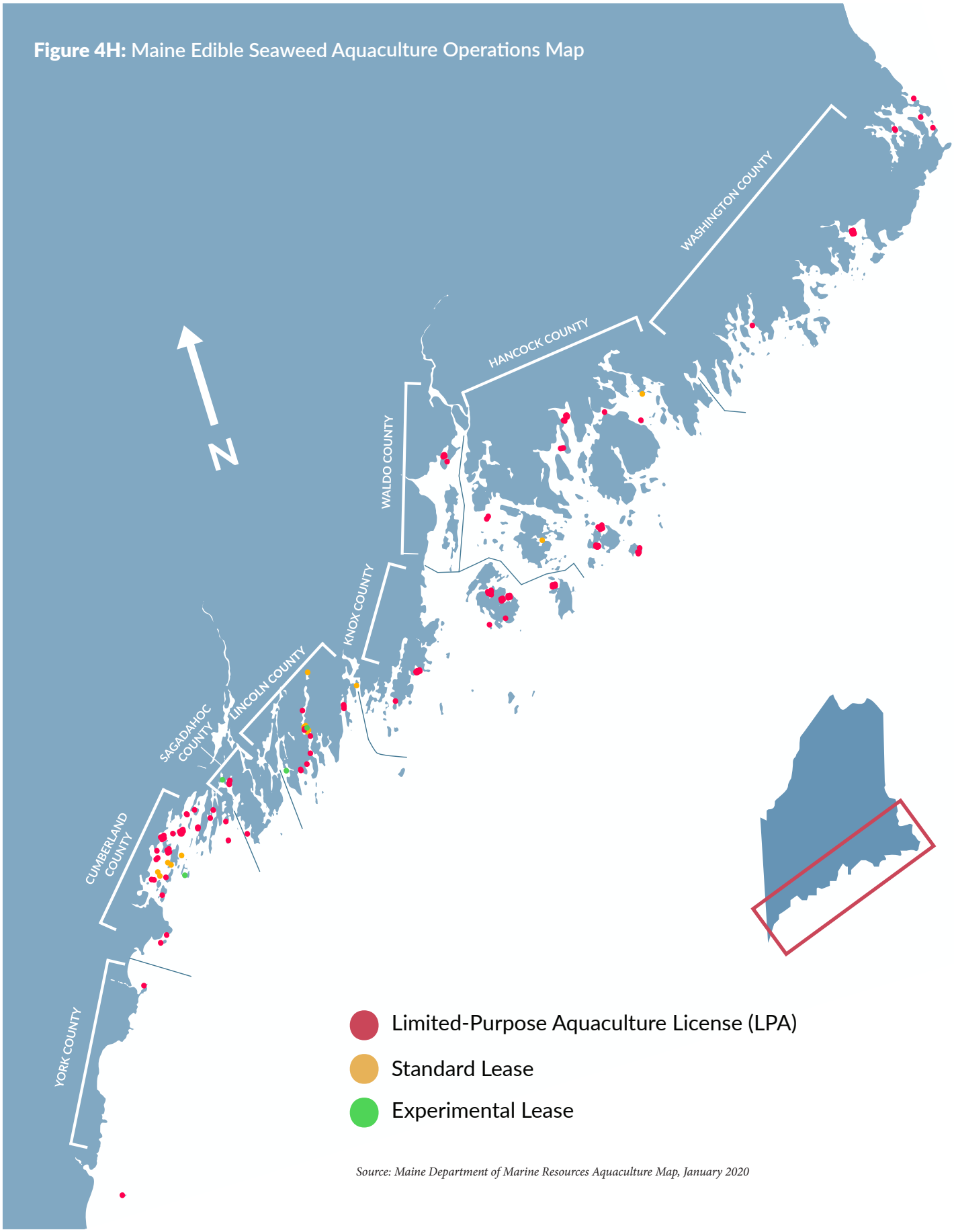
Source: Maine Department of Marine Resources, 2019

Most seaweed aquaculture is in sugar kelp (*Saccharina latissima*), but other seaweed species are being grown, primarily winged kelp (*Alaria esculenta*), dulse (*Palmaria palmata*), horsetail kelp (*Laminaria digitata*), skinny kelp (*Saccharina angustissima*), and laver (*Porphyra umbillicalis*).[21] Based on interviews with growers and policy/agency staff, all seaweed aquaculture is grown for human consumption.[22]

Since 2015, annual seaweed aquaculture harvests have increased by over thirty-fold from about 14,600 wet pounds to an estimated 325,000 wet pounds in 2019. Between 2015 and 2018, annual growth in seaweed aquaculture averaged 57 percent; still, farmed seaweed production was less than a third of wild seaweed harvests. 2018 marked a significant inflection point for seaweed aquaculture, with the growth surge occurring in 2019. While year-over-year wild seaweed harvests substantially increased, seaweed aquaculture rocketed to a production level of more than 125% of wild seaweed.[23]

21. In 2018, DMR reported that 95% of the farmed seaweed harvest was *Saccharina latissima/angustissima*; with Alaria capturing the remaining 5% of the total.
22. This may be different for growers that are outside of existing contract-processor networks; that is, when the product is harvested, there is no identified buyer.
23. As elsewhere in the world, the vast majority of seaweed production is farmed or cultivated.

Figure 4H: Maine Edible Seaweed Aquaculture Operations Map



Source: Maine Department of Marine Resources Aquaculture Map, January 2020

All seaweed farms are operated by leaseholders and/or their assistants. For 2019, an estimated 24 workers were directly engaged in seaweed farming. Similar to wild harvesters, seaweed farmers are very part-time, seasonal workers. Seeding of the suspended long-lines occurs in the fall with harvesting completed by late spring. Tending of the seafarm site occurs weekly during a five-month period between seeding and harvesting. In general, a seaweed farmer's on-site engagement amounts to approximately 25-40 days during a seven-month growing season. Most farmers are under contract with one of the three seaweed aquaculture processors, all of which furnish their contract growers with seeded string, produced in their land-based nursery laboratories.[24] In 2019, the farm-gate value of cultivated seaweed is estimated at $195,000.[25] Gross income earned per harvester amounts to an average $8,125.

In the late spring, three processors—two wet-based processors in York County and one dry-based processor in Hancock County—receive harvests from their contract growers for further processing and packaging into assorted value-added edible products for distribution to wholesale and retail markets. Generally, seaweed aquaculture processors operate during a brief two or three-month period in the late spring. Their combined estimated employment in 2019 is around 28 workers (sole proprietors/partners and wage & salary). Gross sales of Maine farmed edible seaweed products are estimated at $4.60 million.

In summary, the 2019 key economic results for farmed edible seaweed are listed below.

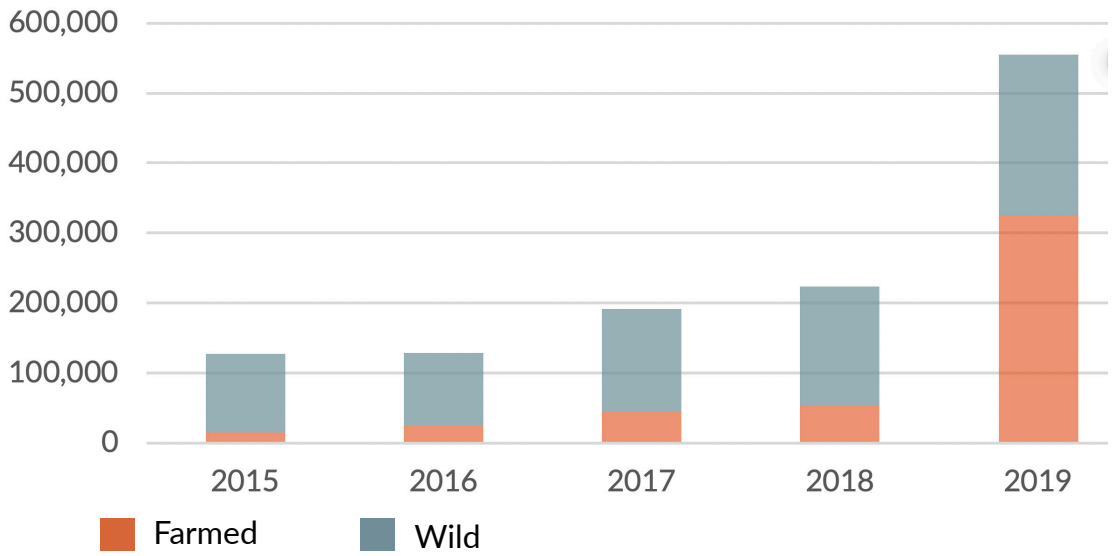
Figure 4I: Maine Seaweed - Annual Farmed Landings (Wet Lbs.)

Activity	2019 Summary Results
Farmed Seaweed Harvest	**Metrics**
Farmed edible harvest	325,000 wet pounds
Value of farmed harvest	$195,000 wet-based
Harvesting employment	24 farmed harvesters
Value of harvest per worker	$8,125 gross income payment
Farmed Seaweed Processing	**Metrics**
3 processors	28 proprietors/workers $4.60 million gross sales

Source: Maine Department of Marine Resources
Estimates by EPR and Pentallect

24. There are three commercial nurseries, two public nurseries, and three other nurseries, operated by non-profit research institutions.
25. Based on an average wet-based per pound price of $0.60.

Figure 4J: Annual Maine Edible Seaweed Harvest – Farmed and Wild (Wet Lbs.)



Source: Maine Department of Marine Resources; EPR and Pentallect research

4.4 Edible Seaweed Production—A Value-Added Approach

The concept of a value-chain comes from business management, first described and popularized by Harvard economist and business professor Michael Porter in his path-breaking volume *Competitive Advantage: Creating and Sustaining Superior Performance*. According to Porter, the idea behind a value chain is the process view of organization system, comprised of sub-systems, each with inputs, transformative activities, and outputs. Products pass through the linked activities of a chain in a certain order, and at each stage the product increases in value.[26] Operationally, value chain activities determine associated costs and hence affected overall profits.

An industry value-chain is a physical representation of the various processes involved in producing goods and services; from harvesting of wild and/or farmed seaweed to further processing to delivering a set of value-added end products for human consumption.

Wild Edible Seaweed

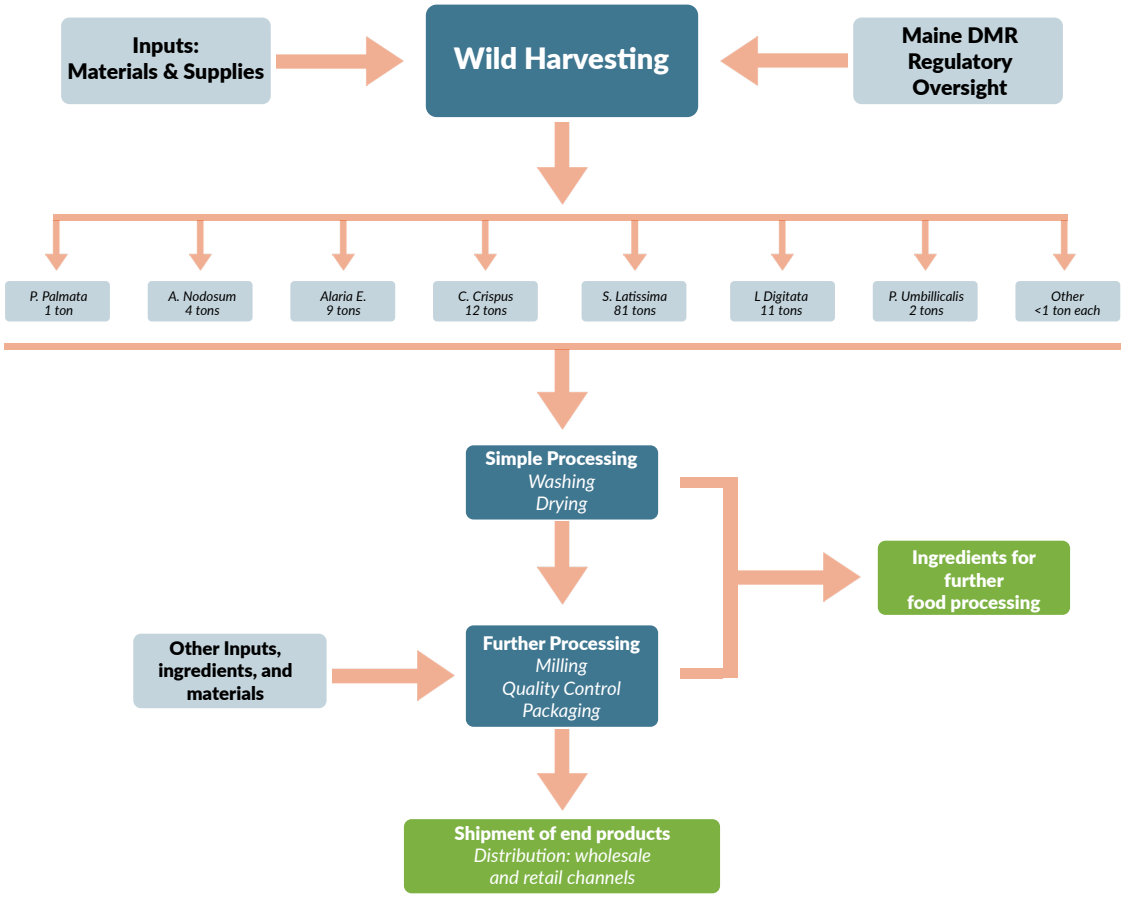
The wild edible seaweed sector in Maine is still indicative of a cottage industry; consisting mainly of micro home-based enterprises or self-employed workers with very limited automation in harvesting and first-stage processing (drying) and closely integrated with a small number of buyers/processors.

As illustrated on the opposite page, the wild seaweed production value chain includes a number of links from the harvester to the processor:

- Production inputs are used at the harvester level to produce seaweed for edible purposes. With relative ease of entry, low capital requirements, and limited inputs for wild harvesters, production costs are modest. A required license for commercial seaweed harvesting is obtained from Maine Department of Marine Resources (DMR).
- For most contract harvesters, compliance to National Organic Program standards to ensure sustainability is adhered to during harvesting and handling of wild seaweed.

26. Hence, the notion of value-added at the link or each stage of production. Differences with mark-ups occurs during wholesale and retail stages.

Figure 4K: Value Stream and Supply Chain of Maine's Edible Wild Seaweed Sector



- For wild harvesting, harvesting equipment includes a boat (with related fuel and maintenance costs), knives (and other hand tools) for cutting the seaweed, and containers/bags for the harvested seaweed. Harvest times for wild seaweed vary by species and location, and specific harvesting is dependent on weather and tidal conditions.[27]
- Wild harvested seaweed is then transported by the harvester to drying facilities—ranging from the simple (e.g., hanging up to dry on a clothesline) to the sophisticated (a greenhouse with a climate-controlled dryer); and subsequently delivered to the buyer for storage and ultimately second-stage or value-added processing.
- At the processor level, an organic certification (e.g., by the Organic Crop Improvement Association) requires rigorous testing for heavy metals, herbicides, and other microbiological/water-born contaminants throughout the drying, milling, and packaging process.[28]
- End food products are distributed via various channels—wholesale, retail and food services. Each of the processors of wild edible seaweed have an online marketing presence with sales direct to consumers and business-to-business sales (i.e., wholesalers, retailers, food services).

27. On March 28, 2019, the Maine Supreme Court unanimously ruled in Ross et. al v. Acadian Seaplants, Ltd. that shoreline property owners are protected from unauthorized commercial seaweed harvested within the intertidal zone of their shoreline property (i.e., the area between a shoreline's high-tide and low-tide footprint). Though the ruling specifies that rockweed growing within the intertidal zone is the private property of the upland shoreline owner and as such is not held in trust by the state for public use and cannot be harvested by members of the public as a matter of right, other issues swirling and unresolved in the case include whether rockweed is a plant or species of algae; application of other seaweed species besides rockweed; and ecological sustainability. Kenneth W. Ross et al. v. Acadian Seaplants, LTD. courts.maine.gov/opinions_orders/supreme/lawcourt/2019/19me045.pdf

28. Organic producers/processors are rigorous in their testing (and transparency) to verify that seaweed products do not contain harmful microbes or unhealthy levels of trace elements, industrial contaminants, and radiation. See for example, Maine Coast Sea Vegetables: seaveg.com

Farmed Edible Seaweed

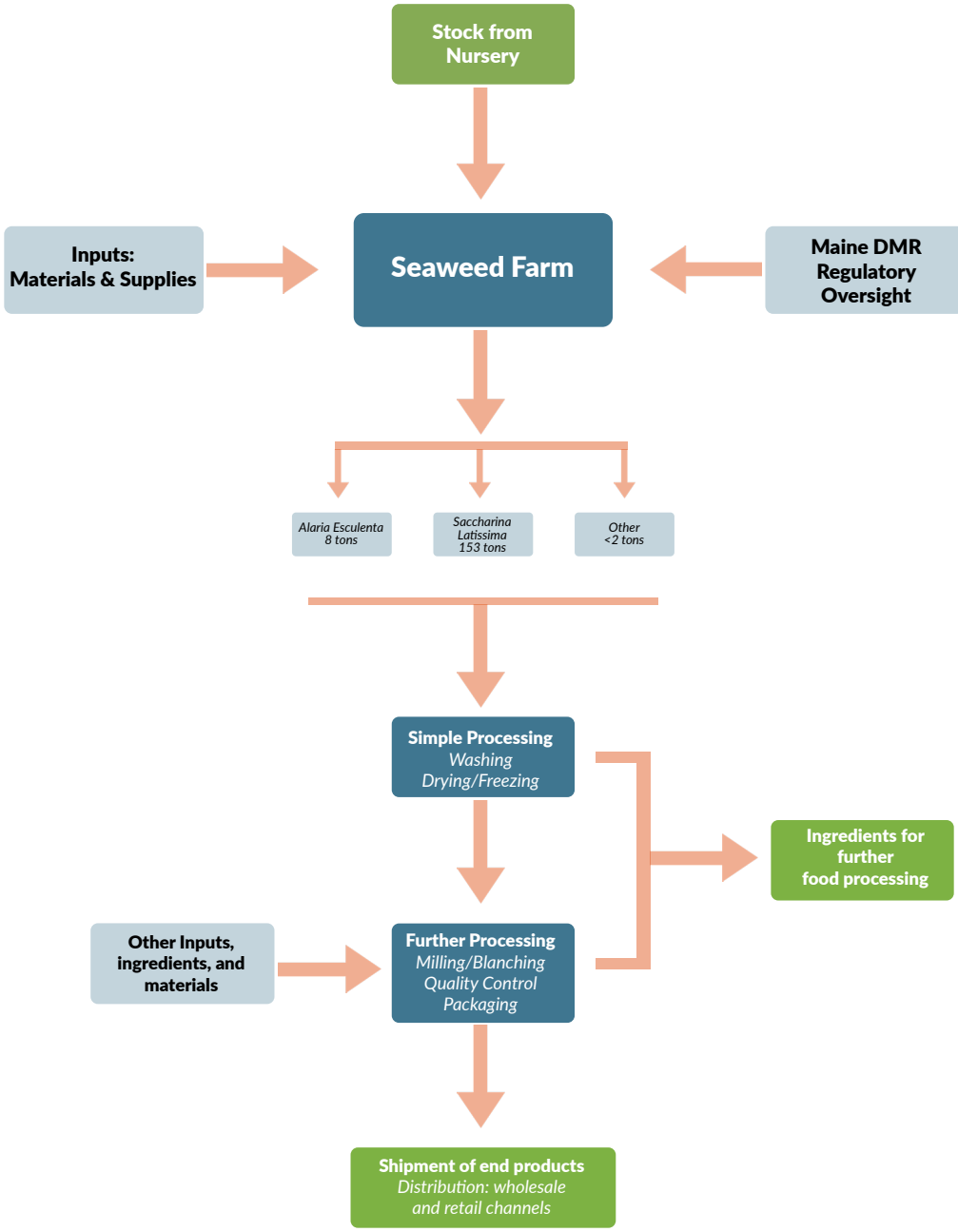
Seaweed aquaculture is composed of a mix of contract and independent growers engaged in growing seaweed often in combination with other seafood aquaculture activities. Production inputs are comparatively more extensive. These growers are aligned with particular buyers/processors who often provide nursery seed and expertise to ensure quality standards. The industry structure is in its nascent stage of three dominant buyers/processors with an estimated 24 growers.

Like its wild seaweed cousin, the farmed seaweed production value chain includes a number of links from the harvester to the processor:

- Although seaweed aquaculture formally commences with a lease permit from DMR, much planning occurs prior including a detailed site development and farm layout, planned inputs, and operations/production plans.
- Production aquaculture begins with seed and is sourced from nurseries delivered via seed spools. As prior noted, growers contract with buyers/processors who provide nursery services for volume (and quality) production commitments and agreed-to price.[29]
- In addition to seed spools produced by nurseries, other inputs (in particular to farm set-up) are gear associated with typically 800-1,000 foot longlines and include mooring balls, float and dropper buoys, PVC, connective ropes and chains, weights and anchors.
- Besides farm-gear, harvesting equipment includes a boat/skiff with a winch to pull in or let out the rope (and motor and fuel); a knife to cut the seaweed off the line; and a pipe to push the rope line along. Other inputs include insurance, disease diagnostics services, marketing intelligence, equipment maintenance, and administrative inputs.
- Once harvested, wet-based seaweed requires shipment to the buyer/processor in controlled-refrigerated transport containers to maintain product quality and limit spoilage.

29. Estimated price (at dock) is $0.60 per wet-pound.

Figure 4L: Value Stream and Supply Chain of Maine's Edible Farmed Seaweed Sector



- Wet-based processors convert the raw product via blanching or flash freezing processes, and in later second-stage processing to produce various value-added food products. Some processed product becomes ingredients for further off-site food processing.

- Processors distribute their end food products via various channels—wholesalers and brokers, retailers, and food services (restaurants, university food services).

4.5 Socioeconomic Metrics and Review of Methods

Definition of Key Metrics

There are numerous ways to measure the economic importance of the edible seaweed sector in Maine. Functionally, the key components of the edible seaweed sector consists of the growing and harvesting of seaweed; and the subsequent value-added processing into food products. As presented, there are two edible seaweed segments in Maine:

- Harvesting of wild seaweed and linked value-added processing
- Seaweed aquaculture and linked value-added processing

In this study, a number of metrics are used to measure the economic contribution of edible seaweed in Maine: employment, value of production or industry/sector sales, labor income, and household income.

- Employment: Jobs either at the seafarm/wild harvester-level or at the processor. As noted, most of these farm-level/wild harvester jobs are part-time and seasonal, associated with the natural growing cycle of seaweed. For wild harvesters, the "time spent at work" is dependent on weather conditions and low tides. On average, wild harvesters spend between 140-200 labor hours per year.[30] For farmers, significant time-consuming activities consist of seeding amounting to a couple of days in the early fall and harvesting over a two to three week period in the late spring amounting to three to five days per week. Routine visits for maintenance generally occur weekly or once every other week. Seaweed farmers, on average, spend between 150-240 labor hours per year.

At the processor level, jobs vary from part-time, seasonal on the production line to full-time, year-round for front-office administration. Production line workers for wet-based processors are fully employed during a four to six week seaweed harvest period; workers for dry-based processors are less oriented towards seasonal employment. As a result, employment here in this study is simply jobs and is not a full-time equivalent.[31] For example, two part-time seasonal jobs created in an enterprise is considered two jobs while one full-time job created in an enterprise is considered one job. No distinction is made between part-time and full-time jobs.

- Value of Production: As in agriculture, the production value of seaweed is the gross production (in pounds) multiplied by the price. For the wild harvest, the value of production is provided in both wet-pounds and dry-pounds. For farmed seaweed, the value of production is typically in wet-pounds.
- Industry/Sector Sales: Generally used at the processing level, the value of output of value-added processing is equivalent to industry sales.

Figure 4M: Harvest Yields by Limited Purpose Aquaculture (LPA) and Experimental Leases

	1 LPA	2 LPAs	4 LPAs	Experimental Lease
Area	400 sf	800 sf	1,600 sf	4 acres
Line Length	400 ft	800 ft	1,600 ft	12,000 - 15,000 ft
5 Lbs./ft at $0.60	$1,200	$2,400	$4,800	$36,000 - $45,000
8 Lbs./ft at $0.60	$1,920	$3,840	$7,680	$57,600 - $72,000

Source: Island Institute

Notes: Harvest yield is variable at either five wet pounds per foot or eight wet pounds per foot and is assumed to have accounted for 50% of harvest variability. Price of harvested seaweed is set at $0.60 per pound based on nursery seed delivered to grower. Monetary Values are gross revenues. For experimental lease of four acres: 174,240 sf, a 25 foot buffer and 10-20 feet of spacing between lines.

30. A full-time/year-round worker is employed for 2,080 hours per year.
31. Converting to a full-time equivalent number is not meaningful, given harvesters are part-timers during a confined season. Likewise, typical reporting of labor income (i.e., average annual wages per worker) are not useful.

- Labor income: Defined as the return to labor in the form of wages & salaries, contract payments, and/or proprietor income. For harvesters, labor income consists of contract payments/receipts from the buyer/processor. Given the part-time, highly seasonal nature of the harvesting activity, income payments received are viewed as supplemental or additional income; labor income viewed as an annual average is not useful in this context.

Review of Methods

In order to assess the economic contribution of edible seaweed in Maine, an input-output tool was utilized.[32] The power of input-output analysis is in the ability of the tool to track how small changes in one sector reverberates throughout the entire economy. For example, the expansion of seaweed aquaculture in the coastal region of Maine introduces new or additional levels of spending in the regional economy. The increase in edible seaweed production harvested from seafarms proceeds from increased purchasing of seed stock from nurseries, and needed gear (e.g., longlines, mooring balls, float and dropper buoys, PVC, connective ropes and chains, weights and anchors) and services commensurate with expanded production. This new spending for increased inputs, materials, supplies, and services for expanded production; and increased sales associated with enhanced seaweed production causes a ripple or multiplier effect throughout the coastal economy. The input-output analysis tool provides the ability to track and measure this economic ripple effect.

To continue with the seaweed aquaculture example, the economic impact of an expansion of seaweed farms is composed of three parts: direct, indirect, and induced. The direct or initial effect captures the event causing the initial change in the economy—for example, a new seaweed farm beginning its operations. This seaweed farm contributes directly to the regional economy by selling its farmed seaweed and paying its employees' wages and salaries and proprietor income to the sea farmer. In general, the new seaweed farm has two types of expenditures that are utilized to better understand its overall impact or multiplier. The first type of expenditures are business-to-business transactions, such as purchase of seed stock from nurseries, gear (anchors, buoys, shackles and chains, and rope for longline systems), fuel for boat/skiff operations, manual harvesting equipment, insurance, disease diagnostic services, transport services, and equipment repairs and maintenance, and others.[33] These business-to-business transactions—or inputs—are captured in the input-output model as indirect effects. A nursery uses the proceeds from seed stock sales to sea farmers to help pay their operating expenses, make investments, and/or buy new equipment.

The second type of expenditure this seaweed farm introduces into the regional economy are income payments—wages and salaries paid to employee hires as well as income received by the owner/proprietor. Spending of this income by sea farm workers as well as spending by workers from indirect supplier and service companies for household consumer goods and services are captured as induced effects. A retailer, for instance, could in turn use some of the sales revenue to pay employees, and the cycle continues.

This combination of direct, indirect, and induced effects provides a portrait of contribution that a particular industry has on the entire regional economy. Looking at indirect and induced effects, for instance, enables policy officials and industry people to gain insights into how an industry is connected or linked within the regional economy. Additional insights into the make-up of the regional economy can be gained by examining the relative size of the multiplier effects.

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32. This economic contribution analysis utilizes REDYN for the purpose of determining the likely new economic impacts associated with edible seaweed. REDYN incorporates a computable general/geographic equilibrium ("CGGE") model for the U.S. economy (and all states and sub-regions such as metro areas), enabling REDYN to accurately measure the interregional economic impacts (including job impacts) of a specific development project for various geographies. These geographies include the county in which the project is sited, the broader linked regional economy (such as a metro region, a state, and/or a group of counties); by explicitly incorporating trade flows, and transportation costs and geographic agglomeration effects. redyn.com

33. For instance, estimated costs for gear (long-line, moorings, chains, mooring lines, buoys, PVC stabilizing pipes, weights) range from $1,625 for a 400-sf LPA and $1,672 for a 800 sf two LPAs to $3,300 for a 1,600 sf four LPAs. Other costs needing estimation include fuel and maintenance, insurance, testing and monitoring, and fees. In general, production costs and revenues are obtained by surveying farmers/operators, called enterprise budgets.

4.6 Economic Contribution of Edible Seaweed in Maine

Overall Current Contribution (2019)

- The edible seaweed sector—by its harvesting and value-added processing activities—contributed $13.4 million to Maine's economy in 2019. The edible sector employs 162 workers with a combined labor income of $3.2 million. Edible seaweed's coastal locus[34] in Maine generates $11.6 million to the region, employing 139 workers with $2.7 million in labor income.
- Looking at edible seaweed's contribution through the lens of economic multipliers indicates that each million dollars of edible seaweed output/industry sales generates an additional $564,000 in output from other linked industries; every ten workers employed in edible seaweed support another three workers in other industries throughout the state; and each million dollars of labor income generates another $617,000 in wages and salaries and proprietor income.

Figure 4N: Combined Economic Contribution – Edible Seaweed Sector in Maine (2019)

	Coastal		Inland	State of Maine			
Metric	Direct	Indirect	Indirect	Direct	Indirect	Total	Multiplier
Employment	102	37	23	102	60	162	1.59
Industry Sales	$8,589,700	$3,097,700	$1,736,400	$8,589,700	$4,834,100	$13,423,800	1.56
Labor Income	$1,973,700	$808,000	$407,400	$1,973,700	$1,215,500	$3,189,200	1.62

Source: EPR research

As noted earlier, wild seaweed and farmed seaweed segments are different—in composition and structure, in production characteristics, and more recently in their respective growth trajectories. Given the differences, a closer look of their respective contributions to the regional and state economies is warranted.

On the Wild Side

Wild seaweed activities—particularly harvesting can be found up and down the "kelp highway" in Maine. An estimated 20 commercial harvesters are under contract to sell their seaweed (after drying) to buyers/processors. Income payments for their part-time seasonal gathering (and drying) of seaweed amount to $224,900. The modest spending for production inputs and limited level of direct income payments lead to small multiplier or ripple effects within the regional and state economies.

Figure 4O: Economic Contribution – Wild Seaweed Harvesting in Maine (2019)

	Coastal		Inland	State of Maine			
Metric	Direct	Indirect	Indirect	Direct	Indirect	Total	Multiplier
Employment	20	5	4	20	9	52	1.45
Value of Production	$264,700	$121,000	$35,020	$264,700	$156,020	$420,720	1.56
Labor Income	$225,000	$109,700	$26,280	$225,000	$135,980	$360,980	1.60

Source: EPR research

34. Edible seaweed enterprises—harvesters, farmers, and processors—are located along the coastal inlets, bays and islands of Maine. The coastal region consists of: York and Cumberland Counties—southern coast; Midcoast is comprised of Sagadahoc, Lincoln, Knox, and Waldo Counties; and Hancock and Washington Counties are Downeast. The other eight counties in Maine represent the inland region.

Wild seaweed processors—located primarily in the Downeast area—operate year-round. Consequently, average wages are not viewed as supplemental income by workers employed by these processors. Economic activity of wild seaweed processors generated $6.2 million in industry sales and supported 52 workers with $1.4 million in labor income.

Figure 4P: Economic Contribution – Wild Seaweed Processors in Maine (2019)

	Coastal		Inland	State of Maine			
Metric	Direct	Indirect	Indirect	Direct	Indirect	Total	Multiplier
Employment	30	12	10	30	22	52	1.73
Industry Sales	$3,530,000	$1,618,900	$1,053,700	$3,530,000	$2,672,500	$6,202,500	1.76
Labor Income	$682,700	$493,700	$225,600	$682,700	$719,300	$1,402,000	2.05

Source: EPR research

Down on the Farm

Farmed seaweed activity also mirrors that of wild harvesting; seaweed aquaculture is found in every coastal county in the state. An estimated 24 growers are directly employed on seaweed farms. Similar to wild harvesting, labor activity is confined to planting during the fall and harvesting in the late spring. With most growers under contract to buyers/processors, earnings can be viewed as supplemental income. Still, direct income payments generated a total of $294,700 throughout the state economy.

Figure 4Q: Economic Contribution – Farmed Seaweed Growers in Maine (2019)

	Coastal		Inland	State of Maine			
Metric	Direct	Indirect	Indirect	Direct	Indirect	Total	Multiplier
Employment	24	10	4	24	14	38	1.58
Value of Production	$195,000	$125,900	$30,200	$195,000	$156,100	$351,100	1.80
Labor Income	$176,450	$92,600	$25,700	$176,450	$118,300	$294,750	1.67

Source: EPR research

Farmed seaweed is processed into value-added niche food products by two wet-based processors located in York County and one dry-based processor in Hancock County. The processing season for wet-based seaweed is currently limited to approximately two-three months during the late spring/early summer.

Figure 4R: Economic Contribution – Farmed Seaweed Processors in Maine (2019)

	Coastal		Inland	State of Maine			
Metric	Direct	Indirect	Indirect	Direct	Indirect	Total	Multiplier
Employment	28	10	5	28	15	43	1.54
Industry Sales	$4,600,000	$1,232,000	$617,500	$4,600,000	$1,849,500	$6,449,500	1.40
Labor Income	$889,600	$112,000	$129,900	$889,600	$241,900	$1,131,500	1.27

Source: EPR research

Contribution of Edible Farmed Seaweed Sector - Forecast

Robust growth in market demand for Maine-sourced edible seaweed end products is expected to continue on "hockey-stick" trend for the next couple of years; thereafter moderating to between 7% - 12% year-over-year growth. Here, the forecast focus is solely on the edible farm seaweed segments; no market forecasts were made for other segments of the edible seaweed sector—namely, wild seaweed harvesting, wild seaweed processors, and farmed seaweed processors. Furthermore, farmed edible seaweed production in Maine is assumed to respond to expected market demand; that is, no shortfall in farmed production that will be met by in-state wild harvest or imports from outside of Maine (either southern New England or Atlantic Canada).

Edible Farmed Seaweed Sector in 2021

Market demand for edible farmed seaweed is forecast to reach 885,000 wet pounds (442.5 tons), with a farm-gate (on-dock) production value of $531,000; generating a total statewide value of production of $956,000. Eight new entrants—farmers—will join this production segment, bringing the total number to 32 farmers. Labor income for these farmers is estimated to increase to $480,500; generating $802,500 in total labor income across Maine.

Figure 4S: Economic Contribution – Farmed Seaweed Growers in Maine (2021 forecast)

	Coastal		Inland	State of Maine			
Metric	Direct	Indirect	Indirect	Direct	Indirect	Total	Multiplier
Employment	32	13	5	32	18	50	1.58
Value of Production	$531,000	$342,700	$82,200	$531,000	$425,000	$956,000	1.80
Labor Income	$480,500	$252,100	$69,900	$480,500	$322,100	$802,500	1.67

Source: EPR research

Edible Farmed Seaweed Sector in 2024

By 2024—five years hence—the edible farmed seaweed sector is expected to quadruple in production to 1,243,000 wet pounds (621.5 tons). An additional eight entrants will join the sector, bringing the total farmers to 40. The production value of the edible farmed seaweed sector is estimated to increase to $702,000, generating a total of $1.26 million in production value for the state. Labor income in 2024 for edible seaweed farmers is expected to reach $635,200, generating a total labor income of $1.06 million.

Figure 4T: Economic Contribution – Farmed Seaweed Growers in Maine (2024 forecast)

	Coastal		Inland	State of Maine			
Metric	Direct	Indirect	Indirect	Direct	Indirect	Total	Multiplier
Employment	40	17	7	40	24	64	1.58
Value of Production	$702,000	$453,100	$108,700	$702,000	$561,800	$1,263,800	1.80
Labor Income	$635,200	$333,300	$92,500	$635,200	$425,800	$1,061,000	1.67

Source: EPR research

Concluding Comments

There is adequate lease space and seed supply available in Maine to support significant growth in the farmed edible seaweed sector, assuming the above-mentioned primary challenges are addressed.

Investing in processing operations, developing value-added end products, building distribution networks, and creating customer demand is a resource-intensive (financial and human investment) proposition that most harvesters are not currently well-suited to excel at. The primary processors have developed these capabilities to varying degrees, so independent harvester alignment with established processors is generally a critical requirement for success. There are certain exception scenarios, such as seafood/seaweed harvesters with well-developed distribution networks and the ability to invest in further processed product development.

Regulatory stability and entrepreneurial confidence are key components for further growth in this sector. Existing regulations allow for growth, while protecting the environment, as well as support for commercial fisherman transitioning into seaweed aquaculture as an alternative income source.

Current and future research into the environmental and economic benefits of multitrophic aquaculture shows promise. Preliminary data suggests that growing kelp can remediate ocean acidification at a very local scale. Culturing kelp alongside mussels can not only improve growing conditions for the mussels but provide an alternate revenue source. Co-cultivated mussels have greater meat yields and thicker, denser shells, making them more durable during harvest. Co-cultivation may provide an efficient methodology for reducing marine calcifier stress.

State-led initiatives and bonds will be critical to supporting this sector. These funds can contribute directly to addressing current research needs and prolonged studies. New businesses can leverage these funds for startup capital or monies which can be used to pilot studies to help inform future research.

Gaining a clear understanding of edible seaweed end-users' market segmentation and evolving expectations, while outside the scope of this research report, will be a critical next phase element to support the growth of the Maine and broader domestic edible seaweed industry. End users include consumers, foodservice operators, retailers, and wholesalers/distributors. Understanding their geographic alignment, purchasing behavior by channel, preferred information sources, seaweed product insight needs, new product ideas, and pricing expectations will enable edible seaweed industry participants to continue to develop relevant products and capabilities to fuel continued growth.

Appendix

Edible Seaweed Organic Certification Example – Maine Organic Farmers & Gardeners Association (MOFGA)

11. GUIDELINES FOR SEA VEGETABLES

MOFGA Certification Services, LLC certifies both cultured and wildcrafted sea vegetables harvested from Maine's coastal waters based on the relevant crop sections of the USDA-NOP (National Organic Program) rule as described below. MOFGA does not certify sea vegetables grown in recirculating systems.

11.1 Definitions of Sea Vegetables

Edible seaweeds which include but are not limited to alaria (Alaria esculenta), dulse (Palmaria palmata), laver/nori (Porphyra spp), sea lettuce (Ulva lactuca), rockweed (Ascophyllum nodosum), digitata (Laminaria digitata), sugar kelp (Saccharina latissima) and fucus (Fucus spp) among others. Propagule—the biological material used to grow the edible crop. In most cases, propagules refer to propagules that develop into diploid sea vegetables and the harvestable crop. In rare cases, a propagule is a haploid gametophyte. For our purposes, propagules are analogous to seeds.

11.2 NOP §205.202 Land Requirements

How we apply NOP §205.202 to Sea Vegetable Cultivation is as follows: Organic sea vegetables must be cultured or wildcrafted from defined ocean areas with waters of high ecological quality. Growing areas or beds must not be located near known sources of radioactive, chemical, or bacteriological contamination. The following buffers apply to both cultured and wild crafted sea vegetables harvesting sites:

- Twenty (20) miles from any nuclear facility
- Three (3) miles from any commercial boat building facility
- Three (3) miles from any industrial waste water discharge area
- Three (3) miles from any city or town sewage discharge
- Three (3) miles from any major harbor or thoroughfare.
- Three-quarters (¾) mile from a small harbor entry. We define a small harbor as having moorings for six to ten boats.
- Three-quarters (¾) mile from a minor waste water treatment facility (these are denoted on DEP maps)
- One-quarter (¼) mile from any overboard discharge area or special circumstance (i.e. fish farm, small boat builder, etc.) NOTE: A bed's location relative to prevailing winds and currents may make the above distances more or less critical. Doubts should be settled by tissue testing for suspected contaminants.

11.3 NOP §205.203 Soil Fertility and Crop Nutrient Management Practice Standard

Fertility and crop nutrients allowed under NOP §205.103 and NOP §205.601 may be used only during the time sporophytes are being cultured in indoor facilities and only at levels necessary for healthy plant growth. Fertility and crop nutrient applications are prohibited in outdoor sea vegetable growing areas.

11.4 NOP §205.204 Seed and Planting Stock

Standard certified organic propagules must be used unless not commercially available in the form, quality or quantity needed. You must document your attempts to source organic propagules. Conventionally raised male and female gametophytes must be transferred to pure seawater or an approved growth medium prior to fertilization and production of propagules. Growth media must meet the requirements of NOP §205.103 and NOP §205.601. Propagules may be cultured indoors until the juvenile sporophytes of kelp, juvenile tetrasporophytes of dulse, or propagules of laver or dulse are 5mm to 10mm in size. Juvenile seaweed should be collected from the wild on a regular basis to supplement culture stock and maintain a diverse gene pool.

11.5 NOP §205.205 Crop Rotation Practice

Standard not applicable.

11.6 NOP §205.206 Crop Pest, Weed and Disease Management Standard

The producer must use management practices to prevent invasive algae, epiphytes, invertebrates and diseases. Management practices include cultural, mechanical, and physical controls. If management practices fail, substances on the PM-2018-01- (Final) 37 National List NOP 205.601 may be used. Bio-fouling shall be removed by mechanical means and disposed of appropriately or, if necessary, by substances allowed under NOP §205.605.

11.7 NOP §205.207. Wild Crop Harvesting Practice Standard

Harvesting shall be from designated areas that have had no prohibited substances, as set forth in NOP 205.105, applied for one growing cycle immediately preceding the harvest of the sea vegetables. Sea vegetables shall be harvested in a sustainable manner that is not destructive to the environment and will sustain the growth and production of the sea vegetables. Sea vegetable harvesting should follow the "Harvester's Field Guide to Maine Seaweeds" of the Maine Seaweed Council.

11.8 NOP §205.272 Commingling and Contact with Prohibited Substances Practice Standard

The producer must implement measures to prevent the commingling of organic and non-organic product and contact of organic product with prohibited substances. Organic integrity of sea vegetables will be maintained from fertilization through cultured growing of sporophytes, deployment in ocean, harvesting, transporting, processing and storing product.

11.9 NOP §205.103 Recordkeeping by Certified Operations

A sea vegetable operation must maintain records demonstrating compliance with the organic standards, including but not necessarily limited to documentation concerning the production, harvesting, handling and sales of cultured and wild crafted sea vegetables. NOTE: If you are drying, packaging or otherwise handling/processing the sea vegetables, you will need to complete an organic handling plan.

The Island Institute works to sustain Maine's island and coastal communities, and exchanges ideas and experiences to further the sustainability of communities here and elsewhere.