Kelp Aquaculture in Massachusetts:

OPPORTUNITIES, CHALLENGES, AND FUTURE DIRECTIONS

A Report Prepared for the Commonwealth of Massachusetts

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KEY FINDINGS

Kelp aquaculture has generated significant interest in Massachusetts as a potential opportunity to diversify coastal economies, support working waterfronts, and provide environmental benefits. This report examines the experiences of Massachusetts kelp growers, available scientific data, and current market conditions. The findings suggest that while sugar kelp (*Saccharina latissima)* can be grown in Massachusetts, significant challenges remain.

Key findings include:

• Kelp growth in Massachusetts has been highly variable. Many growers report inconsistent production and low yields.

• Waters south of Cape Cod often appear limited by low dissolved inorganic nitrogen levels, which may restrict kelp growth.

• Areas north of Cape Cod may provide more favorable growing conditions but have challenges related to Atlantic right whale habitat, and exposed sites.

• Existing markets for Massachusetts-grown sugar kelp remain limited. Many growers reported difficulty finding reliable buyers or receiving sufficient value for harvested product.

• Processing, storage, and distribution infrastructure are currently limited, creating additional barriers to commercial growth.

• Kelp integrates well operationally with shellfish farming because it is grown during the winter months when shellfish activity is reduced.

• Several growers expressed interest in exploring seaweed species other than *Saccharina latissima* that may be better suited to Massachusetts environmental conditions or market opportunities.

Overall, this report suggests that future development of seaweed aquaculture in Massachusetts should focus on improving site selection, supporting market development, expanding processing capacity, and reducing uncertainty through applied research and pilot projects.

An early season kelp line being pulled up to check on status

Executive Summary

Production of sugar kelp, *Saccharina latissima,* as increased in North America over the past decade. There is significant interest in the development of a viable kelp aquaculture sector in Massachusetts, driven by broader regional enthusiasm for seaweed farming, emerging climate and nutrient-mitigation narratives, the desire to diversify coastal economies, and the growing popularity of seaweed in wellness and consumer marketing. However, despite the enthusiasm, the future of kelp aquaculture in Massachusetts remains uncertain, and this report is an attempt to summarize local experience, current status, and potential paths forward.

Through interviews with current and former growers of sugar kelp in Massachusetts, participants consistently described production outcomes as highly variable, frequently low-yielding, and difficult to predict. Several individuals engaged in kelp farming for only a few years before discontinuing operations due to low yields, poor quality, and environmental constraints such as nutrient limitation and weather exposure. While growers generally reported that kelp farming is operationally straightforward and compatible with existing shellfish aquaculture schedules, these practical advantages have been outweighed by uncertainty and limited established markets. In some cases, growers were unable to sell their harvested kelp at all, underscoring the absence of reliable markets, and limited processing and distribution infrastructure.

These firsthand experiences align with the broader market analysis, which finds that Massachusetts is not currently well positioned to compete in global commodity seaweed markets. While small specialty food and boutique markets exist, they can absorb only modest volumes and are insufficient to support large farms. Emerging sectors such as biostimulants, cosmetics, and biotechnology hold longer-term potential but depend on stable supply chains, consistent quality, and specialized processing.

Although the permitting process itself is not perceived as a prohibitive barrier by most growers, suitable sites that could reliably produce marketable kelp appear more limited than previously assumed. The state's coastal waters face competing demands, and current evidence suggests the areas with the most biological promise may also present the greatest regulatory complexity. Within Cape Cod Bay and north of Boston, water conditions appear to be favorable for kelp growth. However, presence of North Atlantic Right Whales and other space conflicts make the siting of kelp farms much more difficult. South of Cape Cod the permitting landscape has historically been less complex, but grower experiences here indicate insufficient nutrient availability to support economically viable kelp growth.

Taken together, these findings point toward a consistent conclusion: sugar kelp can potentially be grown in Massachusetts but has not yet demonstrated consistent commercial predictability or economic viability. As such, future efforts in kelp aquaculture should be cautious, evidence-driven, and targeted toward reducing uncertainty. This includes site-specific research on environmental suitability, pilot-scale processing trials tied to confirmed buyers, exploration of other seaweed species, and stronger coordination among growers, regulators, and researchers. Without these foundations, broad expansion of kelp farming is unlikely to yield durable economic or environmental benefits for Massachusetts.

Introduction:

Massachusetts Aquaculture is a $31 million dollar industry, with an average economic impact of around $50 Million (DMF 2025). Currently the marine aquaculture industry in Massachusetts is dominated by the growth of oysters (*Crassostrea virginica)*, which account for 95% of the production volume and sales. There are currently approximately 400 private marine aquaculture growers in the state, mostly small-scale shellfish farmers. The interest in the aquaculture industry continues to grow, and there is continued interest in diversifying crops and seeking new market opportunities to support this growth. One of these alternative species that many have expressed interest in is sugar kelp (*Saccharina latissima*).

Sugar kelp production has expanded across North America, growing from small pilot efforts to more than 6,000 permitted farming acres in the United States and Canada (GreenWave 2026). While most United States kelp is produced in Maine and Alaska, Massachusetts growers have continued to explore whether the state can support a viable role in the industry. Interest has increased due to regional enthusiasm for seaweed farming, climate and nutrient mitigation goals, coastal economy diversification, and the rising profile of kelp as an important and popular product. Given all the potential benefits of sugar kelp farming, interest often stems from reasons other than economic.

Kelp is a fast growing, regenerative ocean crop that involves limited resources from farmers and is often considered an offseason or supplemental crop for oyster farmers as the growing season encompasses the winter months. Seed sugar kelp has become available through the development of nurseries that specialize in this phase of production. Methods of grow out are also largely established, centered around deploying seed string on grow lines horizontally suspended in the water column. The lines are then managed over the course of a winter season to maintain horizontal suspension, allowing access to water flow containing nutrients and the sun for photosynthesis. Harvest usually occurs in April or May. These traits combined make it appealing for aquaculture farmers and have spurred the interest in kelp farming in Massachusetts.

A kelp line being lifted out of the water to check growth on a farm

Despite this momentum, the future of kelp aquaculture in Massachusetts remains uncertain. This report contains four sections to summarize the kelp industry and outlook in the state of Massachusetts:

- Summarized input from interviews with individuals who have grown kelp in Massachusetts
- Permitting requirements for seaweed aquaculture
- Discussion of physical challenges experienced by Massachusetts growers in terms of kelp production and site-selection
- Market opportunities and challenges for harvested kelp.

Together, these sections provide a concise assessment of the current Massachusetts' kelp industry and help clarify Massachusetts' kelp potential.

Established kelp attached to a grow line showing significant growth

Lived Experiences of Kelp Farmers in Massachusetts

This section presents findings from a series of interviews with individuals who have attempted to cultivate kelp in Massachusetts. The purpose of these interviews was to capture the experiences of growers and identify key factors influencing the viability of kelp aquaculture in the state. Interview questions were structured around production, permitting, markets, and broader system-level constraints.

The findings presented here reflect both quantitative and qualitative insights, with a strong emphasis on participant narratives. These narratives provide critical context for understanding not only what has occurred in kelp farming efforts across Massachusetts, but why these outcomes have occurred. A total of 10 semi-structured video call interviews were conducted with individuals who have direct experience growing kelp in Massachusetts, including both current and former participants, providing a cross-section of production outcomes and perspectives.

1. Production and Farm Performance

Experience and Duration

Participants reported relatively short periods of engagement with kelp farming, typically ranging from one to six years, with most attempting cultivation for two to four seasons. Most participants exited the industry after only a few seasons due to insufficient biomass growth or lack of economic return. At the time of this study, only one interviewed operation remained actively engaged in kelp farming in Massachusetts, while all other participants had discontinued production after a limited number of growing seasons.

A defining characteristic of these experiences was unpredictability. As one participant explained:

> *"Our experience has been just unpredictable what your growth… it's all over the place."*

This variability contributed significantly to decisions to discontinue farming.

Scale of Production

Kelp farming efforts were generally small in scale. Most growers operated one to two lines ranging from approximately 150 to 400 feet in total, while a small number of research or experimental operations reached several thousand feet combined length.

These small-scale efforts were typically exploratory rather than commercial, reflecting a cautious approach to entering an uncertain production environment.

Yield and Productivity

Yield outcomes were consistently low and highly variable. Reported production ranged from zero harvest to approximately 1000 pounds in a season, with many participants describing yields as negligible or not worth quantifying.

In some cases, participants provided rough estimates:

"50–60 pounds"

"Let's say 1,000 pounds"

However, even when biomass was produced, it was often not commercially viable due to sub-optimal product quality or insufficient volume. As one participant noted:

"Well, I mean, it didn't grow as big as the pictures you see online."

Another described limited growth in practical terms:

"*It maxed out at 8 inches… the longest ones we got were probably 3 feet."*

These findings highlight a critical distinction between biological growth and commercially viable production.

Site Performance and Environmental Conditions

Participants frequently reported that their sites appeared suitable based on standard criteria (depth, flow, location) yet still failed to produce viable kelp biomass. This suggests that commonly used siting indicators may not adequately predict kelp performance in Massachusetts waters.

Nutrient limitation emerged as a recurring explanation for poor growth. Participants described kelp as sparse, underdeveloped, and lacking density:

"It was so sparse that, you know, I didn't really harvest. It looked like a lack of nutrients to me."

"Even though there's a lot of nitrogen, it's still just not enough."

Localized variation was also observed by participating kelp growers, with some areas showing better growth than others, suggesting that environmental suitability may operate on a finer spatial scale than currently understood.

Grow-Out Challenges

Despite poor production outcomes, participants consistently described kelp as relatively easy to grow from an operational standpoint. Labor requirements were minimal compared to other aquaculture activities:

"Kelp is, like, the easiest thing… it takes less maintenance than my yard at my house."

However, environmental factors—particularly weather and exposure—were identified as primary risks:

"The catastrophic failures were due to weather for certain."

This combination of low labor demand and high environmental uncertainty creates divergent conditions in kelp farming: operationally simple, but environmentally unreliable.

Seed Supply

Participants generally did not identify seed supply or quality as a major constraint:

"There was never a quality concern."

This suggests that upstream hatchery systems are functioning effectively, and that production limitations are more likely occurring during grow-out rather than early life stages.

Integration with Shellfish Farming

For the 3 participants already engaged in shellfish aquaculture, kelp was often seen as a logical addition to existing operations, particularly as a winter crop:

> *"It integrated well, because it grows in a time when our shellfish activity is lower."*

However, despite this compatibility, integration alone was not sufficient to overcome broader production and market challenges.

2. Permitting and Siting

Permitting was not widely identified as a primary barrier among participants once the permitting process was established. Some reported relatively smooth experiences navigating regulatory processes:

> *"I've never had a problem with permitting… you go and you ask the regulators informally before you submit anything."*

However, siting challenges were implied through discussions of poor site performance, suggesting that the issue may not be regulatory access to sites, but rather the difficulty of identifying sites that will reliably produce kelp. North Atlantic Right Whale habitat conflicts for siting areas north of Cape Cod were also acknowledged.

3. Market Challenges

Market limitations emerged as one of the most significant constraints on kelp farming in Massachusetts.

Many participants reported that even when kelp was produced, there was no viable market for selling it:

> *"There's no market, a dead end."*

> *"I think we just put it in the dumpster."*

In some cases, harvested kelp was discarded entirely:

> *"I just basically pulled it out of the water… and that was it."*

Participants were often direct in their assessment of demand:

> *"No one wants kelp… there's no reason to grow kelp."*

Even in cases where growers attempted to develop markets through value-added products, these efforts remained small-scale and insufficient to support commercial viability. It was further suggested:

> *"More market and product development is required to form the foundation of a robust industry with longevity."*

Scaling Constraints

Participants consistently emphasized that scaling production would not resolve market limitations. Instead, increasing production would likely exacerbate financial losses:

"The more I scale, the more it costs us money… there's no… I don't know… why would we do that?"

"If you brought in 100,000 pounds… what are you gonna do with it?"

This highlights a fundamental disconnect between production potential and market absorption capacity.

4. Overall Limitations to Industry Development

Across interviews, participants identified several interconnected barriers limiting the development of kelp aquaculture in Massachusetts:

- Unpredictable and often poor growth
- Environmental constraints (nutrients, exposure)
- Lack of established markets
- Economic non-viability
- Limited infrastructure for processing and distribution

These constraints collectively contribute to a perception that kelp farming is not currently a viable standalone industry:

"*Nobody's getting rich off of kelp… you're pretty break-even."*

In stronger terms, one participant cautioned against continued investment without addressing fundamental issues:

"*You can grow it, but you can't sell it… it's such a diversion of resources."*

5. Opportunities and Future Considerations

Despite widespread challenges, participants identified potential pathways for improving the viability of seaweed aquaculture in Massachusetts. While participants were generally skeptical about the near-term viability of kelp farming under current conditions, many offered practical recommendations focused on market development, infrastructure investment, applied research, and diversification into alternative seaweed species.

Market Development

Participants emphasized the need for intentional market creation, including institutional procurement and consumer education:

"Create initiatives… we're gonna buy this amount of kelp every year… it's all marketing at that point."

Several participants noted that the primary challenge was not growing kelp, but finding reliable buyers and economically viable market outlets. One grower described the situation directly:

"*There's no reason to [grow kelp]. You can't sell it… there's not a market for it*."

Others expressed frustration with the lack of established purchasing channels:

"*We wish if somebody would show up and just buy it all from us at the dock and be done with it. But that hasn't happened yet*."

While some participants identified niche opportunities through farmers markets, retail sales, and value-added products, they emphasized that these efforts remain too small to support a commercial-scale industry. As one participant explained:

"*We actually purchase [kelp] from Chatham Kelp and bring down stuff from Maine and retail that frozen raw at our farmers market… but we're not creating an economy based around kelp*."

Infrastructure Investment

Processing infrastructure was identified as a critical gap:

"Centralized processing location for seaweed."

Participants described processing as a significant barriers to industry growth. Several noted that Massachusetts lacks the processing infrastructure available in more established seaweed-producing regions.

"*We don't have any processors around here*."

Without access to centralized facilities, growers are often forced to handle drying, storage, and processing themselves:

"*We have to rely on ourself to find a greenhouse and hang it and dry it and deal with all that… that's challenging*."

Participants also noted that processing introduces additional regulatory and operational requirements that many small growers are not equipped to manage:

"*Once you start getting into processing, now you need a facility that's Board of Health approved. You need employees. It becomes a whole different business model*."

Research and Innovation

Participants suggested that technological innovation could improve production outcomes and reduce uncertainty around site selection and cultivation practices.

Several growers reported experimenting with growing depth and farm design in an effort to improve performance:

"We tried 3 or 4 different depths to optimize it."

"I think 5 feet down generally did the best for us."

Others emphasized that sites meeting commonly accepted criteria for kelp cultivation still failed to produce commercially viable yields, highlighting the need for better understanding of environmental conditions in Massachusetts waters. One participant noted that considerable effort was invested in selecting a site that appeared suitable:

"*We did spend some time looking at the current in these locations to make sure we had a higher flow area."*

“We thought it would meet all the criteria of a good site out there.”

Participants also suggested that future research could focus on developing strains better adapted to local environmental conditions:

“If there was research that kind of have kelp that could grow in these conditions here… nutrient areas that are lower.”

<u>Species Diversification</u>

Some participants expressed interest in shifting to alternative seaweed species better suited to local environmental conditions or market opportunities.

Rather than focusing exclusively on sugar kelp, growers suggested exploring species that occur naturally in the region or may be more compatible with Massachusetts growing conditions:

“Maybe even other species. What actually does grow here naturally? Maybe explore some of those.”

Others pointed to species that may offer stronger market potential:

“I bet we could grow other types of seaweed, edible seaweeds… dulse or things like that, that actually have high per pound rates and can accommodate our environment as well.”

Interest in alternative species was also reflected in growers’ willingness to consider new cultivation opportunities:

“I looked at dulse… I would have absolutely considered that.”

These comments suggest that future development efforts may benefit from evaluating a broader range of seaweed species rather than focusing solely on sugar kelp.

Permitting Seaweed Aquaculture in Massachusetts

Kelp growers interviewed suggested the permit process to start a stand-alone kelp farm, or to add kelp to an existing shellfish operation, was not overly burdensome except for those that were first in the water with kelp before there was an outlined process. Massachusetts (MA) has since given the MA Division of Marine Fisheries authority through MGL Chapter 130, section 102: “No person shall harvest for sale or engage in the aquaculture of marine plants except in accordance with any regulations adopted by the director and subject to a permit or written approval issued by the director.”
(https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXIX/Chapter130/Section102)

The current process for licensing a kelp, or other seaweed farm, is outlined here:

1) Kelp or other seaweed aquaculture in state waters requires a Massachusetts Division of Marine Fisheries non-shellfish aquaculture permit. As part of this permit, there will need to be a public hearing. Proponents/towns are encouraged to accomplish this through Select Board public hearings similar to shellfish aquaculture because they receive good public input on all proposed aquaculture projects. If there is not a town held public hearing, DMF must hold a public hearing including a 21-day comment period.
2) Kelp and other seaweed aquaculture requires a Massachusetts Chapter 91, section 10A permit. This most commonly is issued by the local harbormaster, but sometimes comes from other town offices (like conservation commissions).

3) Applicants must also file for review with the Massachusetts Environmental Policy Act (MEPA) Office which includes a 30-day comment period.
4) Finally, applicants must receive their United States Army Corps of Engineers (ACOE) Pre-Construction Notification (PCN) permit. This permit coordinates federal review of the application.

Discussion on Challenges Described by Growers

<u>Lack of Growth</u>

Yields of kelp, often measured as the weight of kelp produced per unit of line planted, can be used to assess overall productivity of a kelp growing site. Growers interviewed for this project were asked to report their yields and those ranged from 0 to around 1 lb per foot of line. Most of the growers had sites on the south side of Cape Cod in the waters of Nantucket or Vineyard Sounds, or Buzzards Bay. These waters had particularly low yields, from 0 to just under 0.5 lbs per foot of line, with descriptions of growth in length of the kelp from just a couple of inches to around a maximum of 4 feet in length. In the small number of grower reports from North of Cape Cod, yield estimates were up to 1 lb per foot of line though could have been higher if storms had not chaffed kelp off the lines in some sections reducing averages. North of Cape Cod descriptions of kelp length were also much larger, on the order of 6-8 feet in frond length (pictured below).

Photo: Duxbury Sugar Kelp

These Massachusetts reported yields are much lower than the nationwide average of roughly 2lbs per foot (GreenWave 2026) and even further below the Maine median production yield of roughly 4 lbs per foot of line (Brayden and Colman 2023). In Maine, it was estimated the kelp yield required to break even with costs was at least 2.69 lbs per foot line (Brayden and Colman 2023), while GreenWave reports profitable farms averaging at least 3.5lbs/ft (GreenWave 2026). Consistent with this, most growers interviewed in Massachusetts reported concerns about overall economic viability of growing kelp at their sites given poor or inconsistent yield not achieving an economically viable level of production.

While low yields North of Cape Cod seemed to be associated with gear and weather impacts rather than poor growth, growers south of Cape Cod reported low yields due simply to poor growth, often growing only several inches over the course of the season. These kelp were also reported to look thin, pale and yellow indicating some form of nutrient starvation, namely low levels of dissolved inorganic nitrogen (Chapman and Craigie 1977; Chapman et al 1978). Nitrogen has also been further described as the nutrient that is most commonly limiting for most all seaweeds in natural systems (Roleda and Hurd 2019).

Pale yellow sugar kelp typical of poor growth areas in Massachusetts

Consequently, assessing nitrogen available to kelp is critical to evaluating growth constraints on the south side of Cape Cod. The forms of nitrogen kelp and other seaweeds most readily use are dissolved inorganic forms of nitrogen (DIN), namely ammonium ($NH4^+$) and nitrate ($NO3^-$) (Roleda and Hurd 2019). Specific to sugar kelp, *Saccharina latissima*, it has been shown in the lab that nitrate concentrations below 3 µM are limiting, and a relatively linear relationship between growth and nitrate concentration up to 10 µM after which did not appear limiting (Chapman et al. 1978). In the natural environment where levels are likely much more variable over time, it has been suggested that dissolved inorganic nitrogen levels less than 1 uM can be limiting (Stephens et al 2024) but more optimally 10 µM or more for kelp growth (Kerrison et al 2015).

Dissolved inorganic forms of nitrogen should be at their maxima during winter when competition with phytoplankton in the water column is lower, often 5-40 µM (Stephens et al 2024). For several years, Cooperative Extension in conjunction with partners have followed small test plantings of kelp seed string in attempts to learn more about what makes a "good" kelp site. These plantings focused on waters to the South of Cape Cod, including both smaller estuary type embayments as well as Nantucket Sound and Buzzards Bay, and over successive years (a total of 15 test sites) further confirmed grower frustrations with poor kelp growth. The only site that showed modest success, was Falmouth Harbor, which showed a higher average DIN value of 3 µM over 2 successive years and never fell below 1 µM. Another site in Shoestring Bay of Mashpee had similar DIN levels but only half the growth likely due to lower salinity levels and ice cover over early 2026. Most all other sites had average DIN values over winter below 1 µM , which is likely a significant limiting factor for the kelp planted in those waters.

There is some thought, as suggested by one of those interviewed, that planting kelp earlier in the fall could help improve growth outcomes by giving newly planted kelp more potential to assimilate during longer days and warmer water temps. This is evidenced by data from a Long Island Sound site that showed dramatic improvement in yield planting in October compared to planting in November or December (Dave Bailey, GreenWave). This remains to be tested thus far in MA waters, and could run into permit constraints as most kelp planting permits stipulate planting in November after most other activity on the water has slowed.

Site Selection Challenges

To understand better how DIN may vary by region in Massachusetts, we compiled available data on DIN during winter months and averaged by larger region. Of note, sites with salinity averaging below 25ppt were removed from the regional averages, reasoning described further below. These regional averages (Figure 1) do suggest the open waters of Nantucket Sound and Buzzards Bay are quite low in DIN compared to Cape Cod Bay and Boston Harbor and well below the 5 to 40 µM seen in other sugar kelp growing regions during winter (Stephens et al 2024; Roleda and Hurd 2019).

It's uncertain why these waters are much lower in DIN but it could stem from the fact that Cape Cod and the South Coast of Massachusetts lack large river system inputs compared to other regions, with nitrogen inputs in large part through the groundwater interface. Inside estuaries surrounding the Nantucket Sound and Buzzards Bay DIN levels are much higher and more appropriate for sugar kelp, but low salinity in these areas can hinder growth as sugar kelp biomass has been negatively correlated with seawater salinity (Monteiro et al. 2021; Bruhn et al. 2025). An example of this is seen in Figure 2 where average DIN and salinity values are plotted together for estuary and open Nantucket Sound sites in Eastern half of Nantucket Sound. There is a tendency for higher winter DIN in areas with lower salinity.

Multiple linear regression using kelp growth results (sites showed a range of no growth to modest kelp growth) during winter 2025-2026 at 5 test sites in Massachusetts estuaries with average DIN and salinity data resulted in an R^2 value of 0.79, suggesting DIN and salinity do help predict kelp growth. Other parameters like phosphate and silicate showed less correlation. Given this, examination of winter DIN and salinity values in seawater embayments around the region can be a useful tool to help with initial examination of whether kelp growth could be supported at a location.

To further explore potential kelp siting opportunities based on DIN and salinity, we augmented existing data by testing waters in nine waterbodies on outer Cape Cod and nine waterbodies adjacent to Buzzards Bay, in time series and averaged over the course of February and March 2026. In addition, two sets of single spot samples were taken at locations on the North Shore as existing data were limited there. This data suggested several areas (shaded in table 1) that may be worth further exploring for kelp if space were to be available for kelp. These areas included Town Cove, Mill Pond, and Salt Pond in the Nauset system on outer Cape Cod, and West Falmouth Harbor in Buzzards Bay. A number of other sites had more variable results so were highlighted but with some hesitation, these include the main section of Pleasant Bay, the upper portion of Buttermilk Bay, Monument Beach, and Megansett Beach.

The North Shore samples should be interpreted carefully as they are based on only 1 spot sample, but the near shore areas highlighted showed particularly high DIN values, including Rockport near the Granite Pier, Wingaersheek Beach, Canoe Beach, Preston Beach, and Gloucester Harbor. Of note, all of the North Shore locations had notably high salinity and natural kelp populations were noted in the waters there near spots sampled. It is also likely the sites sampled in April would have been higher in DIN during February or March as water temperatures were rising in April.

Using existing water quality data that includes DIN and salinity during winter months was somewhat difficult to find, but data was provided through the Center for Coastal Studies for several years, a single season from Buzzards Bay Coalition, and several years for outer Boston Harbor locations from the Massachusetts Water Resources Authority (MWRA). As an initial step, sites which had salinity that averaged below 25ppt were eliminated as not ideal for sugar kelp, and areas with DIN averaging 3 µM or greater were considered good, though levels over 1 µM may be sufficient (Stephens et al 2024):

- All of the MWRA sampled areas of outer Boston Harbor and the islands including Dorchester and Quincy Bays showed winter DIN levels that should be supportive of kelp (Figure 3).
- Center for Coastal Studies data show Cape Cod Bay sites also have DIN levels that would largely support sugar kelp growth (Figure 4). Of note, there was a kelp farm sited in Duxbury on the border of Plymouth within Plymouth Harbor waters. This site reported successful kelp growth and the DIN data would support that (Gonzalez et al 2025, see Figure 2). The greater challenge in the Cape Cod Bay area is right whale habitat conflicts, so only option here is likely working in waters like Plymouth Harbor on the edge or outside of critical habitat area.
- Center for Coastal Studies data show the waters of open Nantucket Sound are clearly quite low in DIN, while adjacent estuaries have varying levels of DIN (Figures 2 and 5). The challenge then becomes matching elevated DIN with high salinity. A number of these estuaries received small test plantings of sugar kelp in recent years, including Lewis Bay, Popponessett Bay, Jehu Pond, Little River, Hamblin Pond, Little Pond and Falmouth Harbor. Falmouth Harbor had the most success with kelp growing to about a meter in length and reaching 3lbs per foot of line in biomass. Popponessett Bay had lower success, but results improved as test plantings moved toward the outlet to Nantucket Sound where salinity is higher.
- Existing Buzzards Bay Coalition data from the single winter season of 2016-17 is shown in Figure 6. The data, like those in our more recent Buzzards Bay sampling (Table 1) suggest DIN levels are fairly low overall with a couple of exceptions. Both data sets suggest DIN levels are high in West Falmouth Harbor and if sticking to higher salinity portions of the Harbor this area has high potential. New Bedford Harbor also had higher levels of DIN and while it is a busy harbor with legacy contamination it could be considered for mitigation type projects. Test plantings of kelp, either commercially or experimentally, were done in Megansett Harbor, Nasketucket Bay, Wareham River, and two locations in Upper Buzzards Bay and none of these supported good sugar kelp growth. The one closest to the Cape Cod Canal along the Mashnee Dike area had the best growth of any in Buzzards Bay but still not at a level where it was continued commercially.

These suggestions are based off spot samples and existing data from stations sampled not for the express purpose of evaluating sugar kelp aquaculture. There are likely other areas that may have opportunity that have not been sampled or identified here. Likewise, further pilot testing is always recommended before further investment in commercial operations.

If growing sugar kelp for human consumption there may be further challenges in Boston Harbor and some coastal North Shore waters. This is due to bacteriological standards of water classification that could indicate other potential human health hazards for seaweed products to be consumed. A good initial indication of bacteriological standards of water quality is to look at Massachusetts designated shellfish growing area classification (https://www.mass.gov/info-details/shellfish-classification-areas). If waters are in the approved class or conditionally approved in the open status they are generally safe for harvest of shellfish and would likely hold similar for seaweed. This again is only for harvest and sale of kelp for human consumption, but kelp grown for restorative purposes or for markets not concerned with microbial standards would likely be unaffected.

In waters east and north of Cape Cod the biggest challenge remains avoiding North Atlantic Right Whale Critical Habitat (Figure 7). Unfortunately, the kelp grow out period extends from winter into April or May when these whales are seen throughout this area. Given kelp grow out involves suspended vertical and horizontal lines this is perceived as an entanglement risk for this critically endangered species, making permitting of a kelp farm in these waters a major challenge. Small scale sites may be possible in more sheltered areas on the edge of the habitat area, evidenced by sites permitted inside Plymouth Harbor and the nearshore waters of Cape Ann. Other areas of opportunity may include Boston Harbor, Salem Sound, and Gloucester Harbor, though water quality concerns may be a challenge for markets for human consumption. For anyone proposing to culture kelp in or adjacent to North Atlantic Right Whale Critical Habitat, due diligence should be taken to consider how the proposed site would limit potential impacts and interactions. Reviewing NOAA resources on the Endangered Species Act and Aquaculture, the NOAA ESA Section 7 Mapper, and the overall process of how the application would eventually be reviewed under the Framework for ESA Section 7 Evaluation of Aquaculture Projects would be advisable.

A further challenge experienced by small scale attempts north of Cape Cod was exposure to storms, particularly Nor'easters. Growers reported significant wind and wave damage to both the infrastructure and kelp so another hard learned recommendation would be to identify sheltered sites, particularly from northeast fetch. Waters south of Cape Cod often had a higher level of protection due to geography.

Seaweed Market Landscape Summary

This section involves a market summary review of the current status of sugar kelp market opportunities in Massachusetts in relation to domestic and global seaweed markets. The central question is not whether seaweed has potential uses (it does), but whether Massachusetts-grown sugar kelp can reach those markets at sufficient scale, quality, and price to compete.

The assessment draws on market reports, national seaweed sector analyses, Massachusetts grower findings where relevant to market access, and comparative production data from Maine and other regions. Farmer interview findings are used only where they inform market feasibility - namely production volume available for sale, ability to meet buyer specifications, processing limitations, and whether reported yields are sufficient for commercial market participation.

Global and Domestic Market Context

The global seaweed market is large, but it presents high barriers to entry as a commodity market for Massachusetts producers. Existing global supply is dominated by countries with established species, large production areas, low-cost labor structures, processing systems, and species already embedded in major food, hydrocolloid, fertilizer, feed, and industrial markets. The World Bank (2023) reports that countries outside Asia produced less than 2% of total farmed seaweed volume in 2020, while North American and European farmed seaweed volumes remained in the hundreds of tons and were growing slowly.

Commercial market reports describe global seaweed demand across human food, hydrocolloids, agriculture, animal feed, personal care, pharmaceuticals, and other applications (Grand View Research, 2022). However, these broad values do not mean Massachusetts sugar kelp can access those markets. Many global markets are supplied by lower-cost international producers and by species other than the native kelps generally cultivated in New England, including *Saccharina japonica*, *Pyropia/Porphyra*, *Gracilaria*, *Kappaphycus*, and *Eucheuma*.

The U.S. sector remains small by comparison. Kotowicz et al. (2024) report that sugar kelp is the dominant cultivated seaweed in the United States and was grown across nine coastal states, with approximately 3 million pounds of farmed sugar kelp produced in 2022 and other cultivated seaweeds together remaining below 2 million pounds. This places the United States at an early-stage relative to global production and limits its ability to compete on commodity volume or price.

Massachusetts is further constrained by native-species requirements, short growing seasons, limited space, and the absence of local mature bulk markets for the native kelps being grown. For market purposes, Massachusetts should therefore be evaluated as a potential supplier to small, differentiated, higher-value regional markets, rather than focusing on competition within the global commodity seaweed market.

<u>Massachusetts Conditions That Affect Market Access</u>

This summary does not repeat the separate production or farmer interview chapters, but market feasibility cannot be separated from whether a product can be grown, stabilized, and sold in a form buyers will accept. Current evidence indicates that Massachusetts sugar kelp production remains limited and demonstrates high inter-annual variability, which presents challenges for consistent market participation at commercial scale (see summary of MA kelp farmer interviews).

GreenWave (2026) classifies Massachusetts north of Cape Cod within the Gulf of Maine region and Massachusetts south of Cape Cod with Southern New England. Southern New England is described as the southernmost range for kelp cultivation along the U.S. Atlantic coastline, and warming waters have affected wild kelp populations throughout the region. From a production perspective, sugar kelp cultivation south of Cape Cod is currently constrained pending site-specific evidence that demonstrates repeatable growth, harvestable quality, and marketable volume.

North of Cape Cod, the biological outlook may be stronger, but the regulatory and spatial environment is more complex. Goldstein and Welles (2024) note that U.S. seaweed farms face variable state permitting frameworks, local and federal approvals, limited processing facilities, and limited coastline available for farming. These permitting and protected-species considerations are market-relevant because they affect whether farms can be sited, permitted, insured, financed, harvested, and scaled. Ultimately, these constraints affect the time, costs, uncertainty, and scalability of any potential market pathway.

Finally, the processing and aggregation infrastructure needed to commercialize a wet, seasonal crop is lacking. GreenWave (2026) describes shared processing and co-packing models emerging in Maine, Connecticut, Alaska, and British Columbia, including shredding, dehydration, hammer milling, cold storage, and aggregation services. Comparable shared infrastructure is not currently established in Massachusetts at a scale that would allow growers to reliably sell stabilized kelp into food, agricultural, cosmetic, or biomaterial markets.

Regional Competitiveness: Massachusetts Compared with Maine and Global Producers

Massachusetts is not competing only with hypothetical future markets; it is competing with existing producers. Within the Northeast, Maine is the leading U.S. kelp production state. GreenWave (2026) reports that Maine accounts for roughly 80% of U.S. kelp landings and that Maine kelp farmers exceeded 1.5 million pounds of landings in 2024, with sugar kelp representing just over half of that production. By contrast, Southern New England - including Connecticut, Massachusetts south of Cape Cod, New York, and Rhode Island - reported annual landings below 152,000 pounds across the entire region (GreenWave, 2026).

Maine also has a more established production and support ecosystem. The Maine Seaweed Benchmarking Report found that Maine farmed seaweed harvest increased substantially between 2017 and 2022, with 9 of 16 farms in the study profitable; however, profitability was associated with scale, and the smallest farms were not profitable (Brayden & Coleman, 2023). This comparison is important because it suggests that even in a more developed kelp-producing state, profitability is not guaranteed and appears linked to volume, experience, and market access.

International competition presents a significant market constraint. Overseas producers benefit from established species, mature seaweed food cultures, long-standing processing systems, larger farms, lower costs, and major buyers already configured around their product forms. Massachusetts sugar kelp is therefore less competitively positioned to enter global commodity channels for food, fertilizer, feed, hydrocolloids, biofuel, or bioplastics. Any viable pathway would need to be small-volume, differentiated, and buyer-specific.

Market Pathways and Timing

The market landscape for sugar kelp can be divided into near-term, medium-term, and long-term or speculative pathways. This distinction is important because broad seaweed market growth does not automatically translate into a viable market for Massachusetts-grown sugar kelp. There are a variety of proposed markets for seaweed products with large differences in biomass required and market value (summarized in Chopin et al. 2024).

Near-term markets: food, boutique products, and regional ingredients. Whole food and specialty food markets are the most accessible near-term pathways for Massachusetts sugar kelp. These include fresh, frozen, blanched, dried, powdered, or pureed kelp used in restaurants, condiments, snacks, seasonings, small-batch products, and direct-to-consumer sales. These markets can absorb small volumes, but they remain limited by consumer unfamiliarity, product-development costs, food-safety requirements, and fragmented demand. They may provide minimal supplemental revenue for individual producers but are not large enough to support statewide industry expansion.

Short-term growth markets: biostimulants and agricultural inputs. Seaweed-based biostimulants and agricultural inputs are frequently identified as promising markets. However, the relevant market is not raw kelp sold as bulk fertilizer. Biostimulant products require stabilization, formulation, evidence of performance, and consistent input quality. The Nature Conservancy, World Bank, and Hatch Blue (2026) note that seaweed biomass can contain 63%-96% moisture, affecting extraction efficiency, stabilization, storage, and product quality. This suggests a possible downstream market, but not an immediate farmgate outlet for unprocessed Massachusetts kelp.

Kelp being dried in a greenhouse

Medium-term markets: cosmetics, personal care, biotechnology, and biomaterials. Cosmetics, personal care, nutraceuticals, biotechnology, and biomaterial applications may support higher value per unit of biomass than commodity markets, but they require consistent quality, contaminant testing, extraction, formulation, and specialized buyer relationships. These sectors may be appropriate for research partnerships or small pilot projects, but the cited resources do not provide sufficient pricing or procurement data to conclude that these markets could support Massachusetts growers at commercial scale.

Long-term or speculative markets: biofuel, carbon credits, bulk bioplastics, and industrial feedstocks. Biofuel, blue carbon, bulk bioplastics, and other large industrial uses are not realistic near-term markets for Massachusetts. They require very large, low-cost, reliable biomass supply and significant processing infrastructure. GreenWave (2026) describes earlier investments in biofuels, blue carbon, and offshore automation as part of a speculative "moonshot" phase that did not build durable processing capacity or commercial foundations for farmers. For Massachusetts, these applications should be treated as research topics rather than market opportunities for current or near-term growers.

Market Pathway Assessment

Table 2 summarizes the relative fit of major market pathways for Massachusetts-grown sugar kelp. The ratings reflect current evidence on production volumes, price sensitivity, secondary processing needs, permitting risk, and likely accessibility to Massachusetts producers (Table 2).

Cross-Sector Findings

The market pathways reviewed in Table 2 point to a consistent conclusion: the most accessible markets currently possess limited capacity to support significant industry-wide scaling, while the larger markets require scale, low-cost feedstock, and processing infrastructure that Massachusetts does not currently have.

Food and boutique markets can absorb limited volumes and may have value for education, branding, or supplemental revenue. However, these markets are fragmented and cannot carry a statewide industry. Fertilizer, feed, biomaterials, and bioplastics offer higher-volume theoretical demand, but they are price-sensitive and generally require biomass volumes, processing capacity, and logistics that favor established producers in Asia or other lower-cost regions.

Cosmetics, biotechnology, and nutraceutical markets may offer higher value per unit of biomass, but they are low-volume, technically demanding, and often proprietary. These markets depend on extraction, quality assurance, contaminant testing, product formulation, and regulatory compliance. They may support university or private-sector R&D, but the reviewed sources do not demonstrate a reliable farmgate market for Massachusetts sugar kelp.

The sources reviewed also lack consistent farmgate pricing data for many market channels. The Ireland market analysis similarly emphasizes that higher value requires processing, automation, drying, milling, extraction, packaging, and product development rather than raw biomass sales (Walsh and Watson). This is a finding in itself. It suggests that the U.S. sugar kelp sector lacks standardized buyer specifications, transparent pricing, and stable procurement pathways. Much of the value in seaweed markets is captured after processing rather than by the grower selling wet biomass.

Highly Constrained Market Pathways

Biofuel: Biofuel presents significant economic and logistical barriers for Massachusetts sugar kelp under current conditions. It requires very large quantities of low-cost biomass, reliable year-round feedstock, conversion infrastructure, and logistics systems that Massachusetts does not possess. GreenWave (2026) identifies biofuels as part of a broader speculative investment period that did not build durable farmer markets.

Blue carbon and carbon credits: Carbon credits should not be treated as a dependable revenue stream for Massachusetts kelp farmers. The World Bank (2023) identifies technical, regulatory, social, financial, and political challenges for seaweed ecosystem service markets. Chopin et al. (2024) go further, arguing that deep-ocean seaweed dumping for carbon sequestration is questionable, risky, and not the best use of biomass; they call for a moratorium until efficacy and environmental, economic, and social sustainability are established. These findings directly undermine the use of carbon sequestration claims as a justification for commercial kelp expansion in Massachusetts.

Bulk fertilizer and commodity animal feed: Fertilizer and animal feed markets are often listed as major seaweed outlets, but they are difficult markets for farmed Massachusetts sugar kelp because they are price-sensitive and already served by wild-harvested, imported, or lower-cost seaweed inputs. A more realistic pathway would be a specialty agricultural input or functional feed additive, but only if processing, quality control, and buyer specifications are in place.

Large-scale bioplastics and biomaterials: Bioplastics and biomaterials may be relevant for research, but they are not near-term markets for Massachusetts growers. These sectors require large and reliable feedstock volumes, processing infrastructure, performance testing, and price competitiveness against established materials. The wet-weight logistics alone create a significant barrier for small Massachusetts farms.

Ecotourism and education: Farm tours, education, and public engagement may have supplemental value as accessory markets, but they should not be treated as a biomass market. These activities do not solve the core market problem: a lack of reliable buyers for Massachusetts-grown sugar kelp at a profitable price. Building reliable markets for biomass first will allow accessory markets like farm tours and public engagement to develop in the future.

Summary

The lived experiences of kelp farmers in Massachusetts reveal a consistent pattern: while kelp can sometimes be grown, current operations face ongoing challenges regarding consistency, scalability, and economic margins. Production has been highly variable, and markets remain underdeveloped. As a result, many growers have exited the industry after only a few seasons, but have shared clear opportunities for intervention, particularly in market development, infrastructure, and applied research as proper siting remains a mystery for Massachusetts.

First, kelp aquaculture in Massachusetts has been limited by site suitability and kelp/seaweed growth performance. The variability in site performance observed across interviews indicates a need for targeted, site-specific research to better understand nutrient dynamics, exposure thresholds, and localized growing conditions. Potentially productive areas north of Cape Cod are limited by conflicts with right whale habitat posing major challenges to large scale developments. South of Cape Cod will require more refined water testing and test plantings to better inform where sugar kelp may be successful. Dissolved inorganic nitrogen levels of at least $3\ \mu M$ seemed to spur kelp growth in small test trials but it can be hard to find these levels and still have salinity of 30ppt or higher as lower salinities have more variable results.

Second, market development does represent a critical bottleneck. Even in cases where kelp was successfully grown, participants consistently reported an inability to sell product at a price or volume that would support commercial operations. This suggests that supply-side investments alone—such as gear, seed, or farm expansion—are insufficient for long term success. Strategic demand-side interventions, including institutional procurement programs, product standardization, and consumer-facing education, may be necessary to establish baseline market stability.

Third, infrastructure gaps—particularly in processing and distribution—limit the ability of growers to aggregate, store, and move seaweed products efficiently. If kelp production were to be scaled up, coordinated investment in shared or centralized processing facilities could reduce individual risk and improve overall market access.

Finally, the findings highlight the importance of engaging directly with industry participants in the development of policy, funding priorities, and research needs. Growers emphasized the need for responsive, industry-informed decision-making, particularly in identifying which seaweed species, technologies, or market pathways warrant further investment. Supporting adaptive, iterative approaches—rather than prescriptive, top-down strategies—may better align state efforts with on-the-ground realities of building a seaweed aquaculture industry.

Taken together, these findings suggest that a coordinated, systems-level approach will be required to support the responsible development of seaweed aquaculture in Massachusetts. This includes aligning research, infrastructure, and market development efforts in a way that reflects both the opportunities and the constraints identified by current and former growers. Addressing these areas will be essential if kelp (or other seaweed) aquaculture is to become a viable component of Massachusetts' coastal economy.

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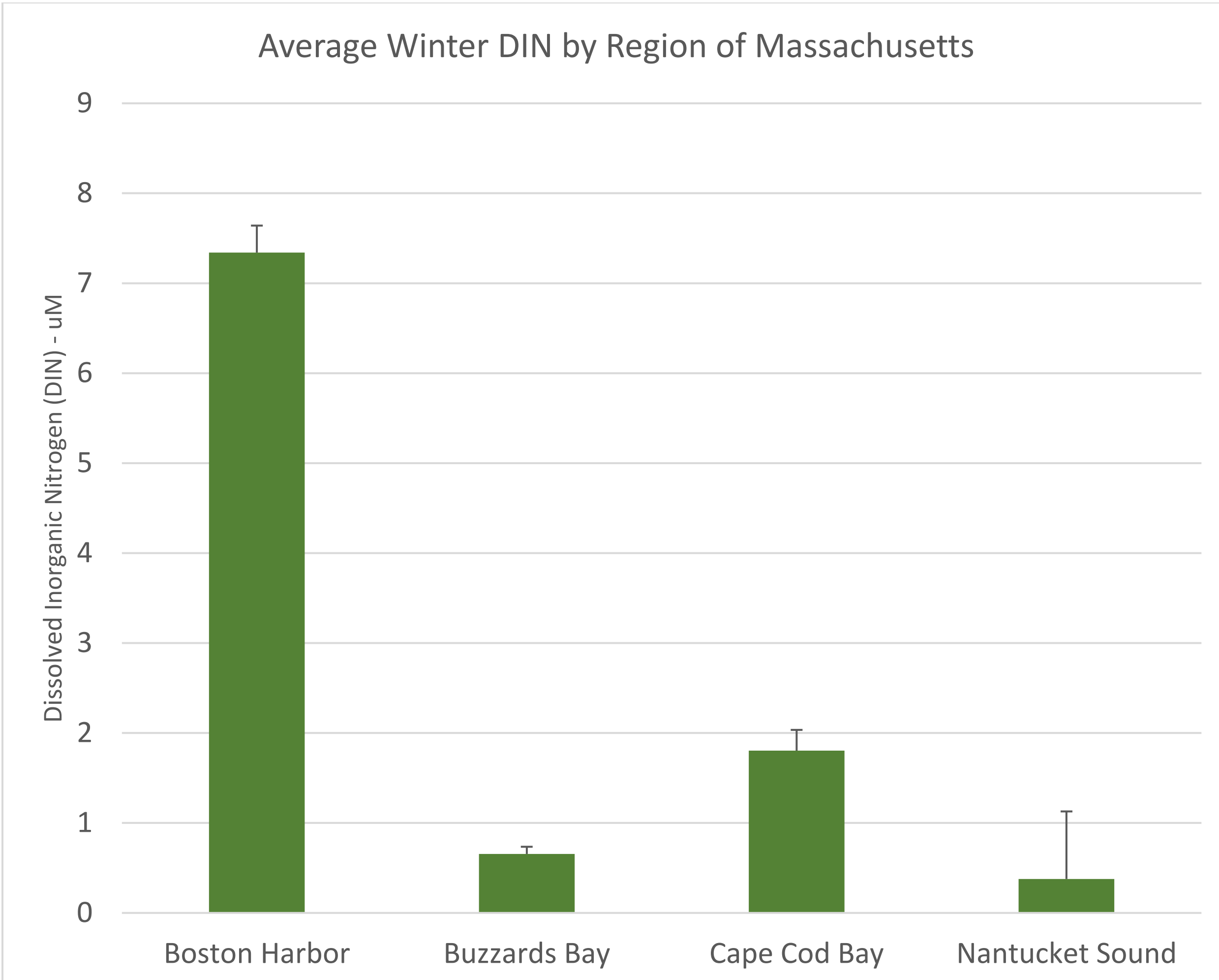

Figure 1: Average DIN by region with standard error. Data were compiled from a variety of existing sources with data between the months of October and May, sites with salinity lower than 25ppt were removed. The data for Nantucket Sound and Cape Cod Bay was collected by the Center for Coastal Studies October through May 2020-2024. Buzzards Bay data was provided by the Buzzards Bay Coalition October based on sampling in May 2016-2017. Boston Harbor data was accessed through the Massachusetts Water Resource Authority October through May 2020-2024.

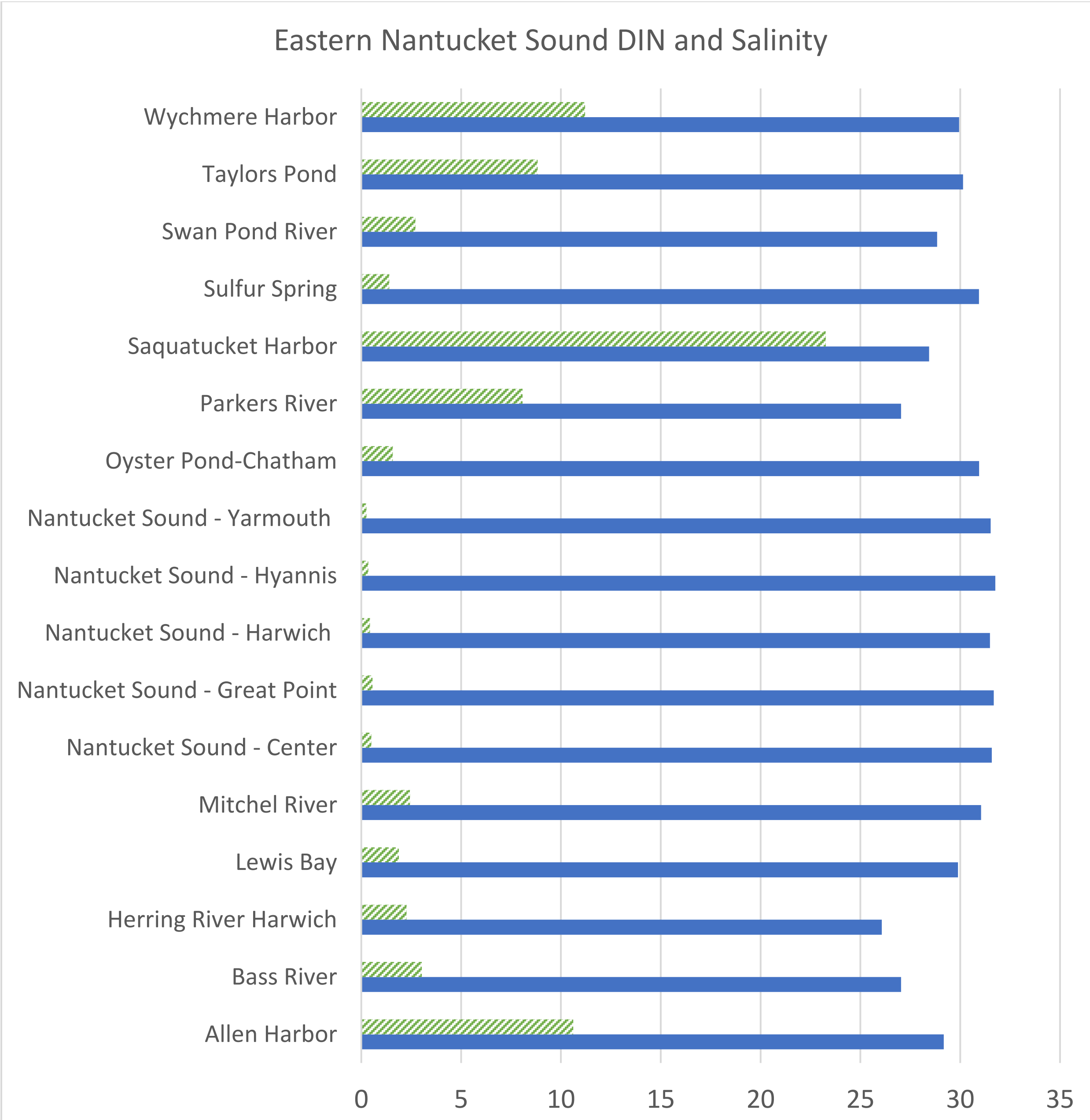

Figure 2: Average Dissolved Inorganic Nitrogen in µM (Green diagonal lined bars) and salinity in ppt (blue bars) of Nantucket Sound sites East of Hyannis Port. Data Collected by the Center for Costal Studies October through May 2020-2024.

Site	Town	N	Date	Temp (C)	Salinity (ppt)	DIN (µM)	Ortho-Phosph (µM)	Silicate (µM)
Outer Cape Cod								
Town Cove - Landing	Orleans	6	Feb/Mar	3.87	28.91	4.92	0.28	22.37
Lower Pleasant Bay	Chatham	6	Feb/Mar	5.38	32.11	0.71	0.29	1.84
Lonnies Pond	Orleans	6	Feb/Mar	5.70	31.64	1.20	0.31	7.86
Mill Pond	Orleans	6	Feb/Mar	5.18	27.15	4.66	0.23	28.14
Pleasant Bay - Rt 28 Landing	Orleans	6	Feb/Mar	5.37	30.80	2.01	0.36	6.08
River at Meetinghouse Pond	Orleans	6	Feb/Mar	4.79	30.41	1.45	0.23	7.19
Ryders Cove	Chatham	6	Feb/Mar	4.28	31.44	0.60	0.18	3.33
Salt Pond	Eastham	5	Feb/Mar	4.68	31.56	5.59	0.44	11.03
Nauset Marsh - Snow Shore	Orleans	6	Feb/Mar	5.12	32.58	1.02	0.45	2.09
Buzzards Bay								
Buttermilk Bay Narrows	Bourne	6	Feb/Mar	2.43	30.53	1.90	0.31	4.66
Monument Beach Landing	Bourne	6	Feb/Mar	2.34	30.14	2.43	0.30	13.28
Clarks Cove Landing	New Bedford	6	Feb/Mar	1.39	32.11	0.57	0.57	0.65
Megansett Beach Landing	Falmouth	6	Feb/Mar	2.08	28.62	1.83	0.28	9.78
Mattapoisett Harbor, Neds Pt	Mattapoisett	6	Feb/Mar	2.13	30.82	0.84	0.43	4.20
Onset Bay Pier	Wareham	6	Feb/Mar	2.08	30.84	0.67	0.36	2.43
Quissett Harbor	Falmouth	4	Feb/Mar	4.29	28.75	0.46	0.36	15.54
Sippican Harbor Pier	Marion	6	Feb/Mar	2.64	29.63	1.25	0.28	4.95
West Falmouth Harbor	Falmouth	6	Feb/Mar	2.63	28.73	4.22	0.38	19.92
North Shore								
Rockport - Granite Pier	Rockport	1	3/12/26	4.5	35	4.91	0.86	5.65
Wingaersheek Beach	Gloucester	1	3/12/26	4.5	34	4.06	0.42	7.07
Canoe Beach	Nahant	1	3/12/26	4.5	34	5.81	0.85	3.17
Preston Beach	Marblehead	1	3/12/26	4.5	33	7.09	0.75	9.12
Milk Island	Rockport	1	4/14/26	6.1	35	0.45	0.13	1.42
Light House Cove	Gloucester	1	4/14/26	7.5	35.5	0.52	0.28	0.97
Never Fail Ledge	Manchester	1	4/14/26	6.5	38	1.21	0.23	0.84
Bakers Island	Salem	1	4/14/26	7.6	37	0.33	0.18	0.34
Tinkers Island	Salem	1	4/14/26	7.3	35	1.00	0.18	0.31
Dry Salvages	Rockport	1	4/14/26	6.4	36	1.12	0.25	2.58
Halfway Rock	Marblehead	1	4/14/26	6.8	37	0.48	0.24	0.41
Outside Gloucester Harbor	Gloucester	1	4/14/26	5.9	37	2.65	0.56	2.08

Table 1: Results of water samples taken in winter of 2026 to assess areas without existing data on DIN and salinity during winter. Sites shaded in green showed consistent DIN and salinity values that seem positive for sugar kelp culture. Sites shaded yellow also showed some promising data but was either inconsistent or based on a single sample.

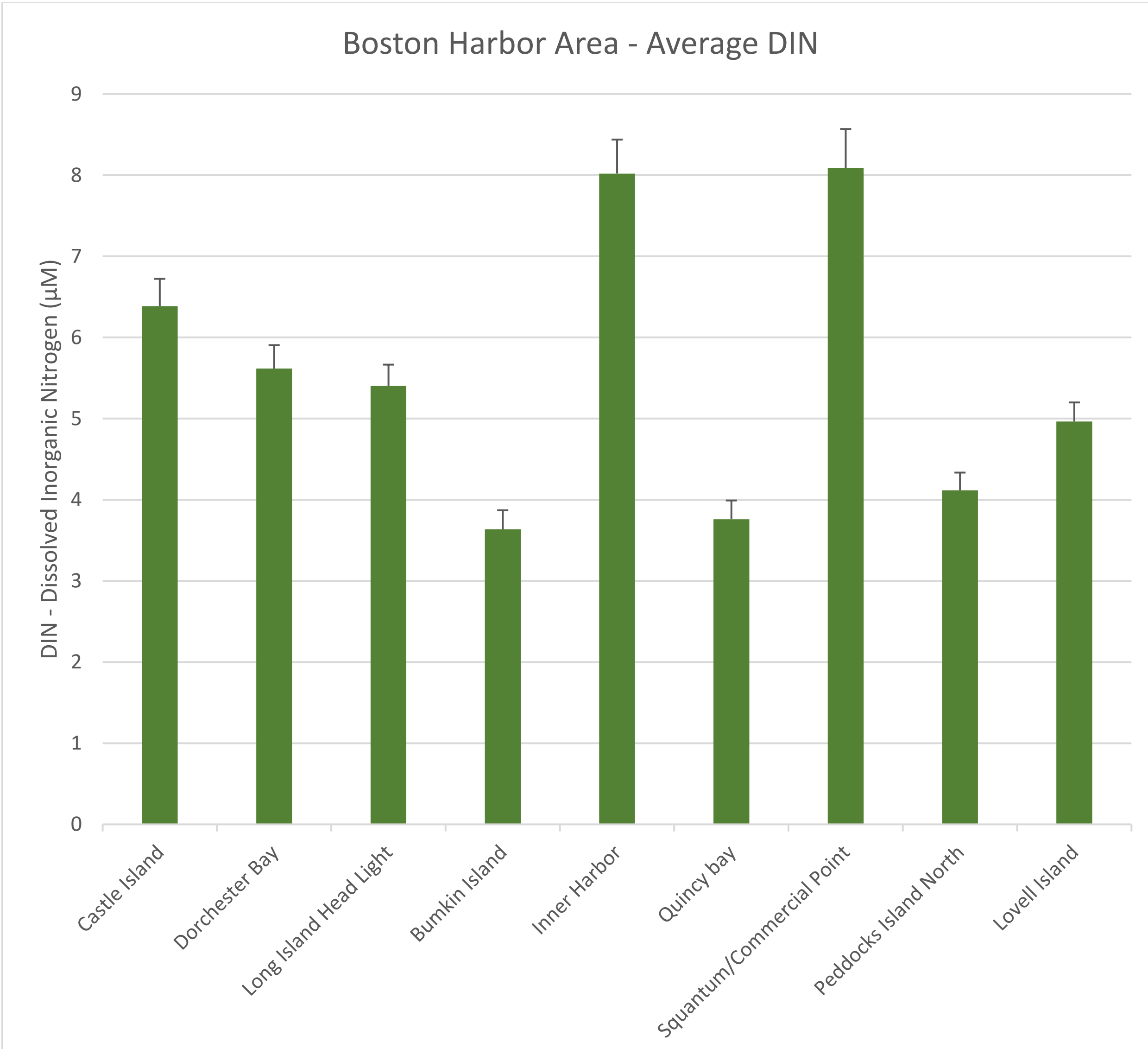

Figure 3: Average dissolved inorganic nitrogen across different Boston Harbor sampling sites. MWRA sample data using October through April 2020-2024.

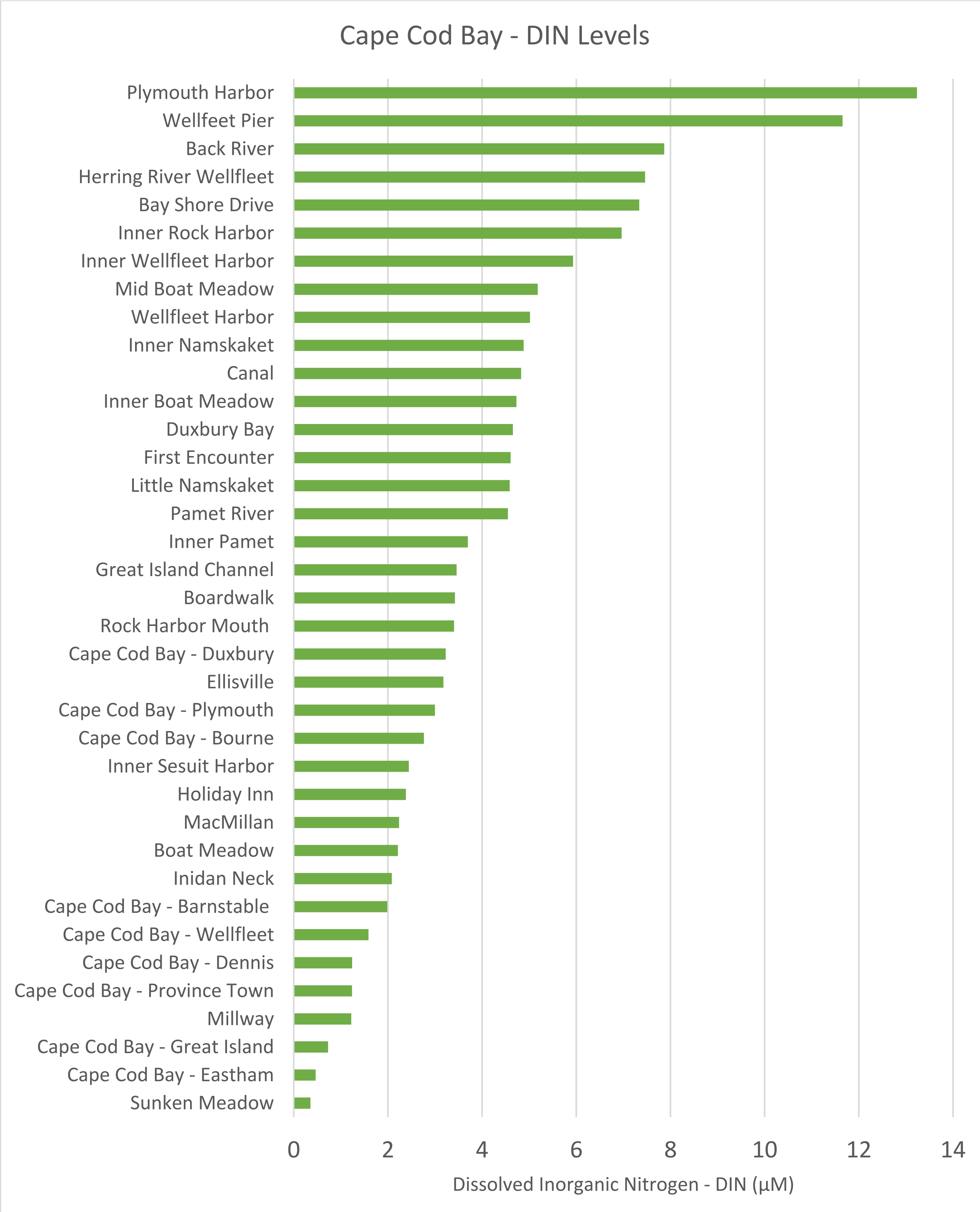

Figure 4: Average DIN of Cape Cod Bay sites. Data Collected by the Center for Costal Studies October through May 2020-2024.

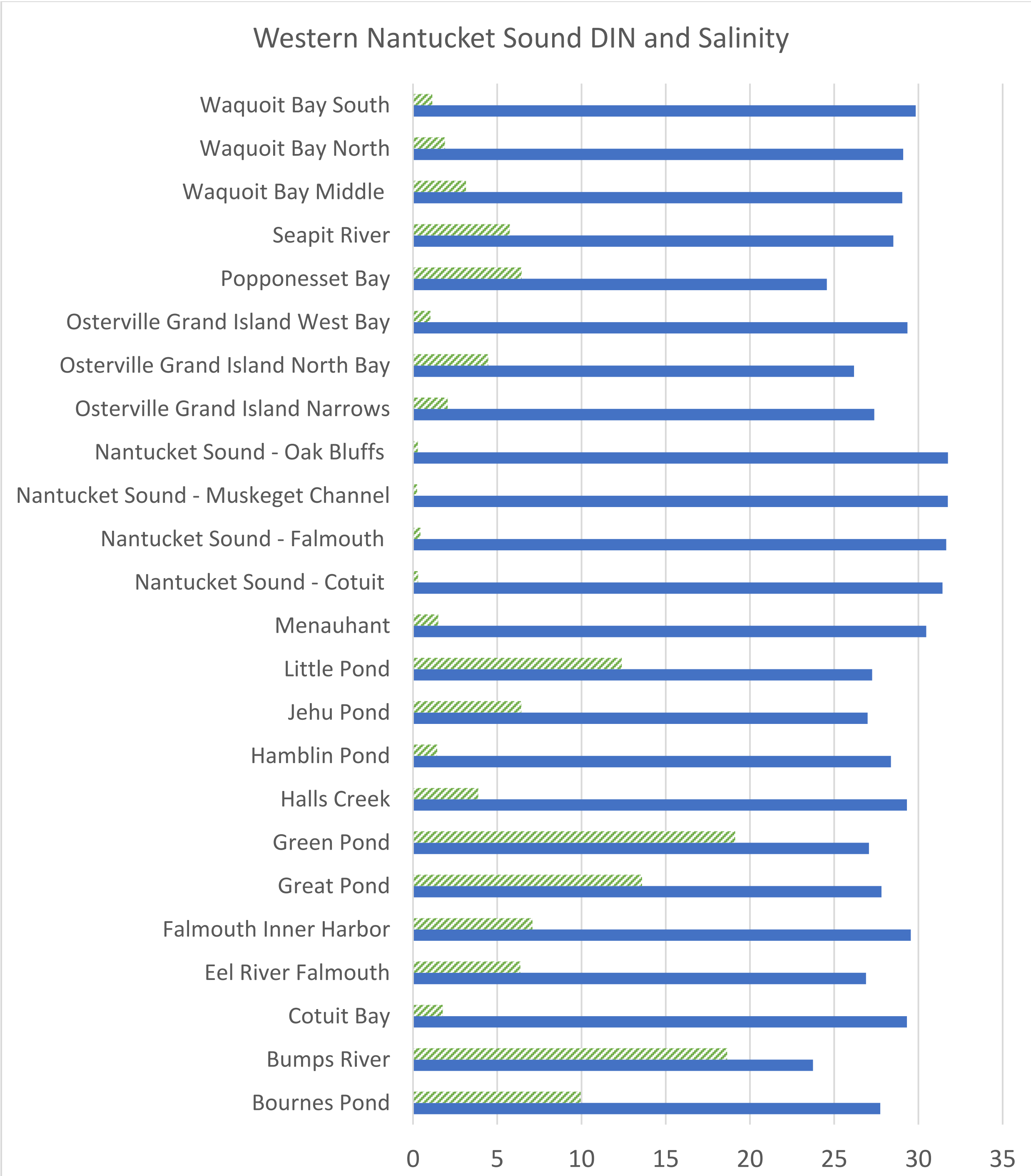

Figure 5: Average Dissolved Inorganic Nitrogen in µM (Green diagonal lined bars) and salinity in ppt (blue bars) of Nantucket Sound sites West of Hyannis Port. Data Collected by the Center for Costal Studies October through May 2020-2024.

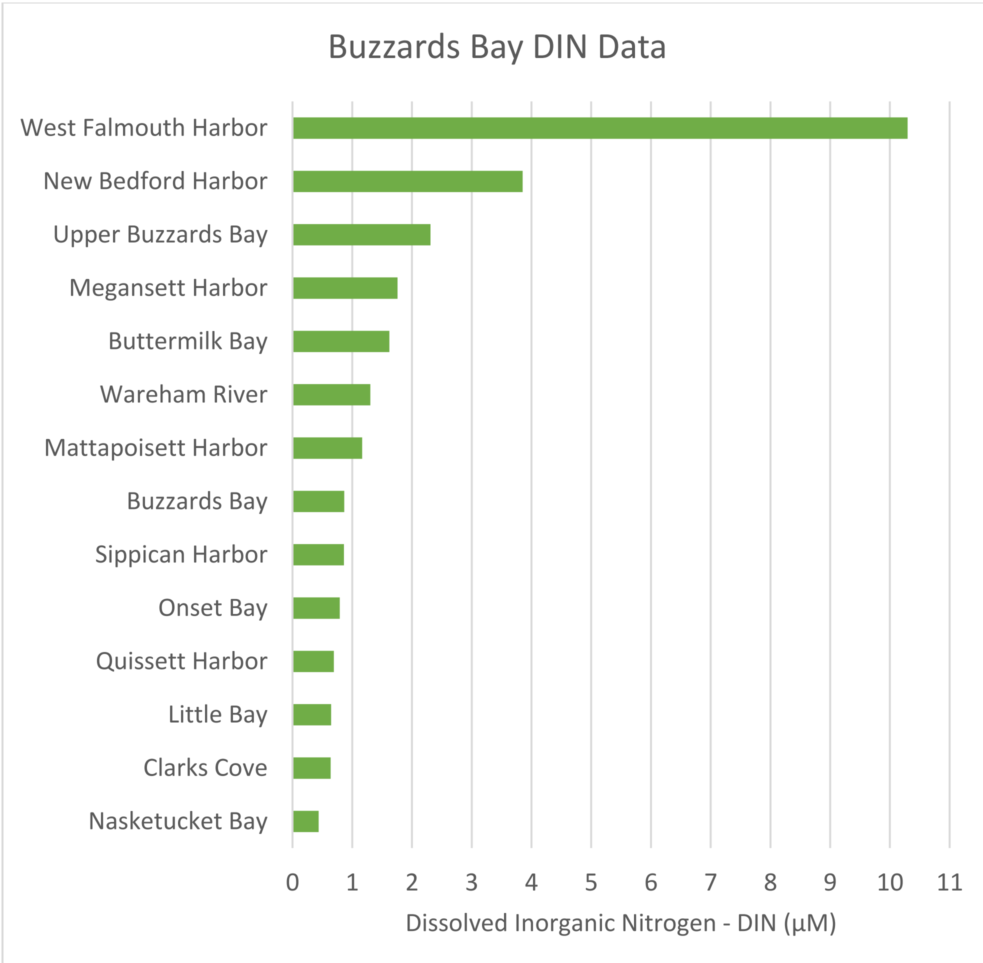

Figure 6: Average DIN of Buzzards Bay sites. Data Collected by the Buzzards Bay Coalition October through May 2016-2017. See Table 1 for additional data from Buzzards Bay.

Market pathway	Volume requirement	Pricing / value signal	Secondary processing requirements	Current fit for Massachusetts
Fresh/frozen food	Low to moderate	Potentially higher value than bulk markets; demand is small and inconsistent	Washing, chilling, blanching, freezing, food safety controls	Limited niche; not scalable without committed buyers and cold-chain processing
Dried food ingredients	Low to moderate	Potentially higher value if branded or specialty; no standardized farmgate pricing	Drying, milling, packaging, contaminant testing	Possible only with shared drying/milling capacity and buyer specifications
Boutique products	Very low	High retail value possible, but highly variable and brand-dependent	Drying, packaging, product development, labeling, direct sales	Possible supplemental market; too small for industry-scale growth
Biostimulants / agricultural inputs	Moderate to high	Processed extracts may have value; raw kelp pricing unclear and price-sensitive	Stabilization, drying, milling, fermentation, ensiling, extraction, QA/QC	Potential downstream market; not viable without processing, aggregation, and validated buyer specifications
Fertilizer / soil amendments	Moderate	Competes with lower-cost wild-harvested and imported	Drying, milling, blending, labeling, possible	Weak fit as bulk fertilizer; possible only as

Market pathway	Volume requirement	Pricing / value signal	Secondary processing requirements	Current fit for Massachusetts
		seaweed products	organic/OMRI compliance	differentiated specialty product
Animal feed additives	Moderate	More plausible as additive than bulk feed; bulk feed is price-sensitive	Drying, milling, contaminant testing, feed compliance	Limited; better treated as research or ingredient partnership opportunity
Pet food	Moderate to high if scaled	Potentially higher value than livestock feed; large buyers need consistent supply	Drying, powdering, contaminant testing, consistent year-round supply	Unlikely near term; Massachusetts cannot currently meet large-volume requirements
Cosmetics / personal care	Low to moderate	Potentially higher value, but raw kelp pricing is not transparent	Drying, extraction, milling, formulation, contaminant testing, traceability	Possible niche opportunity if tied to local sourcing and strict QA/QC
Biotechnology / nutraceuticals	Low biomass volume, high technical requirements	High downstream value possible; value captured in extraction, IP, and formulation	Extraction, purification, compound characterization, regulatory review	R&D partnership opportunity; not a reliable farmgate market
Biomaterials	Moderate to high	Potential, but price-sensitive and volume-dependent	Stabilization, fractionation, cellulose/alginate processing, performance testing	Not near term without regional processing and contracted buyers

Market pathway	Volume requirement	Pricing / value signal	Secondary processing requirements	Current fit for Massachusetts
Bioplastics	High	Premium product in low-price packaging market; requires very large wet biomass volumes	Biorefinery, pellets, formulation, performance testing	Not realistic near term for Massachusetts growers
Biofuel	Very high	Low-value commodity market	Massive biomass supply, conversion facility, logistics infrastructure	Not realistic for Massachusetts
Blue carbon / carbon credits	Not a product market	Credit value and permanence uncertain; claims heavily contested	Monitoring, reporting, verification, legal frameworks, permanence assessment	Not a reliable revenue basis; should not justify public investment
Ecotourism / education	Low biomass volume	Experience-based revenue; site-specific	Boat access, interpretation, insurance, public access, safety	Possible supplemental activity; not a biomass market

Table 2**:** summarizes the relative fit of major market pathways for Massachusetts-grown sugar kelp. The ratings reflect current evidence on production volumes, price sensitivity, secondary processing needs, permitting risk, and likely accessibility to Massachusetts producers.

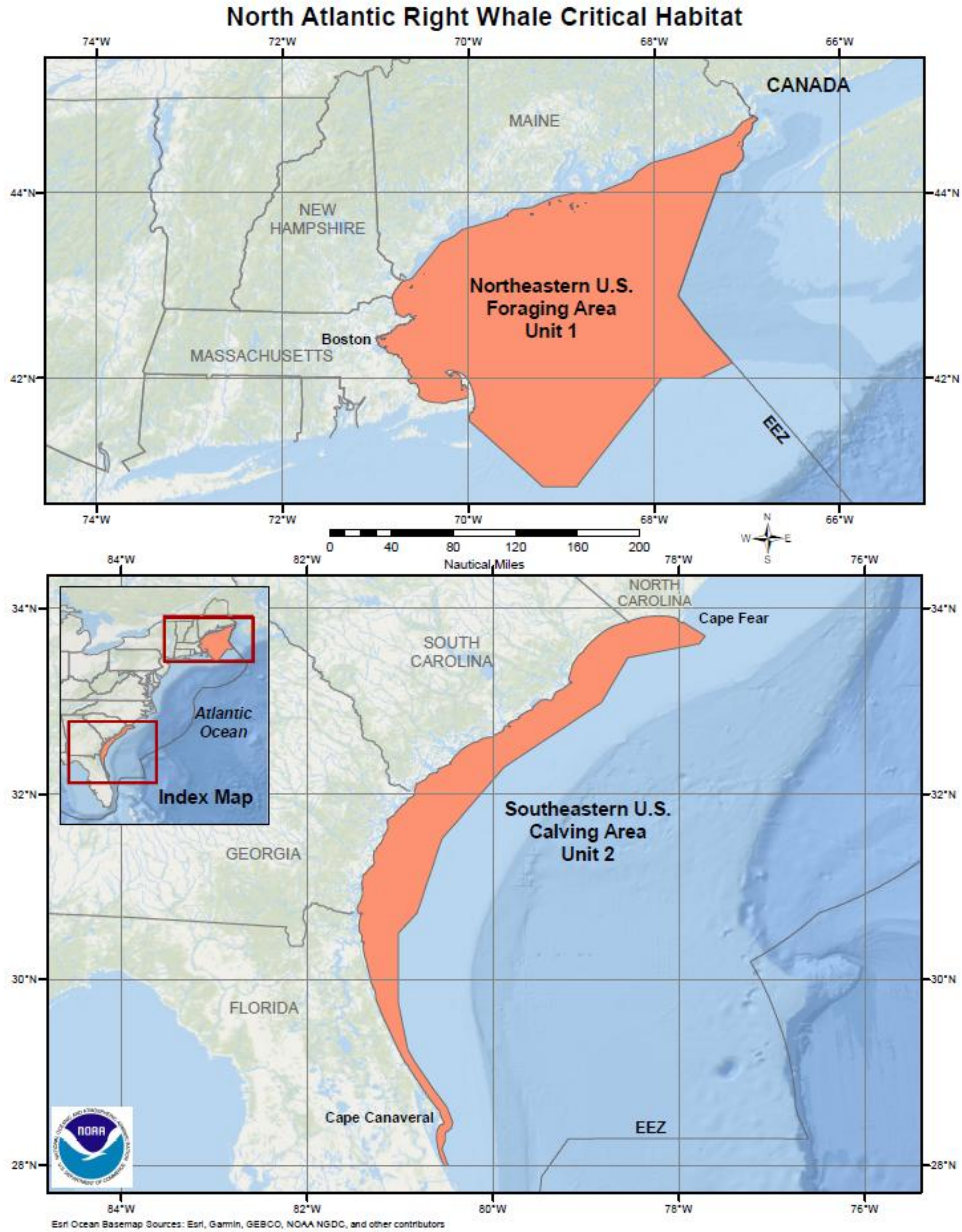

Figure 7: North Atlantic Right Whale Critical Habitat, source NOAA.