Gulf of Maine Research Institute
Science. Education. Community.

Gulf of Maine Responsibly Harvested Verification Report
Kelp (multiple species)
(Alaria esculenta; Saccharina angustissima; Saccharina latissimia)

Criterion 1: Aquaculture operations are regulated by competent authorities that have established and acceptable environmental monitoring regulations in place.

Kelp aquaculture in Maine is managed by the Maine Department of Marine Resources (DMR) and requires a permit from the United States Army Corps of Engineers (ACOE). DMR and ACOE oversight incorporates environmental monitoring regulations that include, but are not limited to, interference with natural and supporting ecosystem processes, flora and fauna, and water quality.

Criterion 2: Regulatory oversight ensures that aquaculture operations have limited and reversible impacts on the surrounding habitat, species, and ecosystem structure and function.

State and federal rules and regulations limit the impacts kelp aquaculture may have on the surrounding environment through DMR lease and licensing requirements, ACOE permitting, and established monitoring and enforcement.

Criterion 3: Sufficient data exists to demonstrate that aquaculture operations have limited and reversible environmental impacts.

Kelp aquaculture has been studied for decades and there are several hundred peer-reviewed articles. Research shows that kelp aquaculture, especially at the scale currently conducted in the Gulf of Maine, has limited and reversible environmental impacts.

Criterion 4: Aquaculture regulations include appropriate compliance and enforcement standards.

Kelp aquaculture management by DMR includes compliance and enforcement standards. DMR conducts annual inspections of all kelp farms to ensure compliance with existing rules and regulations.

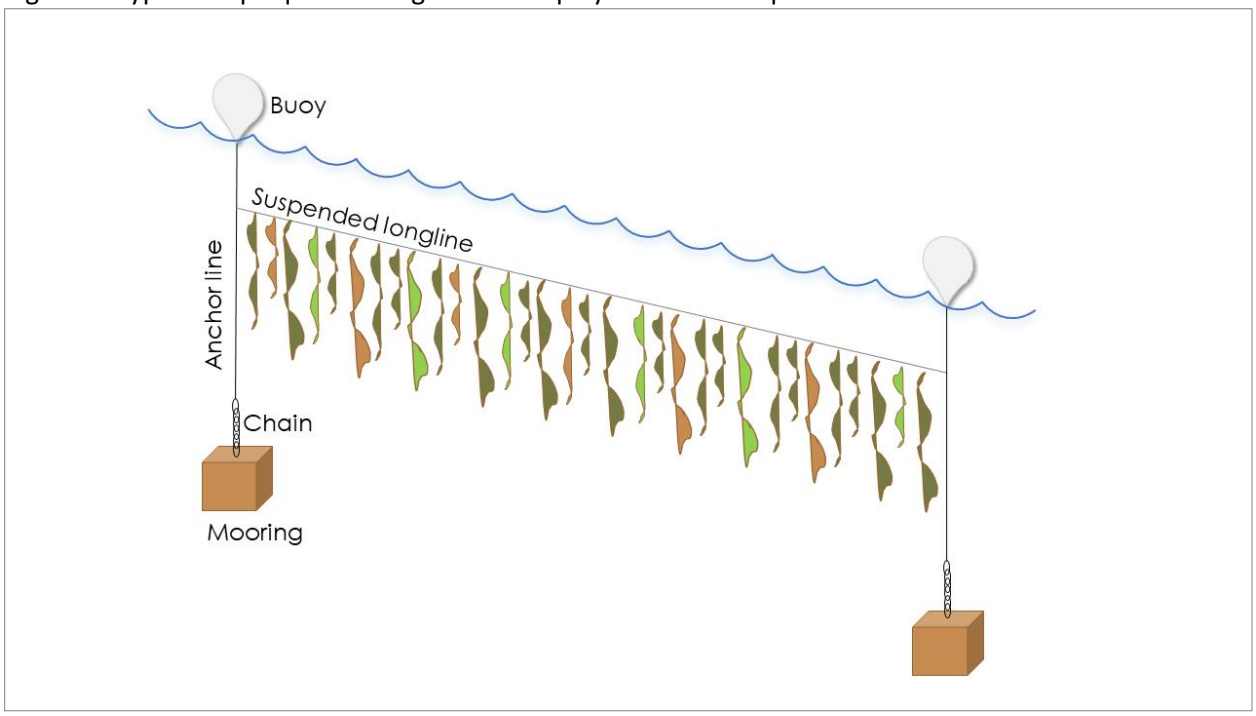
Kelp aquaculture in Maine:

I. Background and typical operations

Marine algae or seaweed has been harvested by humans around the globe for centuries. In the northeast United States, Maine is a leader in seaweed landings. Historically, most seaweed landings have been made through wild harvest. In the past decade, seaweed aquaculture, notably of kelps (order: Laminariales), has increased in the Gulf of Maine. Maine's first seaweed aquaculture operation was established in 2010 in Casco Bay and today there are 94 farms up and down the coast approved for seaweed cultivation (Maine Department of Marine Resources (DMR), 2020). In 2019, the Maine Department of Marine Resources (DMR) reported that 280,612 pounds of marine algae were harvested from aquaculture farms. This is up from 14,582 pounds harvested in 2015. Kelp, specifically sugar kelp (*Saccharina latissimia*), winged kelp (*Alaria esculenta*), and skinny kelp (*Saccharina angustissima)* are the dominant seaweeds that are cultivated in Maine waters (Grebe et al. 2019; Augyte et al. 2018; Augyte et al. 2017).

Typical farm design for kelp aquaculture in Maine consists of an arrangement of seeded horizontal longlines suspended roughly 7' below the surface between two anchor lines (Figure 1) (Grebe et al. 2019; Flavin et al., 2013). The gear required with this design usually includes moorings, buoys, line, chain, and weights. Kelp seed are juvenile marine algae that are cultivated in onshore facilities (nurseries) for use in open ocean farms. Nursey cultivation of kelp seed is reliant on the harvest of sorus tissue (reproductive tissue) from wild kelp (Flavin et al., 2013). In Maine, kelp farms are permitted to be sized up to a maximum of 100 acres. Currently, there are approximately 167 leased and licensed acres approved for seaweed cultivation in the state and an additional 130 acres pending a lease decision (DMR, 2020).

Figure 1. Typical kelp aquaculture gear and display for Maine kelp farms



Regulations for Maine's aquaculture industries have been in place since the early 1970s. DMR leases or licenses all aquaculture operations in the state, including kelp, according to state and federal laws. DMR is also responsible for monitoring aquaculture activities, as well as addressing any compliance issues that arise. Currently, all kelp farm sites are leased or licensed within state waters (within three miles from shore) and, thus, are regulated by the state. At the time of this report, there are no aquaculture sites in federal waters in the Gulf of Maine.

Anyone wishing to establish an aquaculture farm must apply to and be approved by DMR. There are three farm classifications that are available to kelp aquaculturists: standard aquaculture lease, experimental aquaculture lease, and limited-purpose aquaculture license (LPA). Differences between the three options include farm size limitations, duration of lease or license, and renewal terms. A summary of the distinctions between the three classifications is outlined in Table 1.

Table 1. Maine's aquaculture lease and license system (DMR, 2017)

	Standard Lease	**Experimental Lease**	**LPA License**
Size	Up to 100 acres	Up to 4 acres	Up to 400 square feet
Duration	Up to 20 years	Up to 3 years	Up to 1 year
Siting	Commissioner considers other existing aquaculture uses in decision	Commissioner considers other existing aquaculture uses in decision	No more than 3 LPAs allowed in a 1,000-foot radius
Renewal	Renewable and transferable	Renewal only available for scientific research	To renew, applicant must complete educational requirements
DMR site visit	Site visit with dive	Site visit, typically with no dive	No site visit

The process for applying for a standard lease includes a pre-application meeting with DMR, municipal officials, and the harbormaster. Additionally, there must be a public scoping session, public hearing, and defined public comment periods consistent with Maine's Administrative Procedures Act. Experimental lease applicants are not required to hold a pre-application meeting but must convene a public hearing if five or more people request it. Experimental lease holders are also required to submit a yearly report to DMR regarding the results of their scientific or commercial research, as well as plans for the upcoming year. LPA license applicants are not required to hold a pre-application meeting or a public meeting, though the harbormaster (or municipal official in towns without a harbormaster) must confirm that the LPA license site will not unnecessarily conflict with existing uses. Specific lease and license application requirements are detailed in Table 2. Aquaculture installations (for all lease and license sites) must also be permitted by the United States Army Corps of Engineers (ACOE). The ACOE consults with federal agencies to ensure compliance with relevant laws and acts. All kelp aquaculture options consider

environmental impacts, proximity to threatened and endangered species, and require review by and approval from state and federal agencies.

Table 2. DMR lease and license application process (DMR, 2019b; DMR 2017)

	Standard Lease	**Experimental Lease**	**LPA License**
Pre-application meeting	✓		
Draft application	✓		
Draft application review	✓		
Scoping session	✓		
Application submission and review	✓	✓	✓
Site visit and report	✓	✓	
Public hearing	✓	30-day comment period; public hearing if there are five or more written requests	No, but harbormaster or municipal official signature required
Draft decision/DMR review	✓	✓	✓
10-day review of proposed decision	✓	✓	No, but town and nearby landowners may comment each year
Final decision	✓	✓	✓
Notice of decision and appeal period	✓	✓	
Concurrent Army Corps of Engineers permit	✓	✓	✓

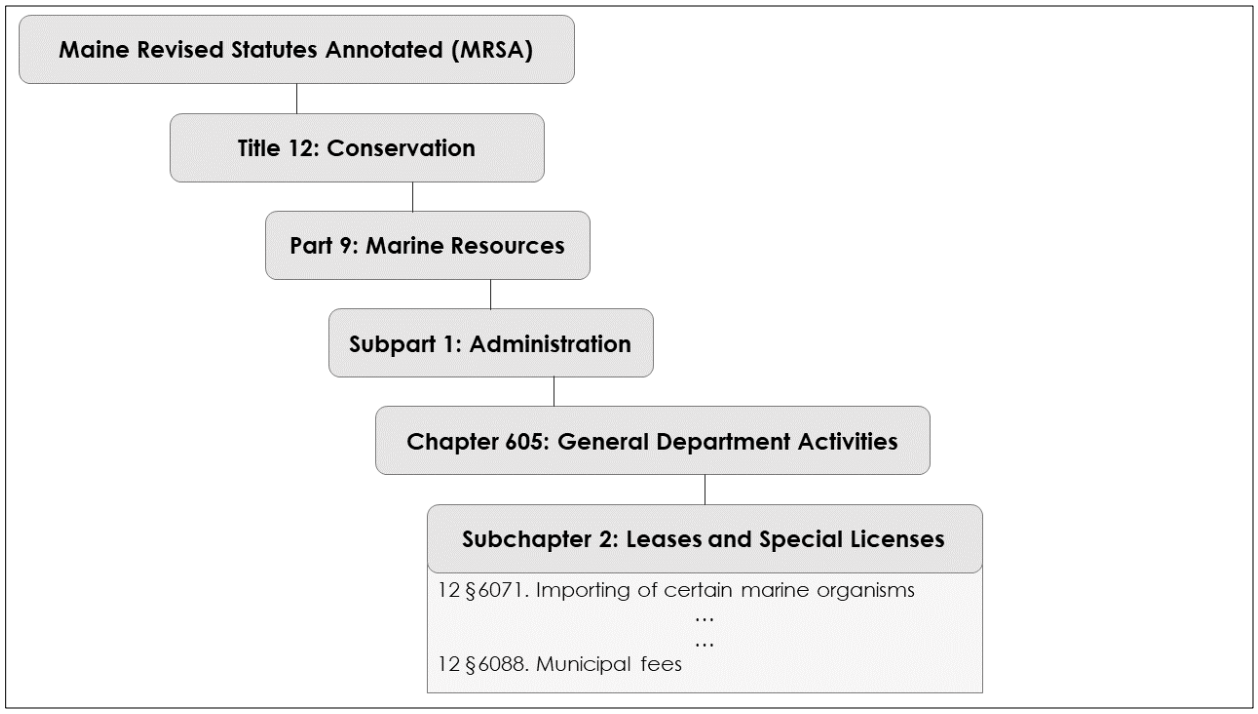
II. Assessment against criteria

Criterion 1: Aquaculture operations are regulated by competent authorities that have established and acceptable environmental monitoring regulations in place.

Maine's aquaculture management system

Aquaculture has been regulated in the State of Maine since the early 1970s. In 1973, Maine's legislature gave the Department of Marine Resources (DMR) the authority to lease state-owned waters for the practice of aquaculture in several state laws: Maine Revised Statutes Annotated, Title 12: Conservation, Chapter 605: General Department Activities, Subchapter 2: Leases and Special Licenses, 12 §6071-12 §6810-B (12 M.R.S.A. §6071-§6088). See Figure 2 for the structure of state regulations around aquaculture. Ten years later, DMR developed the regulations to govern the implementation of these laws. Chapter 2 of DMR's Procedural Rules relate specifically to how the Department will carry out the legislation set forth in 12 M.R.S.A. §6071-§6088. More specifically, Chapter 2 covers the requirements of aquaculture leases and licenses and procedures for all cultured species. Table 3 outlines DMR's decision criteria for aquaculture leases and licenses.

Figure 2. Structure of Maine laws related to aquaculture



12 M.R.S.A. §6071-§6810-B and Chapter 2 of DMR's Procedural Rules encompass the breadth of aquaculture operations in the state, from seaweeds to shellfish to salmon. This report will draw upon only those laws and regulations that relate specifically to the culture of kelp. Further, as this report assesses whether the regulatory body has established and acceptable environmental monitoring regulations in place, only the laws and regulations with environmental considerations will be reviewed.

Table 3. Decision criteria for aquaculture leases and license (DMR, nd; DMR 2019a)

	Standard Lease	Experimental Lease	LPA License
Riparian landowner ingress and egress	✓	✓	✓
Navigation	✓	✓	✓
Fishing and other uses	✓	✓	✓
Other aquaculture uses	✓	✓	✓
Existing support system (ecologically significant flora and fauna; habitat; changes in sedimentation, etc.)	✓	✓	✓
Interference with public facilities (public beaches, parks, conserved lands, etc.)	✓		
Source of cultured species (considerations for biosecurity and sanitation)	✓	✓	✓
Lighting, noise, and visual impacts	✓		

Chapter 2 stipulates the establishment of an environmental baseline for standard and experimental lease sites, as summarized by the lease applicant. The environmental baseline records characteristics such as bottom features, flora and fauna, tide levels, and current speed and direction. For standard and experimental lease applications, DMR will conduct an onsite inspection of the proposed aquaculture site. The site review will cover many of the same environmental conditions described in the environmental baseline: bottom composition, depth and bottom features, flora and fauna, presence of commercial and recreational species, commercial fishing activities, distance to shore, and navigation channels and markers. DMR accesses the proposed lease site via boat and conducts dives or remote video surveillance. The site review and dives and/or video substantiate the environmental baseline conditions described by the applicant. Dives are typically not conducted for experimental leases. DMR site reviews are not required for LPA licenses, though license applicants must include information on bottom characteristics and proximity to eelgrass (*Zostera marina*) beds.

As described in 12 §6072(6)C, DMR is required to notify the following state agencies of all aquaculture lease applications: Department of Environmental Protection (DEP); Department of Agriculture, Conservation, and Forestry (DACF); and Department of Inland Fisheries and Wildlife (IF&W). Chapter 2 adds that DMR may also notify any other state agency as necessary. In the case of kelp aquaculture, the DEP is not notified, as they are only involved if the aquaculture lease application includes discharge. Growing kelp is non-discharge aquaculture as no external materials are added to or released from the

system. In their review, the DACF considers interference with and proximity to public facilities and, therefore, their input is not related to the environmental focus of this assessment. For standard leases and experimental leases, IF&W provides comment on the "existing system support." That is, how the lease site will affect significant wildlife and marine habitat and the related flora and fauna. Typically, this translates to an investigation into the proximity of proposed lease sites to essential habitat for endangered species (such as piping plover and least tern), presence of eelgrass beds, and bald and golden eagle nests, all of which are digitally mapped on the Maine Office of GIS's online database. IF&W will also consider the displacement of marine vegetation, how site design and aquaculture operations will impact current flow, sedimentation impacts, and finfish migration. While IF&W will not review LPA license applications, LPAs cannot be sited in endangered species habitat, pursuant to 12 M.R.S.A. §12803, §12804, and §12806 (related to Maine's endangered species management and research) and IF&W's rules for endangered species (09-137 CMR Chapter 8).

In addition, and as specified in 12 M.R.S.A. §6072(7-A), DMR will consider other aquaculture uses in the area of a proposed site, specifically the intensity and frequency of proximal aquaculture operations for standard and experimental leases. For LPA licenses, there is a limit of no more than three license sites within a 1,000-foot radius.

For all aquaculture leases and licenses, the DMR will review the source of the cultured organism, i.e. the seed source. This consideration is taken to address concerns with the introduction of non-native species and/or disease or pathogens. This is further addressed in 12 M.R.S.A. §6071 (Importing of certain marine organisms). Marine algae seed must be derived from stock originating in Maine waters and come from a DMR approved nursery.

At the federal level, the United States Army Corps of Engineers (ACOE) is involved in the regulation of kelp aquaculture in Maine under section 10 of the River and Harbors Act of 1899. Under this Act, any installations that occur between the high-water mark and 200 miles offshore must be permitted by ACOE. This includes kelp aquaculture infrastructure (moorings, lines, and buoys). Under the National Environmental Policy Act, ACOE consults with other federal agencies when considering issuing a permit for installing aquaculture infrastructure. Specifically, ACOE will review how an aquaculture installation and its operation will conflict with governance authorized under the Endangered Species Act and the Magnuson-Stevens Fishery Conservation and Management Act's Essential Fish Habitat provisions. Further, ACOE may also consult with the National Oceanic and Atmospheric Administration, Environmental Protection Agency, and the United States Fish and Wildlife Service on any aquaculture installation under a number of federal acts, including, but not limited to the Marine Mammal Protection Act and the Fish and Wildlife Coordination Act. Table 4 outlines the federal acts and statutes that ACOE permitting must comply with. Depending on the specifications and siting outlined in the lease or license application, ACOE may incorporate other federal regulations and/or agencies, such as the National Historic Preservation Act, United States Coast Guard, and Federal Aviation Administration. However, consultation with these organizations is outside the scope of the environmental focus of this report.

Kelp aquaculture operations, specifically, are often eligible for Category 2 under ACOE's Maine General Permit, meaning that written approval from ACOE is required before any construction, i.e. gear deployment or

Table 4. Common regulations* considered by ACOE in aquaculture infrastructure permitting

- Magnuson-Stevens Fishery Conservation and Management Act
- Fish and Wildlife Coordination Act
- Endangered Species Act
- Historic Preservation Act
- Coastal Zone Management Act
- Marine Mammal Protection Act
- Migratory Bird Treaty Act
- Bald and Golden Eagle Act

**This is not a complete list; other laws and acts may be considered on a case by case evaluation.*

site buildout. To avoid duplication of work, the ACOE can use the DMR application for leases or licenses for its review. The standard lease, experimental lease, and LPA license applications were jointly developed by DMR and ACOE to ensure they met the requirements of both agencies. Lease and license applicants are encouraged to concurrently submit applications to both DMR and ACOE.

Maine has a long history of regulating aquaculture activities and reviewing rules and regulations to stay current with existing and upcoming activities. DMR's Chapter 2 was recently reviewed and amended in 2019.

Criterion 2: Regulatory oversight ensures that aquaculture operations have limited and reversible impacts on the surrounding habitat, species, and ecosystem structure and function.

Management and its role in responsible harvest

Studies of kelp aquaculture demonstrate numerous environmental benefits, including the uptake of excess nutrients (Pechsiri et al. 2016; Kim et al. 2015; Holdt and Edwards 2014) and habitat provision (Walls et al. 2016). However, there are also some concerns about the impact of aquaculture on the surrounding environs and ecosystem. These include impacts on the benthic environment, such as shading (Walls et al. 2017) and changes in sedimentation (Campbell, 2017), nutrient competition and depletion (Wood et al. 2017), and biosecurity and alien species (Campbell, 2017).

Current aquaculture rules and regulations in Maine address many of these concerns. For benthic impacts, the DMR site visit and subsequent report aim to determine if the lease site will impact ecologically significant flora and fauna and the associated habitat, including rooted or attached marine vegetation. Federal review, coordinated by ACOE, stipulates that aquaculture installations result in no net loss of eelgrass. DMR reviews the site report and considers the findings in a lease decision. The site visit and report also serve as an established environmental baseline for yearly inspections by DMR staff.

LPA license applicants must describe the bottom characteristics of the proposed site and must verify with their signature that the application does not contain any false information. As LPAs are designed for aquaculturists to test areas for future lease sites and are limited in size, benthic impacts are considered to be limited and quickly reversible.

Kelp farms may dampen current flow, which can result in changes to sedimentation (Campbell, 2017; Grant and Bacher, 2001). DMR considers sedimentation and sediment resuspension in the lease determination. Furthermore, the ACOE permit (required for both aquaculture leases and licenses) will not be issued if a proposed kelp aquaculture operation will impede navigation.

Shading is another possible impact of kelp aquaculture (Hasselstrom et al., 2018; Walls et al. 2017). Large kelp farms may shade out native marine plants such as eelgrass. Lease and LPA sites are required to be located away from established eelgrass beds. Maine's IF&W includes this requirement in its review of lease applications. LPA applications must provide maps demarcating the boundaries of eelgrass and other essential habitats in their application and are not permitted to site within those locations. Further, ACOE permitting of any aquaculture installation requires that there is no net loss of eelgrass from resulting farm installation or operation.

Some have raised concerns regarding competition of kelp aquaculture with wild macroalgae populations for nutrients (Wood et al. 2017) or creating nutrient-poor areas (Park et al., 2018; Shim et al., 2014; Zhang et al. 2004). The number, size, location, and type of proximal aquaculture sites are considered in granting lease applications. LPAs have siting limitations in that there may be no more than three LPAs within a 1,000-foot radius.

With any aquaculture activity, there are concerns about the source of seed and the propensity for the introduction of disease and/or non-native species (Campbell 2017). State rules (12 M.R.S.A. §6071 and 12 M.R.S.A. §6085) strictly regulate the introduction of non-native species, as well as the movement of marine organisms from one area of the coast to another to limit the spread of invasive species and/or disease. Kelp seed must be derived from wild species in state waters and come from a DMR approved nursery.

Aquaculture impacts on ecologically significant habitat and flora and fauna are limited by Maine rules and regulations. DMR ensures that kelp lease and license sites are not permitted near eelgrass beds. Review by Maine's IF&W prohibits aquaculture siting in areas with essential habitat for endangered species or areas known to support endangered species, including nesting areas for piping plover and least tern and bald and golden eagle nests. This state regulation is further bolstered by the necessary permit from the ACOE. When permitting aquaculture operations, the ACOE consults with federal agencies such as US Fish and Wildlife Service and strictly adheres to the Endangered Species Act. Maine DMR also considers the presence of recreational and commercial species in the proximity of any proposed lease site.

Criterion 3: Sufficient data exists to demonstrate that aquaculture operations have limited and reversible environmental impacts.

An overview of kelp aquaculture research

Environmental impacts from kelp aquaculture are largely limited and reversible. This is supported by existing peer-reviewed literature. Some of the environmental concerns around kelp aquaculture include changes to the benthic habitat, shading, nutrient competition with wild populations, and changes in sedimentation patterns. Literature reviews, notably Buschmann et al. 2017, Chopin et al. 2004, and Neori et al. 2004 have demonstrated the extent of the current research on kelp aquaculture.

Kelp cultivation infrastructure and gear has a small footprint compared with almost all other aquaculture practices. The farm set up typically consists of longlines secured between two anchor lines with moorings and buoys (Figure 1) (Flavin et al., 2013). In Maine, the farm structure is set up in the fall, prior to the growing season, and removed post-harvest in the spring. Therefore, any stress on the surrounding ecosystem from the placement of moorings or other gear is limited to only a portion of the year. Similarly, any environmental benefits provided by the farm equipment, such as moorings providing habitat for benthic species (Hasselstrom et al., 2018; Walls et al., 2017) or kelp growth attracting other species (Smale et al., 2013; Christie et al., 2009) will be limited to the kelp growing season. However, seasonality of positive or negative effects requires further research (Hasselstrom et al., 2018; Wood et al. 2017). Large kelp farms may impact the surrounding environment by altering benthic communities or changing primary production (Stévant et al., 2017). However, some studies have shown there has been little impact on benthic organisms and community structure or eelgrass beds below kelp operations (Walls et al. 2017).

Kelp aquaculture has been touted as a tool for nutrient extraction in eutrophic waters (Pechsiri et al., 2016; Kim et al. 2015; Rose et al. 2015; Holdt and Edwards, 2014). Growing kelp has been shown to remove excess nitrogen and phosphorus from the surrounding waters (Pechsiri et al. 2016; Kim et al. 2015; Holdt and Edwards 2014). Furthermore, kelp cultivation can also act as a short-term carbon sink (Duarte et al., 2017; Chung et al., 2011; Nellemann et al., 2009) and can reduce the impacts of ocean acidification within a limited distance from the cultivation site (Duarte et al., 2017; Mongin et al. 2016). In Asia, intense and concentrated kelp operations have limited the carrying capacity of some ecosystems by restricting nutrients in the surrounding waters (Park et al., 2018; Shim et al., 2014; Zhang et al., 2004). However, in the coastal Gulf of Maine and other nutrient-rich waters, the bioextractive properties of kelp farming may have a positive environmental impact by removing excess nutrients and helping abate eutrophication in nearshore environments (Grebe et al., 2019; Fei 2004).

Changes to sediment retention and resuspension can be impacted by kelp aquaculture operations, though effects can vary and are site-specific (Hasselstrom et al., 2018). Some research has shown that kelp farms can lessen wave energy and reduce shore side erosion (Mork 1996). Any impacts are dependent upon farm size and specific location (Campbell et al., 2017).

Wild kelp beds are known to be areas of high biodiversity and research shows areas of kelp cultivation may have similar benefits (Hasselstrom et al., 2018). Kelp farm moorings can serve as habitats for benthic species (Hasselstrom et al., 2018), and the kelp holdfasts have been shown to have high biodiversity (Walls et al., 2016) and to create habitat for other species (Wood et al., 2017).

Currently, kelp aquaculture is reliant on wild kelp sorus tissue for seed cultivation (Grebe et al., 2019; Redmond et al. 2014; Flavin et al. 2013). Attention to wild kelp populations will remain important as wild stocks are a necessary source for growing out kelp seed in the nursery stage and maintaining genetic diversity.

Criterion 4: Aquaculture regulations include appropriate compliance and enforcement standards.

Compliance and enforcement standards for Maine kelp farms

Staff from DMR's Division of Aquaculture, Bureau of Public Health, and Marine Patrol conduct annual inspections for all aquaculture leases and LPAs to verify that the sites comply with the existing rules and regulations around aquaculture. Under the US Food and Drug Administration (FDA), the National Shellfish Model Ordinance requires an annual inspection for shellfish aquaculture. Maine DMR has established the state policy to go beyond the FDA's requirement and to include the inspection of not just shellfish farms, but all farms, including seaweed. Inspections involve a surface assessment to verify site location, gear, cultured species, and farm condition. DMR responds to and follows up with any complaint issued against an aquaculture lease or LPA license site.

Future considerations

Kelp aquaculture in Maine is still a relatively new and growing industry. As kelp aquaculture scales up, state rules and regulations must evolve and adapt to ensure responsible harvest. It will remain important that DMR and other regulatory bodies advance rules and regulations alongside an expanding industry. As such, this assessment report will need to be updated and revaluated as the industry grows and changes. The following factors are noted as potential trigger points for a revaluation of this report:

- **Continued reliance on wild sorus tissue for nursery grow out:** Kelp aquaculture is currently reliant on wild sorus tissue for seed cultivation (Grebe et al., 2019, Redmond et al. 2014, Flavin et al. 2013.) Given the limited regulations around the harvest of wild reproductive kelp seedstock, consideration around how to maintain healthy wild populations alongside a burgeoning kelp aquaculture industry may need to be addressed. Pressure on kelp donor populations, notably those that have very restrictive distributions, such as low intertidal kelp species *Saccharina angustissima* will need to be evaluated to avoid the overharvesting of wild populations.
- **Significant scaling up of industry:** Significant scaling up of the kelp industry in Maine will magnify concerns around kelp aquaculture. As the industry grows, consideration regarding how increased cultivation could amplify impacts may need to be addressed.

WORKS CITED

Buschmann,A. H., Camus, C., Infante, J., Neori, A., Israel, A., Hernández-González, M.C., Pereda, V.S., Gomez-Pinchetti, J.L., Golberg, A., Tadmor-Shalev, N., and Critchley, A.T. 2017. Seaweed production: overview of the global state of exploitation, farming and emerging research activity, European Journal of Phycology, 52:4, 391-406, DOI: 10.1080/09670262.2017.1365175

Campbell, I., Macleod, A., Sahlmann, C., Neves, L., Funerud, J., Overland, M., Hughes, A.D., Stanley, M., 2019. The environmental risks associated with the development of seaweed farming in Europe – prioritizing key knowledge gaps. Frontiers in Marine Science. 22 March 2019 | https://doi.org/10.3389/fmars.2019.00107

Chopin, T., Yarish, C., and Sharp, G. 2007.Beyond the monospecific approach to animal aquaculture – the light of integrated aquaculture. *In: Ecological and Genetic Implications of Aquaculture Activities.* T. Bert (Ed.). Springer, Dordrecht, 447-458.

Christie, H., Norderhaug, K.M., Fredriksen, S., 2009. Macrophytes as habitat for fauna. Marine Ecology Progress Series 396, 221–233.

Chung, I.K., Beardall, J., Mehta, S., Sahoo, D., Stojkovic, S. 2011. Using marine macroalgae for carbon sequestration: a critical appraisal. Journal of Applied Phycology. 23, 877-886.

Cottier-Cook, E.J., Nagabhatla, N., Badis, Y., Campbell, M., Chopin, T, Dai, W, Fang, J., He, P, Hewitt, C, Kim, G. H., Huo, Y, Jiang, Z, Kema, G, Li, X, Liu, F, Liu, H, Liu, Y, Lu, Q, Luo, Q, Mao, Y, Msuya, F. E, Rebours, C, Shen, H., Stentiford, G. D., Yarish, C, Wu, H, Yang, X, Zhang, J, Zhou, Y, Gachon, C. M. M. (2016). Safeguarding the future of the global seaweed aquaculture industry. United Nations University (INWEH) and Scottish Association for Marine Science Policy Brief. ISBN 978-92-808-6080-1. 12pp.

Duarte, C.M., Wu, J., Xiao, X., Bruhn, A., Krause-Jensen, D., 2017. Can seaweed farming play a role in climate change mitigation and adaptation? Frontiers of Marine Science. 12 April 2017. https://doi.org/10.3389/fmars.2017.00100

Grant, J., Bacher, C. 2001.A numerical model of flow modification induced by suspended aquaculture in a Chinese bay. Canadian Journal of Fisheries and Aquatic Sciences. 58, 1003-1011.

Grebe, G., Byron, C. St. Gelais, A., Kotowicz, D.M., Olson, T.K. 2019. An ecosystem approach to kelp aquaculture in the Americas and Europe. Aquaculture Reports. 15 (100215).

Fei, X. 2004. Solving the coastal eutrophication problem by large scale seaweed cultivation. Hydrobiologia. 512, 145-151.

Flavin, K., Flavin, N. & Flahive, B. 2013. Kelp Farming Manual: A Guide to the Processes, Techniques, and Equipment for Farming Kelp in New England Waters. Ocean Approved. Available from:https://static1.squarespace.com/static/52f23e95e4b0a96c7b53ad7c/t/52f78b0de4b0374e6a0a4da8/1391954701750/OceanApproved_KelpManualLowRez.pdf

Hasselstrom, L., Visch, W., Grondahl, F., Nylund, G., Pavia, H., 2018. The impact of seaweed cultivation on ecosystem services – a case study from the west coast of Sweden. Marine Pollution Bulletin. 133, 53-64.

He, P., Xu, S., Zhang,H., Wen, S., Dai, Y., Lin, S., and Yarish, C. 2008. Bioremediation efficiency in removal of dissolved nutrients by the red seaweed *Porphyra yezoensis* cultivated in open sea. Journal of Water Research 42, 1281-1289.

Holdt, S.L., and Edwards, M.D. 2014. Cost-effective IMTA: a comparison of the production efficiencies of mussels and seaweed. Journal of Applied Phycology. 26, 933-945.

Kim, J.K., Kraemer, G.P., Yarish, C., 2015. Use of sugar kelp aquaculture in Long Island sound and the Bronx River estuary for nutrient extraction. Marine Ecology Progress Series. 531, 155-166.

Kim, J.K., Kraemer, G.P., and Yarish, C. 2014. Field scale evaluation of seaweed aquaculture as a nutrient bioextraction strategy in Long Island Sound and the Bronx River Estuary. Aquaculture 433, 148-156.

Nellemann, C., Corcoran, E., Duarte, C.M., Valdes, L. De Young, C., Fonseca, L., Grimsditch, G. 2009. Blue carbon. The role of healthy oceans in binding carbon. A rapid response assessment. In: United Nations Environment Programme, GRID-Arendal. (ISBN: 978-82-7701-060-1).

Neori et al. 2004 → ADD REFERENCE Neori, A., T. Chopin, M. Troell, A.H. Buschmann, G. Kraemer, C. Halling, M. Shpigel and C. Yarish. 2004. Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern aquaculture. Aquaculture. 231: 361-391.

Pechisir, J.S., Thomas, J.-B. E., Risen, E., Riberio, M.S., Malmstrom, M., Nylund, G., Jasson, A., Welander, U., Pavia, H. Grondahl, F., 2016. Energy performance and greenhouse gas emissions of kelp cultivation for biogas and fertilizer recovery in Sweden. Science of the Total Environment. 573, 347-355.

Maine Department of Marine Resources. 2017. Conducting Aquaculture in Maine. Available from: https://www.maine.gov/dmr/aquaculture/documents/CONDUCTINGAQUACULTUREINMAINErev2-22-17.pdf

Maine Department of Marine Resources. 2019a. Department of Marine Resources – Procedural Rules; Chapter 2: Aquaculture Lease Regulations. Available from: https://www.maine.gov/dmr/laws-regulations/regulations/documents/Chapter2-04012019.pdf

Maine Department of Marine Resources. 2019b. MEDMR Standard Lease Application Process; MEDMR Experimental Lease Application Process. Available from: https://www.maine.gov/dmr/aquaculture/documents/StandardLeaseApplicationFlowChart3.1.19.pptx.pdf

Maine Department of Marine Resources. 2020a. Maine DMR Open Data. Available from: https://dmr-maine.opendata.arcgis.com/search?tags=aquaculture

Maine Department of Marine Resources. 2020b. Standard: Non-Discharge Aquaculture Lease Application. Available from: https://www.maine.gov/dmr/aquaculture/forms/documents/standardapplication-nondischarge-03162020.pdf

Maine Department of Marine Resources. 2020c. Experimental Aquaculture Lease Application. Available from: https://www.maine.gov/dmr/aquaculture/forms/documents/experimentalleaseapplication_03162020.pdf

Maine Department of Marine Resources. 2020d. Limited Purpose Aquaculture License (LPA) Application. Available from: https://www.maine.gov/dmr/aquaculture/forms/documents/LPAApplication1.8.2020.pdf

Maine Department of Marine Resources. Nd. Criteria for Issuing Aquaculture Leases. Available from: https://www.maine.gov/dmr/aquaculture/documents/decisioncriteria.pdf

Mongin, M., Baird, M.E., Hadley, S., Lenton, A. 2016. Optimising reef-scale CO2 removal by seaweed to buffer ocean acidification. Environmental Research Letters. 11(3).

Park, M., Shin, S.K., Do, Y.H., Yarish, C., Kim, J.K., 2018. Application of open water integrated multi-trophic aquaculture to intensive monoculture: a review of the current status and challenges in Korea. Aquaculture 497, 174–183.

Rose, J.M., Bricker, S.B., Deonarine, S., Ferreira, J.G., Getchis, T., Grant, J., Kim, J.K., Krumholz, J.S., Kraemer, G.P., Stephenson, K., Wikfors, G.H., and Yarish, C. 2015. Nutrient Bioextraction. In: R. A. Meyers (ed.), Encyclopedia of Sustainability Science and Technology, 6_944-1, 1-33. DOI 10.1007/978-1-4939-2493-6_944-1Shim, J., Hwang, J.R., Lee, S.Y., Kwon, J.N., 2014. Variations in nutrients & CO2 uptake rates of Porphyra yezoensis Ueda and a simple evaluation of in situN & C demand rates at aquaculture farms in South Korea. Korean J. Environ. Biol 32, 297–305. https://doi.org/10.11626/KJEB.2014.32.4.297.

Smale, D.A., Burrows, M.T., Moore, P., O'Connor, N., Hawkins, S.J., 2013. Threats and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective. Ecology and Evolution 3 (11), 4016–4038.

Stévant, P., Rebours, C., Chapman, A., 2017. Seaweed aquaculture in Norway: recent industrial developments and future perspectives. Aquaculture International .2017. http://dx.doi.org/10.1007/s10499-017-0120-7.

Walls, A.M., Kennedy, R., Fitzgerald, R.D., Blight, A.J., Johnson, M.P., Edwards, M.D., 2016. Potential novel habitat created by holdfasts from cultivated Laminaria digitata; assessing the macroinvertebrate assemblages. Aquaculture Environment Interaction. 8, 157–169.

Walls, A.M., Kennedy, R., Edwards, M.D., Johnson, M.P., 2017. Impact of kelp cultivation on the ecological status of benthic habitats and Zostera marina seagrass biomass. Marine Pollution Bulletin. http://dx.doi.org/10.1016/j.marpolbul.2017.07.048.

Wood, D., Capuzzo, E., Kirby, D., Mooney-McAuley, K., Kerrison, P., 2017. UK macroalgae aquaculture: what are the key environmental and licensing considerations? Marine Policy 83, 29–39. https://doi.org/10.1016/j.marpol.2017.05.021.

Zhang, J., Nagahama, T., Ohwaki, H., Ishibashi, Y., Fujita, Y., Yamazaki, S., 2004. Analytical approach to the discoloration of edible laver “Nori” in the Ariake Sea. Analytical sciences 20 (1), 37–43.