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**Impacts of Hurricane Fiona on Atlantic Canada's  
Aquaculture Industry and Recommendations for Future  
Preparedness**

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## Executive Summary

In Atlantic Canada, the aquaculture industry contributes economic and employment opportunities for rural communities. Most aquaculture activities occur near or in coastal waters, which results in increased exposure to extreme environmental events and conditions such as hurricanes, flooding, wind, and waves. Impacts from Hurricane Fiona highlighted the need to assess farming practices and governance, especially for shellfish operations, to ensure the industry is increasing resilience through climate proofing. Growers are encouraged to develop a site-specific disaster preparedness plan (DDP), incorporating best management practices, and design their site infrastructure to decrease impact risks. In the event of incurring damages or losses, growers may have access to financial assistance programs (i.e., federal or provincial). Increased record keeping (i.e., production cycle and general operational costs) could facilitate processing claims by improving efficiencies and verifying claims to ensure equitable reimbursement. Government regulators also have an opportunity to increase industry's resilience through modification of existing policies, legislation, regulatory framework, and reporting standards which would include best management practices and accurate documentation of operations. These standards would, ideally be auditable, promoting incorporation and implementation on a farm-level and the development of insurance and/or Business Risk Management (BRM) programs to support the aquaculture industry under our changing climate.

### 1 Aquaculture Industry Overview

Aquaculture is essential to meet the gap of seafood supply worldwide. The contribution of world aquaculture to global fish production increased from 25.7 % in 2000 to 46.0 % in 2018 (FAO, 2022). In Atlantic Canada, aquaculture contributes significantly to the Gross Domestic Product (GDP) of coastal and rural communities through the production of finfish, shellfish, and marine plants (Figure 1). This industry has grown significantly in the past decade, with the national GDP increasing from \$92 million in 2007 to \$200 million in 2021 (Employment and Social Development Canada, 2022). According to Fisheries and Oceans Canada (2023a), aquaculture represented 20% of Canada's total seafood production and the Atlantic region accounted for 44.6% of the nation's output. Nova Scotia and Prince Edward Island, combined, accounted for almost \$142 million in value for aquaculture production in 2021 (Fisheries and Oceans Canada, 2023a).

	Production Weight <sup>1</sup>	Production Value <sup>2</sup>	GDP <sup>3</sup>	Employment <sup>4</sup>
	191,249	\$1,344,745	\$352.4 M	3825
	11,057	\$82,983	\$34.9 M	440
	24,779	\$58,911	\$32.8 M	280

<sup>1,2</sup> 2021 Production weight and value in tonnes and hundred thousand dollars (Fisheries and Oceans Canada, 2023a)

<sup>3</sup> Gross Domestic Product (GDP) in million chained dollars to the year 2012 (i.e., adjust dollar amounts accounting for inflation to allow for comparison between different years (Statistics Canada, 2023)

<sup>4</sup> 2021 Direct full time employment (FTE) (Government of Canada, 2022a)

**Figure 1.** Economic contributions of aquaculture across Canada and select Atlantic Canadian Provinces

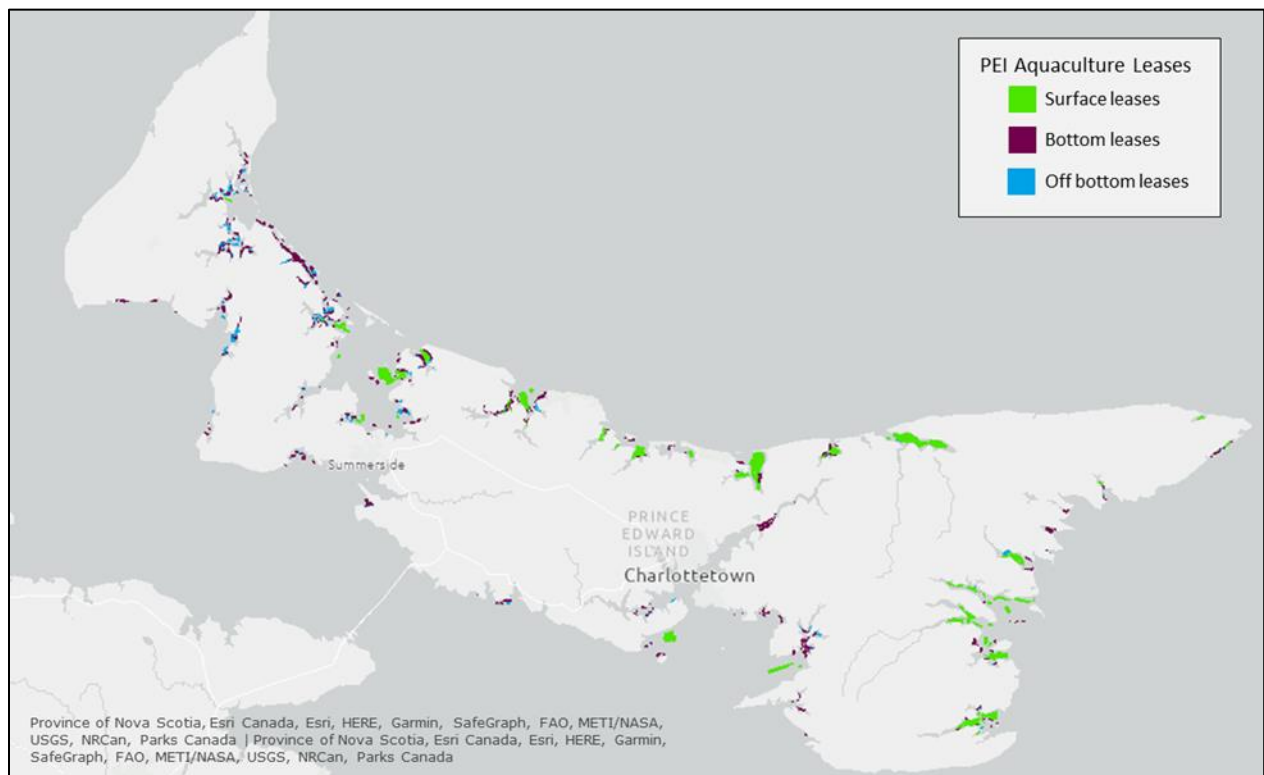
### 1.1 Prince Edward Island

Prince Edward Island's (PEI) aquaculture industry contributes approximately \$59 million to the province's economy annually (Fisheries and Oceans Canada, 2023b). In 2020, the aquaculture sector created \$23 million in wages and provided 630 full time jobs (Department of Fisheries and Communities, 2021). PEI is Canada's largest aquaculture producer by weight (Statistics Canada, 2022a), predominantly culturing mussels and oysters (Fisheries and Oceans Canada, 2021a). Roughly 75.4 % and 34.9 % of Canadian mussel and oyster production originates from PEI, respectively (Fisheries and Oceans Canada, 2023b). This province also has a small hatchery-focused finfish industry for Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus*

*mykiss*) as well as a land-based Atlantic halibut (*Hippoglossus hippoglossus*) and a spotted wolffish (*Anarhichas minor*) farm. In 2021, the finfish sector had a production value of \$4.1 million (Fisheries and Oceans Canada, 2021b).

In PEI, there are approximately 1,145 marine shellfish aquaculture leases covering over 19,000 acres (Figure 2). Information about aquaculture sites in the province can be viewed online via an interactive map (Government of Canada, 2022b). In 2020, 1,145 lease holders cultured oysters through both bottom (5,000 acres) and off-bottom (2,700 acres) culture along PEI's north and south shores (Government of Prince Edward Island, 2021). Approximately 300 surface leases for mussels (11,200 acres) were located throughout the province in 2020.

PEI aquaculture is jointly managed by Fisheries and Oceans Canada (DFO) and the Government of PEI (Department of Fisheries, Tourism, Sport and Culture) through provisions set out in the Prince Edward Island Shellfish Aquaculture Leasing Policy (Government of Canada, 2022c). The Prince Edward Island Aquaculture Leasing division is responsible for aquaculture leasing under DFO.

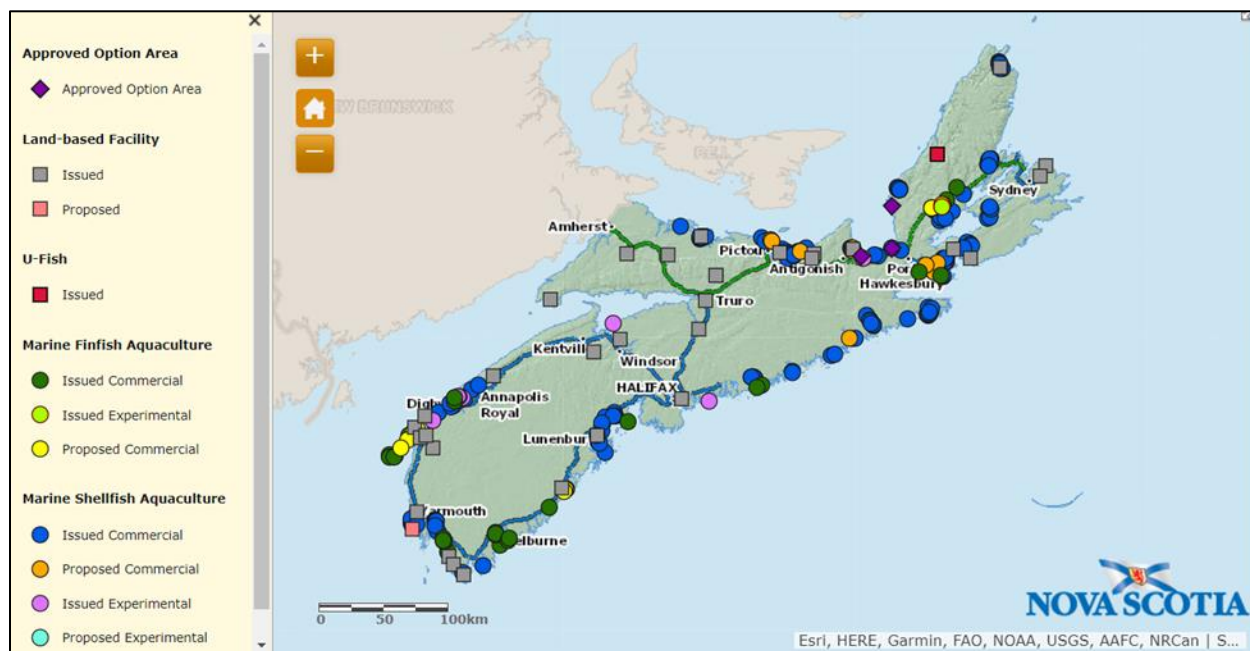


**Figure 2.** Location of marine aquaculture leases in Prince Edward Island (Government of Canada, 2022b).

## 1.2 Nova Scotia

Nova Scotia's (NS) aquaculture industry contributes approximately \$83 million to the province's economy annually (Fisheries and Oceans Canada, 2021a). In 2020, the aquaculture sector directly supported 877 part- and full-time jobs (Province of Nova Scotia, 2021a). Nova Scotia is Canada's fourth largest aquaculture producer by value, with Atlantic salmon (*Salmo salar*) contributing nearly 83% of the provincial value (\$68.7 million) (Fisheries and Oceans Canada, 2023b). In 2021, NS aquaculture production was valued at \$1.3 million for mussels and \$4.7 million for oysters (Fisheries and Oceans Canada, 2023b). Nova Scotia's aquaculture industry is diverse, culturing many finfish and shellfish species, both on land and in the marine environment.

In NS, there are 234 licensed aquaculture sites: 170 marine shellfish, 33 marine finfish, and 31 land-based sites comprised of small to large lease holders (Province of Nova Scotia, 2021a). Six of the 13 band councils are also engaged in aquaculture (Mayer, 2021). These leases are distributed throughout the province. The Nova Scotia Department of Fisheries and Aquaculture hosts an online site mapping tool to display information for each lease such as the lease holder, size of the lease, and species farmed (Figure 3) (Province of Nova Scotia, 2022).



**Figure 3.** Location of aquaculture leases throughout Nova Scotia (Province of Nova Scotia, 2022).



**Table 1.** Saffir-Simpson Hurricane Wind Scale for each storm category(National Oceanic and Atmospheric Administration, N.D.)

<b>Storm Category</b>	<b>Sustained Winds (km/h)</b>
Tropical Storm	≤ 119
Hurricane Category 1	119 – 153
Hurricane Category 2	154 – 177
Hurricane Category 3	178 – 208
Hurricane Category 4	209 – 251
Hurricane Category 5	≥ 252

## 2.2 Predicted future conditions

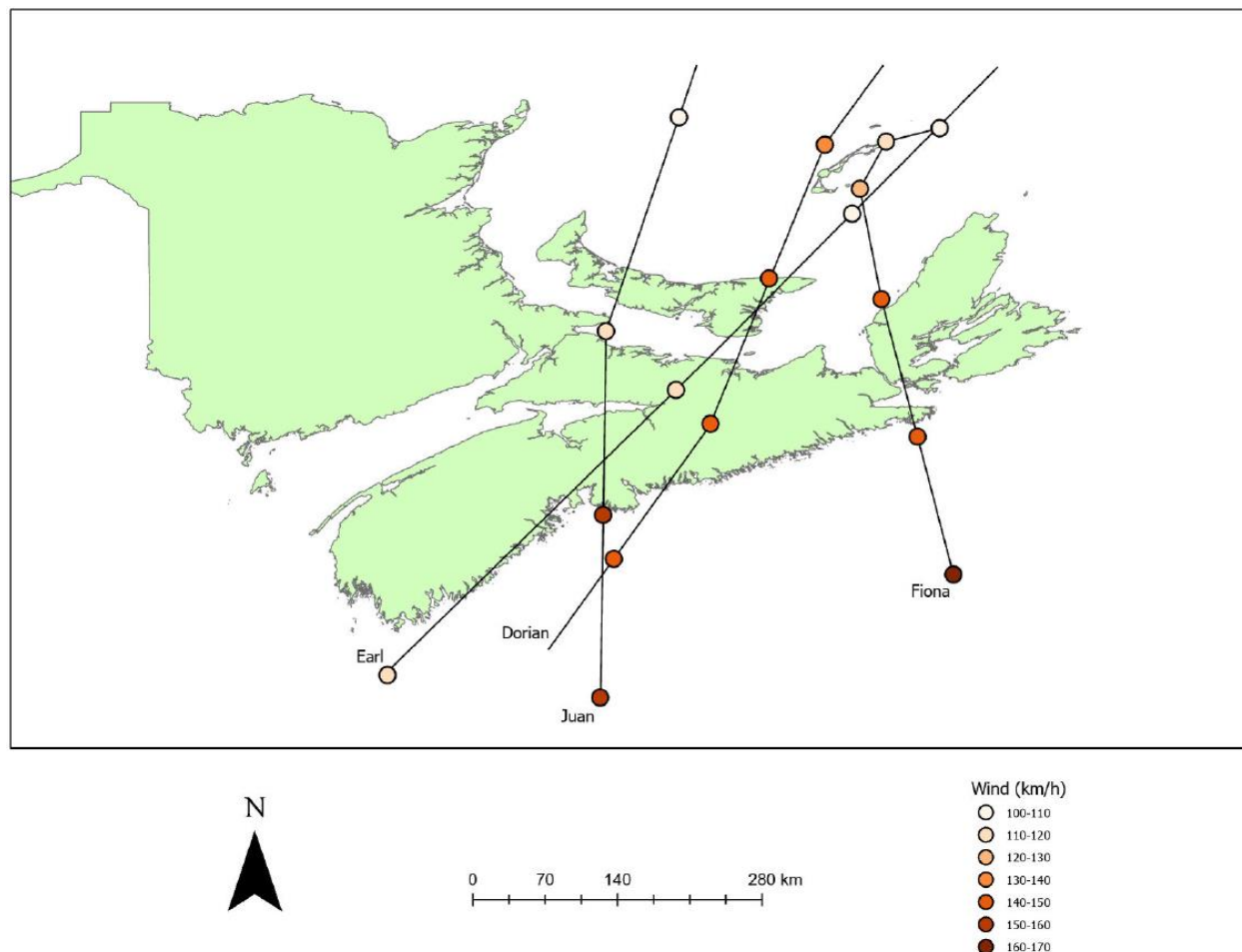
The Northwest Atlantic ocean temperatures have increased faster than the global average (Wu et al., 2012; Forsyth et al., 2015) with the Southern Atlantic Canadian sea surface temperatures (SST) projected to increase up to 4 °C by 2050 under a high greenhouse emissions scenario (Greenan et al., 2018). While the formation of hurricanes occurs over warm waters, there are contradictory relationships between known warming Atlantic SSTs and tropical cyclone / hurricane activity (reviewed by Knutson, 2024). However, differences in projections are due to comparing hurricane strength with projected mean SST and relative SST, which the latter has minimally altered over the last century (reviewed by Swanson, 2008; Vecchi et al., 2008; Knutson, 2024). In general, there is medium to high confidence that tropical cyclone intensities are projected to increase on average between 1 to 10 % with a 2 °C increase of average SST resulting in more severe tropical cyclones (i.e., Category 4 and 5) (reviewed by Knutson, 2024).

## 2.3 Significant hurricanes in the Maritimes

As indicated, Atlantic Canada has experienced numerous severe storms and due to climate change, storm intensities are projected to increase. Over the last two decades, there have been four named hurricanes - Hurricanes Dorian, Earl, Fiona, and Juan, that were similar in magnitude and general trajectory (i.e., north northeast path; National Oceanic and Atmospheric Administration, 2022). These storms first made landfall in Nova Scotia prior to tracking over Prince Edward Island (PEI), except for Fiona which came within ~47 km of PEI's coastline (Figure 5). Fiona crossed approximately 85 km of land in Nova Scotia before entering the waters of the Northumberland Strait, compared to Juan, Earl, and Dorian each crossing 141 km, 285 km, and 62 km, respectively, over Nova Scotian land (derived from National Oceanic and Atmospheric Administration, 2022; Zoom Earth, 2022). Unlike the other three hurricanes, Fiona was downgraded from hurricane status to an extratropical cyclone prior to first landfall in Nova Scotia (Table 2). However, Fiona had the most extreme conditions observed in both provinces with wind

gusts of 179 km/hr at Arisaig, NS and 149 km/hr at East Point, PEI; sustained winds of 126 km/hr at Beaver Island, NS and 112 km/hr East Point, PEI, and maximum recorded wave heights of 30.3 m (Environmental Canada buoy) ([Appendix A](#)).

Despite being relatively similar events, damages from Hurricane Fiona were unprecedented and is now recognized as one of the top 10 most expensive climate disasters worldwide with nearly \$4 billion in damages (CBC News, 2022). These record-breaking impacts were particularly notable for the shellfish aquaculture industry in Nova Scotia and PEI. In response, there are recommendations for the industry to implement best management practices and mitigation measures to reduce impacts of future storms, which are predicted to intensify due to climate change. Government regulators can also play a significant role in supporting the aquaculture industry by altering policy and management procedures to establish standards for which risks can be mitigated and applied to organize and secure financial assistance. The following sections provide recommendations to build the industry back better after being severely affected by Hurricane Fiona.



**Figure 5.** Recorded trajectory and sustained winds during select named hurricanes from weather stations and buoys in Atlantic Canadian waters (National Oceanic and Atmospheric Administration, 2022; Zoom Earth, 2022).

**Table 2.** Severity and tracking details for four named hurricanes impacting Atlantic Canada.

<b>Named Hurricane</b>	<b>Date in Atlantic Canadian Waters</b>	<b>Landfall</b>	<b>Category</b>
Juan <sup>1</sup>	Sept 29, 2003	Nova Scotia Prince Edward Island	Hurricane: Category 2 Hurricane: Category 1
Earl <sup>1</sup>	Sept 4, 2010	Nova Scotia Prince Edward Island	Hurricane: Category 1 Tropical Storm
Dorian <sup>1</sup>	Sept 7, 2019	Nova Scotia Prince Edward Island	Hurricane: Category 1 Hurricane: Category 1
Fiona <sup>2</sup>	Sept 24, 2022	Nova Scotia Prince Edward Island	Extratropical Cyclone Extratropical Cyclone

<sup>1</sup> National Oceanic and Atmospheric Administration (2022)

<sup>2</sup> Zoom Earth (2022)

### 3 Industry storm preparedness

In Atlantic Canada, aquaculture operations are predominantly located near the coast in land-based facilities or on marine leases. With predictions of increasing tropical storm intensities in the Atlantic Ocean, growers must establish rigorous practices to protect their assets (i.e., infrastructure, gear, equipment, and product) from severe damages and losses due to extreme weather events. This section outlines recommended procedures for the shellfish aquaculture industry to reduce impacts and improve recovery efforts after an extreme storm event.

#### 3.1 Disaster preparedness plan

Each aquaculture operation, including marine and land-based sites, should consider developing and implementing a site-specific Disaster Preparedness Plan (DPP). Within this plan, best practices to prepare a site and associated gear (i.e., vessels) for poor weather must be identified. It is also recommended to incorporate steps to guide recovery efforts.

Based on Mississippi-Alabama Sea Grant Consortium (MASGC)'s "*An Oyster Farm Self-Assessment – Understanding how prepared your oyster farm is for a disaster*", at minimum the plan should include (see Section 3 of [Appendix B](#)):

- Operational procedures and procurement of supporting materials to maintain critical functions of the facility (i.e., routine maintenance of a generator and adequate fuel to operate the generator over a specified time).
- A communications plan to maintain contact with essential staff during an emergency which includes documenting contact information and providing emergency methods for mobile communications (e.g., satellite phones or two-way radios).

- Establish agreements or contracts to recover a site after a storm event with personnel, community members, and/or contractors identified to assist with the collection of lost gear, repair and maintain critical infrastructure, or store harvested product.
- A mechanism to review and update the DPP on an annual basis by business owner(s), ideally after each disaster, to ensure the plan is current, practical, and actionable.
- Incorporate details on practicing the execution of the DPP, including storm preparation and recovery, with staff on a regular basis.

Operators could also develop their DPP further to incorporate other established procedures to better protect and recover their assets. The National Oceanic and Atmospheric Administration (NOAA) Sea Grant published detailed storm preparedness fact sheets to guide shellfish growers in areas subject to frequent hurricanes (e.g. Florida, Mississippi, and Louisiana) in preparing their sites to minimize impacts from extreme weather events ([Appendix B](#) through [F](#)) (Callam et al., 2022; Grice et al., 2022; Walton et al., 2022a; Walton et al., 2022b; Walton et al., 2022c). Another useful reference outlining procedures to prepare finfish aquaculture sites for a hurricane in Southeastern United States was developed the U.S. Department of Agriculture Forest Services (Sink et al., 2021) These references are very comprehensive, to a fault, as they are lengthy and excessively verbose which may reduce industry use.

Using NOAA's fact sheets as a template, the Centre for Marine Applied Research (CMAR) developed three concise reference guides outlining recommended procedures for short term preparations and recovery to increase useability by Atlantic Canadian shellfish growers. These documents were produced to guide preparedness activities for suspended culture, land-based infrastructure, and vessels (Appendices [H](#), [I](#), and [J](#), respectively). The reference guides provide recommendations for activities: 1) prior to hurricane season, 2) during hurricane season, and 3) after a storm (i.e., recovery). They can easily be displayed in an office or shed for quick reference and could also be used as training material for new staff or to guide a farm's standard operating procedures. While the information presented in the guides are straightforward and logical, some processes may be overlooked when preparing a site for or recovering from a hurricane (i.e., taking pre- and post-photographs of damages). For this reason, prominently displaying printed copies of these preparedness guides could increase enactment and serve as a quick reference during a time of an emergency, when operators and staff are likely cognitively distressed or distracted.

### **3.1.1 Prior to hurricane season guidelines**

To optimize the performance of a site, growers can incorporate operational best practices that could be implemented throughout the year, regardless of extreme weather threats. In general, all gear, equipment, and infrastructure associated with marine and land-based facilities should be continually evaluated and repaired or replaced, when needed (see [Section 3.4](#)). Regular maintenance of a site is recommended, which includes cleaning up and securing loose or unused gear and equipment in permanent structures, relocating any items to areas with less flood risk, removal of dead or dying branches and trees from the property, and ensuring critical assets, such as vessels and generators, are in good working order. In addition, it is crucial to maintain structural

integrity of gear and infrastructure to reduce potential failure or damage. This includes controlling biofouling on the gear to reduce excess weight that could cause structural fatigue and increased drag, resulting in failure of the grid during times of extreme wind and wave events (Fitridge et al., 2012; Bannister et al., 2019). This regular maintenance will ensure individual components, systems, and infrastructure are in good working order.

Preparation and acquisition of appropriate documentation for a site is also important. This includes establishing and practicing a disaster preparedness plan, securing emergency phone numbers (i.e., staff, recovery contractors, emergency services), and ensuring the site has adequate insurance. All documentation should be duplicated and secured, not just electronically, for ease of accessibility.

### **3.1.2 Pre-extreme weather event guidelines**

In the event that a storm is predicted to track into Atlantic Canadian waters, operators can execute procedures to minimize potential damages or losses to their site and aid in recovery efforts (i.e., financial reimbursement from insurance companies or government financial programs). Sites, both land- and marine-based, should be evaluated for potential risks and remediated to the best of the operator's ability. This may include repairing, replacing, or removal of all critical gear and infrastructure, evaluating stock location and biomass which may require growers to redistribute stock evenly among the grid, combine seed and / or early juveniles to an area(s) for immediate recovery post-storm, and amalgamate product to fewer tanks thereby reduce potential strain on generators in the event of a power outage.

It must be assumed areas, particularly near the coast, will have limited to no power, cellular service, or access to supplies post-extreme storm. Therefore, all supplies and equipment necessary for recovery and ongoing operation post-storm event must be obtained or prepared prior to the storm. This includes procurement of alternate power and communications such as generators and two-way radios, gas / diesel to run critical equipment, and supplies such as algal concentrations or artificial salt. Growers and producers should also examine the option to harvest and sell their product prior to the storm or storing product in potentially less affected areas as suggested in NOAA's storm preparedness guides for adjustable long-line oyster farms (Walton et al., 2022c). However, early harvesting can transfer the risk from the growers to processors and potential reduce unit costs due to excess product in the market therefore, early harvesting must be carefully assessed.

### **3.1.3 Guidelines after tropical storm or hurricane watch has been issued**

Areas are typically issued with a tropical storm or hurricane watch **48 hours** prior to the onset of tropical-storm-force winds. Operators need to employ due diligence to protect their property and site. Marine lease operators are instructed to prepare their site as early as possible to ensure ample time to protect (i.e., secure) their vessel. This includes lowering or sinking any surface gear, harvesting product, and removal, relocation, or fortifying floating workstations/platforms. It is essential for operators to avoid any ocean activities less than 12 hours in advance of an extreme storm since wind and wave conditions tend to increase substantially and are unpredictable. After

all preparations are made on a marine lease, focus must be placed on the vessel and trailer, if applicable. The vessel is a critical piece of equipment a marine lease owner has, as it will enable access to and recovery of the site post-storm. Vessels should be secured, preferably on land, in an area with minimal potential impacts from flooding, downed trees, or flying debris. Land-based facilities should be focused particularly on cleaning all systems, securing redundant, crucial equipment, and arranging the selling of or moving product to other less risky locations.

Continuous tracking of the storm is imperative to understand potential risk and urgency to execute preparations to lessen impacts. Operators should also ensure all staff are versed with the established DPP and understand their specific duties as it relates to protecting the business' assets as the storm approaches. Once a watch has been issued, all emergency equipment must be prepared, including charging batteries and equipment, and obtaining remaining supplies.

### **3.1.4 Guidelines to follow prior to landfall of an extreme weather event**

Growers should consider not visiting their marine site less than 12 hours prior to an anticipated weather event, therefore they should only defer to visual inspections from the shore. Employers should verify all emergency contacts, including emergency services, personnel, and recovery contractors. They should provide key personnel with charged alternative communication technologies (i.e., two-way radio) to aid in post-storm recovery. After a site is prepared, the focus should then be shifted to the personnel who need to prepare and make arrangements for their own personal protection.

### **3.1.5 Post-storm recovery preparations**

After an extreme storm event, the operator or senior personnel are responsible for contacting employees to evaluate their personal availability and mobilization risk. Access to any site should only be done when reasonably safe to do so. Once on site, regardless of land- or marine-based facilities, all post-storm conditions must be documented with time and date stamped photographs or video footage. Marine vessels should only be launched in conditions amenable for the vessel. While on site, any debris should be removed (in the case of marine sites), secured with rope, or moved to a building. Finally, the stock or product loss must be evaluated, and distributors / processors should be contacted to update expected time to resume operations. In addition, communications with local associations, such as the Aquaculture Association of Nova Scotia or the Prince Edward Island Aquaculture Alliance, local government, and insurance providers is key to obtaining support (i.e., physical and financial). If possible, operators should retain damaged equipment for future assessment by financial assistance administrators to verify the extent of the damages.

### **3.1.6 Future recommendations**

While the compiled reference guides are brief, it was stated by Prince Edward Island's Aquaculture Alliance and Aquaculture Association of Nova Scotia (AANS) that they may be inaccessible to some growers due to technological or language barriers. To reduce the requirement to possess either a computer or a printer, these guides could be printed and distributed to growers via mail.

Furthermore, they could be digitized as animations or traditional videos, available in both English and French, to minimize language constraints.

While the focus of this report's recommended best management practices was for Nova Scotia and Prince Edward Island shellfish producers, storm preparedness practices for the finfish industry could also be compiled.

## 3.2 Production information

### 3.2.1 Operational data

Public Safety Canada's Disaster Financial Assistance Arrangements (DFAA) reimburses growers for lost product 'at cost', which excludes reimbursement for profit or market value (Public Safety Canada, 2023). Calculating a fair 'at cost' value of a specific product is cumbersome, especially for the aquaculture industry since operations differ significantly despite culturing the same species. It is further complicated to standardize across a single province let alone multiple provinces due to regional differences, like grow-out period being dependent upon water temperature.

To assign 'at cost' value for a specific product, financial assistance administrators could apply an industry average for production cycle length, operational costs, and farm gate value based on government collected production data, which is limited (See [Section 4.1.3](#)), or poll industry for data. The latter is not ideal as it is time consuming and introduces industry bias and error, potentially skewing 'at cost' values. Additionally, applying a standard 'at cost' value for each type of lost product will undercompensate some growers, while overcompensating others.

To circumvent reimbursement inequality, financial assistance programs should request farm specific data in their application process. This information includes receipts and tax documents detailing:

- a) Previous year's operational costs - Operational costs are typically regionally dependent. These costs include addressing labour shortages for rural areas (e.g., increased wages for retention), fuel prices, and impacts from invasive species (i.e., number of biofouling treatments). Operational costs will vary depending on culture method (i.e., on bottom versus suspended) and species cultured.
- b) Evidence of production cycle length – Production cycles vary depending on culture method (i.e., bottom versus suspended oyster culture) and location of operation. For instance, water temperature is a significant factor for shellfish growth as higher water temperatures (within thermal tolerances) decreases production cycle length (Lowe et al., 2017). Consequently, the amount of time to grow oysters on the south shore of Nova Scotia (i.e., Yarmouth county) is lower than the time to grow the same product in Cape Breton. Additionally, production cycle length for PEI grown oysters would be dissimilar to Nova Scotia.
- c) Farm gate value of product: Evidence (i.e., sales receipts) of farm gate value for a farm's product, on the basis of species (i.e., mussels versus oysters) and quality (i.e., cocktail,

standard, choice, and large choice) should be provided to the financial assistance administrator.

- d) Cost of seed: Receipts for purchased seed or approximate cost of wild harvested seed must be submitted.
- e) Mortality: Site specific estimated annual mortality is important to incorporate to capture costs (i.e., seed) prior to the weather event.

To access public resources, such as DFAA, growers will be required to provide site-specific data to receive compensation for lost product in the future. This is to ensure adequate documentation is obtained for the claimant file, improving transparency, and reimbursement accuracy as data inputs would be farm specific, not an industry average. To support efforts and reduce burdens, growers should maintain quality records and report accurate production data (see [Section 4.1](#)).

### 3.2.2 Inventory data

It is an important practice to continually assess biomass throughout the lease, to aid in completing annual reports and improving operations. Uneven distribution of stocking densities can result in poor growth rates and increased loading and stress on equipment and infrastructure, which can increase risk of system failure. Tracking of product, including standing biomass and grow out location, is valuable for targeting storm preparedness mitigation strategies, such as sinking / lowering the grid or sinking bags in part or whole (Walton et al., 2022a; Walton et al., 2022b). This is a time-consuming activity that is also labour intensive as post-storm recovery will include raising the product and gear. If the grower accurately tracks their product, they could direct their storm preparedness efforts to certain areas of the lease containing the most valued stock (i.e., early juveniles or harvestable product). Also, growers equipped with up-to-date biomass data for each life stage can accurately report on mortalities and lost product due to an event, which aids in validating claims.

### 3.3 Best engineering design

DSA Ocean, an ocean engineering consultant, was contracted to provide guidance on shellfish aquaculture site design based on site-specific environmental variables and estimated costs for multiple tiers of engineering analyses to improve site design. Overall, DSA Ocean's report provides key recommendations to increase shellfish aquaculture systems resiliency to extreme storm conditions, thereby reducing financial and environmental risk (see [Appendix K](#)).

### 3.4 Tracking equipment

Governance of aquaculture site design differs by species grown. In Nova Scotia, the finfish industry is mandated to submit engineer approved, scaled site diagrams detailing technical specifications and locational information for all installed infrastructure (Province of Nova Scotia, 2015b; Province of Nova Scotia, 2021c). Conversely, installing infrastructure within lease boundaries is the only constraint for shellfish site design in Nova Scotia and Prince Edward Island (see [Section 4.1.1](#)). This permits growers to configure and install gear and equipment on an ad hoc basis, which may result

in poor documentation of grid system components. However, detailed tracking of equipment position, repair and maintenance, and age is essential to ensure components are functioning at the required specification. Using unique identifiers, tags or bar codes, physical assets can be tracked throughout their lifespan, from installation to decommissioning, using simple Excel spreadsheets or comprehensive tracking software. Adequate tracking can also identify critical components requiring inspection or preventive maintenance to extend its use. Taking a proactive position in maintaining a site will reduce risk of failure, especially during extreme weather conditions such as waves and wind.

## 4 Proposed Government Initiatives

It is assumed aquaculture operators have a vested interest in protecting their site and associated assets from damage or loss. However, recommended procedures (see [Section 3](#)) may not be incorporated into day-to-day operations, for all farms. For this reason, government regulators could modify their existing policies and management regulations to increase adoption of these best management practices, with the aim to increase future resilience of the shellfish aquaculture industry.

### 4.1 Development and Implementation of Farm-Specific Plans

In Nova Scotia, the government regulator, Nova Scotia Department of Fisheries and Aquaculture – NSDFA, mandates each aquaculture licence holder to prepare a site-specific Farm Management Plan (FMP) which is reviewed and approved by NSDFA (Province of Nova Scotia, 2021b; Province of Nova Scotia, 2021d; Province of Nova Scotia, 2021c). An FMP outlines a farm’s operations / procedures and record keeping to ensure the farm is in compliance with the province’s Aquaculture Management Regulations (Province of Nova Scotia, 2015b) and is operating using best management practices (Province of Nova Scotia, 2020).

Prince Edward Island’s aquaculture operators are not currently required to submit their operational details, except for production information requested by the Department of Fisheries and Ocean’s annual lease report (ALR; see [Section 4.1.3](#)).

In the absence of government approved policies, procedures, and risk management controls specific to site specifications and storm preparedness, the shellfish aquaculture industry is unrestricted. Future claims of damages and losses from extreme weather events may be ineligible for public funds due to the lack of enforceable standards.

#### 4.1.1 Engineering requirements

In NS, both marine shellfish and finfish growers must describe the site’s production plan and farm description (i.e., site diagram and equipment / infrastructure) in their FMPs. Finfish FMPs further requires a ‘scaled’ site diagram, technical specifications for containment management, hazard analysis for critical control points / limits, and details on monitoring / corrective actions. Finfish operators are also required to provide proof of a professional engineer’s approval for the site design and installation, including all containment management structures, for each production cycle (See Section 15 of Province of Nova Scotia, 2020). These additional compliance requirements

are absent in the shellfish FMP template as they are specifically aimed to avoid containment breaches of domesticated finfish.

Sound containment management procedures are essential for finfish aquaculture to prevent fish escapes in the event of containment failure due to predation, damage from ice and storms, or structural / operational related incidents. The focus of containment management for the finfish aquaculture industry is to reduce ecological impacts on wild salmonids, specifically predation, competition for food / habitat, disease transfer, and genetic introgression (reviewed by Jensen et al., 2010). While containment management concerns regarding ecological impacts are minimal for the shellfish industry, maintaining structural integrity during extreme events (i.e., ice and extreme wind / waves) is still relevant.

Preventing damages to infrastructure also reduces financial cost due to stock loss or equipment replacement. Marine shellfish operators can engage an engineering consultant or firm to provide advice on site design which ranges in price depending upon the level of service provided. In Nova Scotia, NSDFA can incorporate the following into their shellfish FMP template:

- a) Incorporate 'scaled' site design and engineering approval of site design and installation within the FMP;
- b) Require all shellfish aquaculture operators, or those that produce a specified amount of product each year, to engage an engineering consultant or firm to provide advice on site design. The cost will vary depending upon the level of service provided (i.e., component recommendations versus site design) and the scope of environmental data required to compile engineering recommendations ([Appendix K](#)).
- c) Utilize DSA Ocean's considerations for the robust design of shellfish farms (Section 7 of [Appendix K](#)) to assess new or amending applications;
- d) Within the FMP, shellfish growers could update their site design as the configuration alters as a part of record keeping; or
- e) Within the FMP, growers can acknowledge the site design adheres to manufacturer specifications (i.e., minimum breaking load requirements for each grid component or anchor selection).

Incorporating "scaled" site design and engineering approval of site design and installation within the FMP may be cost prohibitive for Atlantic Canada's shellfish aquaculture, resulting in minimal compliance, and reducing sustainability of the industry. Applying basic advice provided by ocean engineering consultants can generally improve site design for many, however future climate proofing may be required to withstand unprecedented environmental conditions as the severity of storms are only predicted to increase (see [Section 2.2](#)). Alteration of the marine shellfish FMP enables auditing of shellfish sites by government regulating bodies (i.e., Nova Scotia Department of Resources and Natural Renewables) for which fines may be associated with non-compliance of gear configuration and design. (Province of Nova Scotia, 2021d). These may be viable policies to

adopt by government to establish a standard for the industry which can enable provision of future financial assistance due to extreme weather events.

#### 4.1.2 Incorporating Disaster Preparedness Plan in Farm Management Plan

In Nova Scotia, only the marine finfish FMP requires a site to outline established procedures to respond to unusual events or severe weather. The focus is on containment management to reduce ecological impacts of wild fish (Section 6.6 of Province of Nova Scotia, 2021c). While each FMP requires a detailed site strategy on maintaining the site in good order and retrieval of loose gear, response to unusual events is absent for shellfish and land-based operations (Section 8.0 of Province of Nova Scotia, 2021b; Province of Nova Scotia, 2021d).

A strategy for responding to unusual events and severe weather should be incorporated within each FMP for land based and marine finfish / shellfish operations. A Disaster Preparedness Plan should be developed for each site using recommended best practices and procedures detailed in [Section 3](#) of this document. Absence of government approved operational procedures specific to disaster preparedness for each site, may preclude shellfish growers from accessing public funding, like Public Safety Canada's DFAA, in the future.

#### 4.1.3 Production data

In evaluating claim eligibility for financial assistance, assessors must validate the claimed lost product and assign an 'at cost' value for reimbursement since Public Safety Canada's DFAA does not reimburse market value. Collection of site-specific production data from growers would aid in assessing claims.

In Nova Scotia, NSDFA administers the licences for marine and land-based aquaculture sites as well as leases for marine based sites. Under the *Aquaculture Licence and Lease Regulations*, aquaculture license holders are required to maintain records of all aquaculture produce sales, any losses including natural mortality, predation, or weather, and on-site inventory for a minimum of 7 years (Province of Nova Scotia, 2015a). On an annual basis, the license holder must submit this data in a productivity report to the province's Minister of Fisheries and Aquaculture. The production data could then be utilized to calculate fluctuations of harvestable product "at cost" value (not market value) and validate individual lease activity which could be cross referenced with reported lost product.

Conversely, DFO is responsible for administering shellfish aquaculture leases in PEI. Under the *Prince Edward Island Shellfish Aquaculture Leasing Policy*, aquaculture lease holders must submit an annual lease report (ALR) to DFO (Government of Canada, 2022b). The ALR collects basic lease activity data (i.e., if the lease was in production), harvested amounts (by weight only), restocking amounts, and which species of seed / spat were collected in the reporting period. This data could only support validation of lease activity since annual production sales is not a reporting requirement. Data collected by DFO is not currently shared with PEI's Department of Fisheries and Communities (DFC) due to lease holders' privacy rights.

In general, financial assistance administrators will have a limited ability to validate claims and assign an updated 'at cost value' for claimed lost product by only using annual reports submitted by industry. Collection of site-specific production information is recommended to improve accuracy for reimbursement as detailed in [Section 3.2.1](#).

## 4.2 Creation of an Atlantic Canadian disaster assistance working group

As identified in the "*Tools and Recommendations for Assessing Atlantic Canada's Aquaculture Industry's Claims due to Impacts of Hurricane Fiona*" report, one of the recommendations is establishing a mechanism for assembling key stakeholders such as government regulators and financial assistance program administrators in Atlantic Canada. Since extreme weather events rarely impact only one province, regular working group meetings, or at the very least ad hoc meetings in response to a recognized past weather event is recommended. These meetings would facilitate sharing of lessons learned from evaluating past claims, identify financial program administration improvements that could be applied in other jurisdictions, and promote discussion of identified concerns or questions.

A working group could also enable the creation of a shared database comprised of cost of gear and equipment common to aquaculture activities in Atlantic Canada, thereby reducing duplication of efforts by disaster financial assistance administrators for verifying claims of damages and losses. It would also serve as a means to ensure equitable reimbursement for eligible expenses, including at-value cost of lost product, across the Atlantic Canadian provinces from the same weather event.

## 4.3 Mechanism to mitigate risk

### 4.3.1 Insurance

According to Food and Agriculture Organization of the United Nations (FAO), small-scale producers, like many Atlantic Canadian shellfish producers, make up the majority of global aquaculture (Food and Agriculture Organization of the United Nations (FAO), 2020). These producers can implement best management practices ([see Section 3](#)) and procure "self-insurance tools" (i.e., savings and credit lines) for response to small events. However, chronic and significant events (i.e., extreme weather events, diseases, and water quality issues) resulting in extensive losses cannot be directly absorbed by producers, thereby requiring external funding to support growers after incurring major losses (Fodrie et al., 2018; Food and Agriculture Organization of the United Nations (FAO), 2020).

Complete reliance on government support is problematic, as it is a substantial strain on government resources (i.e., labour costs and funds). Delayed reimbursement associated with accessing government funding may also hinder recovery and building operational capacity, which is particularly crucial for smaller businesses (Food and Agriculture Organization of the United Nations (FAO), 2020). Besides accessing intermittent government funds to subsidize losses, aquaculture insurance could provide a more stable source of coverage. However, despite the growth of global aquaculture, aquaculture insurance is uncommon.

Of the total global aquaculture production value, only 0.06% is insured, with Indonesia and China possessing the greatest amount of coverage. (Hohl, 2021; Van Anrooy et al., 2022). In North America, insurance for aquaculture operations is limited due to the perceived risks associated with growing product in the water (i.e., water quality, storms and climate change pressures) and difficulty in quantifying and verifying claimed losses, as compared to land-based crops and livestock (Shaik et al., 2003; van Anrooy et al., 2006; Food and Agriculture Organization of the United Nations (FAO), 2020; Van Anrooy et al., 2022). Recognizing the importance of aquaculture insurance, FAO's Blue Growth Initiative proposes government involvement through establishment of policy, legislation, and regulatory framework that promotes development of insurance systems. These include defined auditable standards and procedures (i.e., NS FMP – [Section 4.1](#)) aimed at reducing the risk of losses or damages and minimizing impacts from severe events. Through implementation and enforcement of best management practices aimed at controlling risk, underwriters can evaluate and analyze the risks associated with insuring companies and individual assets.

### 4.3.2 Business Risk Management Program

Considering the lack of commercial insurers and / or reasonably priced insurance policies available to Canada's aquaculture industry, specifically shellfish, exploration of other processes to mitigate risk could be explored. This includes business risk management (BRM) programs which the Canadian agriculture industry has access to under the Canadian Agricultural Partnership. The BRM programs assist producers by supporting loss of income due to market instability, natural disasters, unpredictable growing conditions, unanticipated disease outbreaks, and access to funds for future investments (i.e., improved technologies and operations). These programs include:

- [AgriStability](#) – margin-based program to support producers experiencing large income declines in the event of production loss, increased costs, and poor market.
- [AgriInvest](#) – program that permits growers to deposit money into a self-managed producer-government savings account. These funds are matched by the federal, provincial, and territorial (FPT) governments to assist producers during small income declines and use funds to make investments to manage risk and improve income.
- [AgriInsurance](#) – a federal-provincial-producer cost-shared program, administered by the province, providing affordable insurance to subsidize financial losses (i.e., production and assets) from natural hazards.
- [AgriRecovery](#) – a FPT framework to assist producers by subsidizing extraordinary costs associated with recovering from natural disasters.
- [Advance Payments Program Lobbying](#) – a federal loan guarantee program for producers to access cash advances with the Government of Canada paying interest on the first \$100,000 (increased to \$250,000 for 2022 and 2023).

The BRM programs were established to support high-risk agriculture activities as the industry is recognized as "[one of Canada's main economic pillars](#)". While the Canadian aquaculture industry

has a lower direct revenue per annum in comparison to agriculture (2021 - aquaculture: \$1.3 billion versus agriculture: \$76.9 billion), aquaculture should also be considered economically important since it creates direct and indirect employment opportunities and supports local economies for many rural and coastal communities (Government of Nova Scotia, 2012). Like agriculture, aquaculture growers also face market instability, suboptimal growing conditions, and weather events that can significantly impact revenue. Despite meeting the criteria for which BRM programming was established for the agriculture industry, aquaculture does not have access to a BRM program. Industry request for BRM programming, either under the current agriculture program or as a stand-alone program, is not novel and has been previously lobbied by the Canadian Aquaculture Industry Alliance (CAIA) (Canadian Aquaculture Industry Alliance, 2018). It is recommended for federal, provincial, and territory governments to assess options for implementing BRM programs to mitigate risk associated with aquaculture activities.

## 5 Recommendations

- Government regulators should require producers to develop and implement a site-specific disaster preparedness plan. Ideally, this plan should at minimum include best practices, as identified a governing body, and be approved and audited periodically.
- Site specific operational and production records should be vigilantly maintained and made available to financial assistance administrators, upon request.
- To improve site design, growers should consider collection of site-specific environmental conditions and adhere to manufacturer specifications when designing a site. While there are recommendations for best engineering design, some areas may require infrastructure to be built beyond these specifications. Growers may also contract an engineering consultant to make recommendations for site design, ensuring infrastructure is built to withstand extreme conditions (i.e., 10- or 50- year storm)
- Regulate the shellfish aquaculture industry with enforceable and auditable standards and procedures to support development of mechanism(s) to mitigate risk (i.e., reasonable insurance and business risk management programs).
- An Atlantic Canadian disaster assistance working group should be established to facilitate discussion regarding reimbursement schedules and improvements, promoting program consistency throughout the provinces.

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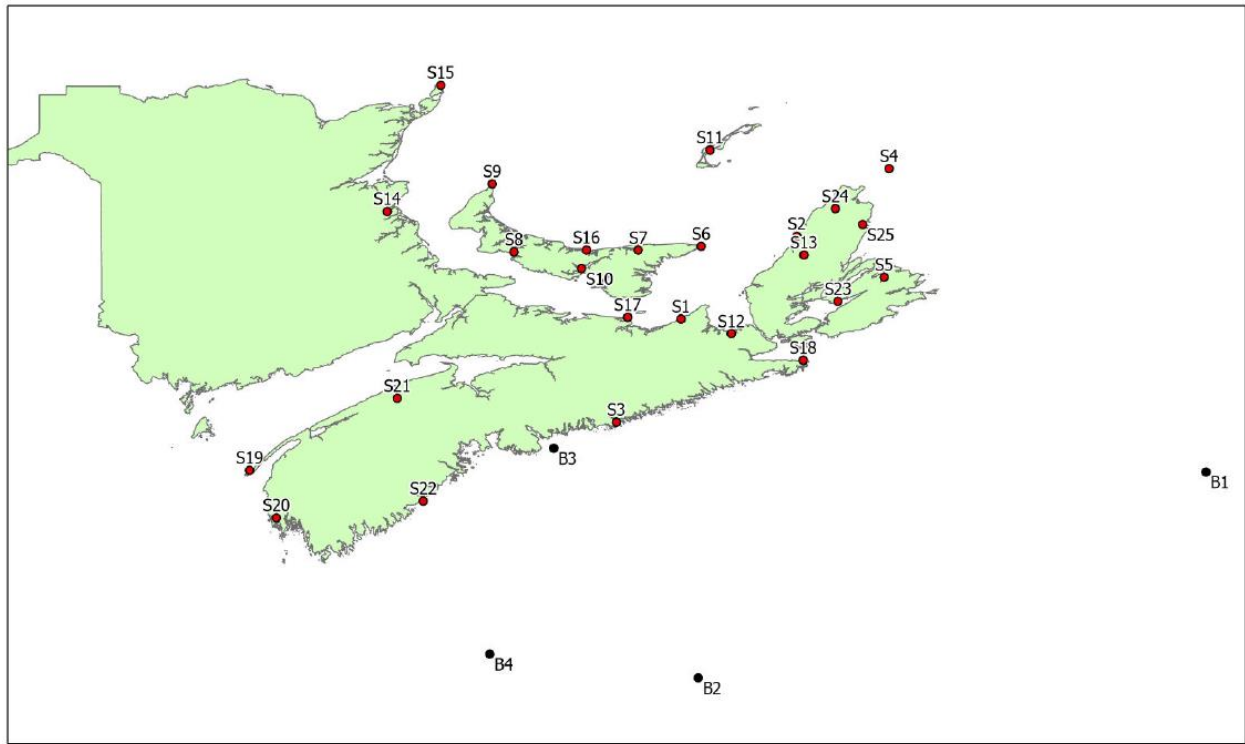
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**Appendix A: Wind and wave data collected during Hurricanes Dorian, Earl, Fiona, and Juan**



**Figure A1.** Location of buoys and Environment Canada (EC) weather stations collecting wind and wave data during hurricane events. (Environment and Climate Change Canada, 2022a; Environment and Climate Change Canada, 2022b; Fisheries and Oceans Canada, 2022a; Fisheries and Oceans Canada, 2022b; Fisheries and Oceans Canada, 2022c; Fisheries and Oceans Canada, 2022d)

**Table A1.** Recorded wind gusts and sustained winds during select named hurricanes from weather stations and buoys in Atlantic Canadian waters (Environment and Climate Change Canada, 2022a; Environment and Climate Change Canada, 2022b; Fisheries and Oceans Canada, 2022a; Fisheries and Oceans Canada, 2022b; Fisheries and Oceans Canada, 2022c; Fisheries and Oceans Canada, 2022d)

Location	Site/Buoy	Number	Fiona (2022)		Dorian (2019)		Earl (2010)		Juan (2003)	
			Gust (km/h)	Sustained (km/h)	Gust (km/h)	Sustained (km/h)	Gust (km/h)	Sustained (km/h)	Gust (km/h)	Sustained (km/h)
NS	Arisaig	S1	<b>179</b>	121	No Data	No Data	No Data	No Data	No Data	No Data
	Grand Etang	S2	167	94	<b>155</b>	75	No Data	72	No Data	65
	Beaver Island	S3	160	<b>126</b>	145	<b>106</b>	<b>135</b>	<b>104</b>	<b>131</b>	<b>95</b>
	St. Paul Island	S4	158	123	No Data	No Data	130	100	109	78
	Sydney	S5	149	96	87	72	85	63	70	46
	Tracadie	S12	136	91	96	60	93	56	83	54
	Margaree	S13	75	91	82	60	No Data	56	No Data	54
	Caribou Point	S17	146	103	122	95	107	76	119	No Data
	Hart Island	S18	128	86	126	88	109	78	89	69
	Brier Island	S19	98	80	110	85	69	41	No Data	39
	Yarmouth	S20	89	57	98	75	69	43	32	22
	Greenwood	S21	91	68	104	63	65	50	56	35
	Western Head	S22	70	42	88	54	98	70	70	43
	Eskasoni	S23	125	96	113	82	No Data	No Data	No Data	No Data
	North Mountain	S24	127	72	111	68	No Data	65	No Data	41
Ingonish Beach	S25	89	47	90	46	89	43	67	35	
PEI	East Point	S6	<b>149</b>	<b>112</b>	<b>120</b>	<b>95</b>	<b>98</b>	<b>69</b>	96	67
	St. Peters	S7	141	79	99	52	72	46	107	59
	Summerside	S8	140	89	117	86	70	50	83	61
	North Cape	S9	136	101	122	91	85	67	89	69
	Charlottetown	S10	131	73	107	69	78	48	<b>139</b>	<b>82</b>
	Stanhope	S16	131	89	92	55	No Data	No Data	No Data	No Data
NB	Kouchibouguac	S14	70	39	66	36	No Data	No Data	No Data	No Data
	Miscou Island	S15	113	83	106	80	74	46	56	43
Magdalen Islands	Isles de la Madeleine	S11	126	83	117	82	91	69	107	74
Ocean	44139	B1	107	81	81	61	59	50	No Data	No Data
	44137	B2	10	9	107	94	89	70	88	73
	44258	B3	115	91	112	90	121	84	135	99
	44150	B4	100	79	121	97	122	84	49	41

**Table A2.** Maximum and sustained wind recorded from ocean buoys during select named hurricanes. (Fisheries and Oceans Canada, 2022a; Fisheries and Oceans Canada, 2022b; Fisheries and Oceans Canada, 2022c; Fisheries and Oceans Canada, 2022d)

Buoy Name	Number	Fiona (2022)		Dorian (2019)		Earl (2010)		Juan (2003)	
		Max (km/h)	Significant (km/h)	Max (km/h)	Significant (km/h)	Max (km/h)	Significant (km/h)	Max (km/h)	Significant (km/h)
44139	B1	<b>30.3</b>	<b>13.4</b>	18.5	9.1	12.5	6.6	No Data	No Data
44137	B2	23.5	11.9	27.1	<b>15.2</b>	17.9	10.3	12.5	6.9
44258	B3	7.3	4.2	23.5	9.5	23.3	10.1	<b>19.9</b>	<b>9</b>
44150	B4	13.7	8.2	<b>27.7</b>	13.6	<b>24.6</b>	<b>13.1</b>	2.6	1.4

**Appendix B: Mississippi-Alabama Sea Grant Consortium (MASGP):  
Oyster Farming Resilience Index: An Oyster Farm Self-Assessment**



# An Oyster Farm Self-Assessment

Understanding How Prepared  
Your Oyster Farm is for a Disaster



*“On the road to oyster farm resilience”*

# Oyster Farming Resilience Index

Oyster Farm Name: \_\_\_\_\_

Date Completed: \_\_\_\_\_

Name	Title

## Introduction

All oyster farmers face challenges during disasters. The **Oyster Farming Resilience Index (OFRI)** is a self-assessment tool developed for oyster farmers. It serves as a simple and inexpensive method of predicting if individual businesses are prepared to maintain operations during and after disasters. Completing the OFRI will assist farmers in identifying actions for long-term resilience for natural, human and economic disasters.

The OFRI can be completed by farmers. However, Sea Grant staff are willing to meet individual farmers to assist in completing the OFRI and will not share your results with anyone else. When the OFRI is used, each farm should consider the farm's level of preparedness for both large- and small-scale events. Being able to withstand and adapt to change has become a focal point for businesses and industries. Resilient businesses recognize the vital role that planning, preparation and collaboration play in developing and executing strategies to respond to challenges, adapt to changes and thrive.

Oyster farmers will benefit from the OFRI by identifying strengths and weaknesses in their overall farm operation. These indicators can provide an important baseline to measure progress toward resilience goals. Progress toward resilience goals of a farm can be measured by retaking the OFRI every 18 months. In addition, the OFRI assists in assessing the overall resilience of the industry by identifying best practices used by farmers. The process of completing the OFRI will help identify the action items farmers should work towards to address system vulnerabilities and maintain long-term viability.

## How was the OFRI Developed

The OFRI was developed with broad participation from industry leaders. The development team coordinated with an industry steering committee to identify measures of resilience, or indicators. Each of the 122 indicators was written in the form of a “yes” or “no” question. Using those indicators, the OFRI was organized into seven categories: business planning, marketing, disaster preparedness planning, workforce, monitoring of water and oysters, regulatory knowledge and resource access and knowledge. The OFRI was then pilot tested with farmers in Alabama and Mississippi, and modifications to the OFRI were made before finalizing it.

A point system is used for each indicator so an overall score can be calculated. It is important to note that the process of completing the OFRI is intended to be an in-person activity bringing together employees of your farm to discuss the questions and determine answers. This process creates conversations across important issues and joint solutions to challenges your farm may face as well as documents your farm’s strengths and best practices. An understanding of how your farm addresses or does not address the indicators is the most valuable part of completing the index, not the scores.

## Results Overview

After completing this self-assessment, you should complete the summary table that will help you determine the resilience of your farm using this self-assessment (see page 14). For more details about interpreting OFRI results, go to page 15.

## Business Planning

### Section 1: Does your business include the following information?

Check Yes or No for the 33 questions in this section.

Section 1: Business Planning	Yes	No
1. Do you have a written business plan containing at least the following:		
a. Mission statement and goals		
b. Company overview (legal structure, products or services, location, management, insurance)		
c. Industry analysis (differentiates business functions/activities including seed availability/access to product)		
d. Do you know how much it costs for you to grow an oyster to market size and the anticipated amount you will be paid for an oyster that reaches market size?		
e. Financial plan (cash flow statement, three-year income projection, sources and uses of funds, summary of financial needs, financial statements and profits/losses)		

<b>Section 1: Business Planning</b>		<b>Yes</b>	<b>No</b>
f.	Business operations plan (facilities, equipment and staffing)		
g.	Farm expansion plan (1-3 years, 3-5 years and 5-10 years) that also accounts for markets, labor, availability of seed/spat and equipment		
h.	Recruitment, training, leadership development and staff succession strategy		
2.	Has your written business plan been reviewed or updated in the last 12 months?		
3.	Does your farm have enough cash on hand (e.g. 3 months) or a line of credit to cover expenses for extended periods of time due to harvest closures, storms or unforeseen circumstances (e.g. COVID-19, equipment damage)?		
4.	Do you have an inventory management system that includes product tracking at different growth stages, photographs of oysters at all sizes and a way to recover your records to document any losses that occur, including a backup of electronic records?		
5.	Do you have an adequate supply of products and services such as:		
a.	Seed and spat		
b.	Equipment (e.g. gear, generator, lines, graders, anchors, etc.)		
c.	Supplies (e.g. fuel, ice, etc.)		
d.	Labor and contractors		
6.	Do you test your oysters for contaminants and pathogens?		
7.	Do you have adequate water-dependent infrastructure (boats, boat launches, navigation aids, docks, pier) during normal operations?		
8.	Do you have insurance or are you pre-registered for emergency assistance for the following:		
a.	Crop [e.g. Emergency Assistance for Livestock, Honey Bees, and Farm-raised Fish (ELAP) and Noninsured Crop Disaster Assistance Program (NAP)]		
b.	Catastrophic loss of gear and/or oysters (hurricane, freshwater flooding, harmful algae bloom)		
c.	Boat and other equipment		
d.	Wind (for structures and equipment)		
e.	Fire		
f.	Flood		
g.	Theft (oysters and cages)		
h.	Product liability (customer becomes sick from consuming oysters)		
i.	General liability (employees and visitors)		
j.	Health (owner and employees)		
k.	Disability		
l.	Workers compensation (e.g. Jones Act Coverage)		

<b>Section 1: Business Planning</b>	<b>Yes</b>	<b>No</b>
9. Do you know the limitations of various types of oyster farming-related insurance?		
10. Does your farm employ methods to reduce theft or vandalism?		
11. Do you have an alternate source of income to cover on-farm losses (e.g. another job)?		
12. Do you have the information (e.g. contacts, farm records and application information) needed to obtain capital improvement or operating loans?		
<b>Total number of Yes and No answers:</b>		

**Additional Comments or areas where you would like to learn more.**

## Marketing

**Section 2: Does your business have the following marketing plans, procedures and strategies?**  
Check Yes or No for the 27 questions in this section.

<b>Section 2: Marketing</b>	<b>Yes</b>	<b>No</b>
13. Do you have a written marketing plan as part of your business plan containing at least the following:		
a. Company analysis (strengths, weaknesses, opportunities and threats)		
b. Customer analysis (customer demographics, target markets, needs of target customers)		
c. Situation analysis (short-, mid- and long-term competition, growth, price elasticity, market availability, potential expansion)		
d. Goals		
e. Strategies		
f. Tactics		
g. Timeline		

<b>Section 2: Marketing</b>	<b>Yes</b>	<b>No</b>
14. If you have a written marketing plan, is your marketing plan reviewed and updated as needed?		
15. Do you use targeted marketing methods?		
16. Do you have an established brand and a promotion plan (e.g. social media, TV, radio) for your oysters?		
17. Do you have an adequate supply to fill the market demand for your oysters?		
18. Does your farm (if allowed by regulations) sell directly to consumers?		
19. Do you employ diverse marketing strategies including the following:		
a. Have arrangements with alternative markets in the event of a disruption with your primary market		
b. Provide multiple sizes and product forms (e.g. half-shell, shucking, food or restoration)		
c. Use multiple distribution channels (e.g. food truck, on-farm, pop-ups, online, processor)		
d. Have additional streams of revenue for your business, such as weddings, farm tours, carbon or nutrient credits, equipment clothing and/or other branded items		
e. Receive compensation from the state or third-party companies for the ecosystem services provided by oysters, such as carbon or nutrient credits		
f. Offer packages of your products or services with other businesses, such as gift boxes for special occasions or holidays		
20. Do you have reliable transportation services to deliver your oysters to market?		
21. Do you take part in collaborative marketing in the following ways:		
a. Participate in a coordinated industry driven program to improve the public perception of oysters		
b. Participate in your local or a regional chamber of commerce?		
c. Participate in marketing or restaurant organizations (local, state, regional or national)		
d. Partner with local restaurants who sell your oysters		
22. Do you have a designated employee trained to serve as a spokesperson to manage any questions from the general public and media?		
23. Do you have a communication plan to address potential negative press (e.g. vibrio outbreak)?		
24. Do you communicate to customers and the public about your product(s), including closures and salinity levels?		
25. Do you have communication materials that you share with the public about oysters that include nutritional values, preparation methods and safety tips?		

Section 2: Marketing	Yes	No
<b>Total number of Yes and No answers:</b>		

Additional Comments or areas where you would like to learn more.

### Disaster Preparedness Planning

**Section 3: Does your business have the following disaster preparedness plan in place?**

Check Yes or No for the 16 questions in this section.

Section 3: Disaster Preparedness Plan	Yes	No
26. Have key personnel in your business had firsthand experience with disaster recovery during the last 10 years?		
27. Do you have a written disaster preparedness plan that includes at least the following:		
a. Evacuation, re-entry and shelter-in-place plan		
b. Continuity of operations plan (e.g. essential personnel/services/equipment, alternate reporting locations, reopening, critical records storage)		
c. Agreements and contracts with suppliers and contractors for critical operations (e.g. anchors, pilings, generators, debris removal and cleanup services)		
d. Mobile communications ready for use in the event of a disaster (e.g. satellite phones, Garmin inReach, two-way radios, phone apps)		
e. Emergency supplies (e.g. fuel, ice, batteries)		
f. Internal (employee) communications plan including for non-English speaking employees (e.g. established phone numbers for staff to call for information, schedule for staff to return to work)		
g. Communications plan for media, customers and the public (e.g. predetermined messages and messaging channels)		
h. Gear recovery strategy		

<b>Section 3: Disaster Preparedness Plan</b>	<b>Yes</b>	<b>No</b>
28. Is your disaster preparedness plan reviewed and updated as needed with lessons learned after each disaster?		
29. Do you practice various disaster scenarios including practicing preparing your gear (e.g. storm preparation and recovery)?		
30. Do you perform regular maintenance on your anchoring system and pilings for your cages and lines and check knots, zip ties and other methods you use to secure your equipment and oysters?		
31. Does your farm have pre-existing agreements to move oysters to a site out of harm's way in the event of a storm, harmful algae bloom or some other disaster?		
32. Do you participate in any post-disaster surveys by federal or state agencies to determine the extent of damage from a disaster and the status of the recovery progress?		
33. Have you identified the appropriate public or private resources to obtain up-to-date disaster information within your city, county or state (e.g. local emergency management hotline, local municipalities' website)?		
34. Do you know the flood zone for your land-based facilities?		
<b>Total number of Yes and No answers:</b>		

**Additional Comments or areas where you would like to learn more.**

## Workforce

### Section 4: Does your business meet the following criteria in relation to your local workforce?

Check Yes or No for the 10 questions in this section.

<b>Section 4: Workforce</b>	<b>Yes</b>	<b>No</b>
35. Are you able to hire qualified employees when needed?		
36. Do you have enough supplemental labor (non-employees) willing to work before and after disasters (e.g. storms, harmful algae blooms, freshwater inflow)?		

<b>Section 4: Workforce</b>	<b>Yes</b>	<b>No</b>
37. Do you have employees who are cross-trained in tasks outside of their normal job duties to assist with disaster recovery?		
38. Are you part of a social network that connects you to other farmers whom you can call on for support if needed (e.g. shared labor pool to assist in relocating oysters)?		
39. Do you provide training for new or current employees that includes the following:		
a. Farm operations and management		
b. Mentoring or farmer-to-farmer exchange program		
c. Health and safety training specific to your business (e.g. first aid/CPR training, food safety, OSHA, mental health services)		
40. Do you have enough adequately trained staff for normal operations under regular working conditions (including disruption of work due to absences of staff)?		
41. Do your employees have adequate wrap-around services (e.g. affordable housing, transportation, child care)?		
42. Do you provide employee incentives to assist with retention (e.g. bonuses, flexible hours, discounted oyster purchases, housing stipends, health insurance, retirement contributions, accommodating class schedules)?		
<b>Total number of Yes and No answers:</b>		

**Additional Comments or areas where you would like to learn more.**

## Monitoring of Water and Oysters

### Section 5 Does your business track water quality, quantity and monitoring issues in local waters?

Check Yes or No for the 21 questions in this section.

Section 5: Monitoring of Water and Oysters	Yes	No
43. Do you monitor growth rates of your oysters at different sizes and times of the year?		
44. Do you monitor the following:		
a. Salinity		
b. Water temperature		
c. Dissolved oxygen		
d. Turbidity		
e. Air temperature		
f. Local rainfall		
g. Pathogens (e.g. viruses or bacteria)		
h. Toxins (e.g. harmful algae blooms)		
i. Metals (e.g. cadmium, lead, mercury, arsenic)		
45. Do you currently share your monitoring data or would you be willing to share it with state agencies to aid in informing regulatory closures and reopenings?		
46. Do you receive adequate advance notice from state or local government agencies if water quality-related closures are about to occur?		
47. Over the last 12 months, has your farm remained open without regulatory closures (e.g. closures due to freshwater inflow, harmful algae blooms, pathogens, stormwater overflow)?		
48. Are you prepared to act in response to potential closures due to the following:		
a. Freshwater inflow		
b. Harmful algae blooms		
c. Sewage overflows		
d. Storms		
e. Chemical or oil spills		
f. Dredging		
49. Do you have access to local facilities for more advanced testing of toxins and pathogens?		
50. Do you utilize wet storage of oysters to hold oysters in anticipation of water quality closures?		
<b>Total number of Yes and No answers:</b>		

**Additional Comments or areas where you would like to learn more.**

## Regulatory Knowledge

### Section 6: Does your business monitor and participate in regulatory activities?

Check Yes or No for the 11 questions in this section.

Section 6: Regulatory Knowledge	Yes	No
51. Do you renew your permits or licenses as required and on time?		
52. Do you know the permitting requirements and timeline to obtain a permit to expand your farm (e.g. U.S. Army Corps of Engineers Nationwide Permit 48)?		
53. Do you know who to contact to obtain the latest regulations related to your farm?		
54. Do you know the oyster management policies on a local level (e.g. cause for closures, reopening processes)?		
55. Are you involved in the Interstate Shellfish Sanitation Conference (ISSC)?		
56. Do you know how the ISSC National Shellfish Sanitation Program Guide is managed?		
57. Do you know how the classification of oyster growing waters can change?		
58. Do you know the regulations for moving your oysters to other locations (relaying) if the need arises?		
59. If you have a license to process, does your farm have a Hazard Analysis and Critical Control Point (HACCP) plan?		
60. Do you use your knowledge or experience to influence oyster farming policies (e.g. public comment, calling your regulatory office)?		
61. Do you know how to learn of planned restoration projects and do you provide input or comment on restoration projects that could impact your farm?		
<b>Total number of Yes and No answers:</b>		

**Additional Comments or areas where you would like to learn more.**

### Resource Access and Knowledge

#### Section 7: Does your business access additional resources regularly?

Check Yes or No for the 4 questions in this section.

<b>Section 7: Resource Access and Knowledge</b>	<b>Yes</b>	<b>No</b>
62. Do you participate in any oyster industry communities of practice that bring together members of the industry to solve problems?		
63. Are you aware of the latest farming science and technology developments that are being used by the industry?		
64. Do you participate in resource sustainability activities on your farm (e.g. habitat conservation and restoration, erosion prevention, stormwater management, nutrient reduction, recycling, local sourcing, energy efficiencies)?		
65. Are you a member of any local, regional or national professional industry associations?		
<b>Total number of Yes and No answers:</b>		

**Additional Comments or areas where you would like to learn more.**

Use the row labeled “Total Number of Yes or No Answers” from Sections 1-7 to complete the following table.

Sections 1-7	Number of Yes answers	Your Assessment of Your Farm’s Resilience (Low, Medium or High)	Comments
<b>Example</b> using the Workforce section	4/7	Medium	Staff training would increase our farm’s resilience in the workforce section.
<b>Section 1: Business Planning (33 yes or no questions)</b>			
<b>Section 2: Marketing (27 yes or no questions)</b>			
<b>Section 3: Disaster Preparedness Planning (16 yes or no questions)</b>			
<b>Section 4: Workforce (10 yes or no questions)</b>			
<b>Section 5: Monitoring of Water and Oysters (21 yes or no questions)</b>			
<b>Section 6: Regulatory Knowledge (11 yes or no questions)</b>			
<b>Section 7: Resource Access and Knowledge (4 yes or no questions)</b>			

**What do you believe about your overall farm resilience (Low, Medium or High)? Please explain why you assigned your rating.**

### **Rating and Interpreting Your Results**

**Resilience Index:** The Oyster Farming Resilience Index is an index using indicators to gauge your oyster farm’s ability to return to an acceptable level of operations after a disaster. After completing the scoring table of this self-assessment, your resilience index can be categorized as LOW, MEDIUM, or HIGH in each section.

**LOW Resilience Index.** A low score in any section may indicate that your farm should pay specific attention to that section and should make efforts to address the areas of low ratings. It could also indicate that it would take more time to return to normal operations than would a higher resilience rating.

**MEDIUM Resilience Index.** A medium score in any section indicates that more work could be done to improve your areas of low ratings.

**HIGH Resilience Index.** A high score in any section indicates that your farm is prepared for disasters (natural, economic and human caused) for that section. A high resilience rating does not guarantee that your farm will not suffer major losses during a catastrophic disaster.

## Next Steps

Regardless of your farm's score, you should learn about and investigate the weaknesses you have identified during this process. You may refer to the following section (supporting resources) for additional information on resources, training and support.

**What are some steps you can take to increase your resilience rating?**

**What do you believe Sea Grant should do to help your farm increase its resilience?**

## Contacts

For more information, contact Rusty Grice with the Mississippi-Alabama Sea Grant Consortium and Auburn University Shellfish Lab at [rtg0010@auburn.edu](mailto:rtg0010@auburn.edu) or LaDon Swann at [ladon.swann@usm.edu](mailto:ladon.swann@usm.edu) or 251-648-5877.

## Supporting Materials

The following resources are provided to assist you in building a more resilient business. You will find templates for creating a business plan, visualization tools to help you assess your risk and best practices to guide your future long-term planning efforts. In addition to these resources, check with your local and regional chambers of commerce and destination marketing organizations.

## **U.S. Small Business Administration**

<http://www.sba.gov/writing-business-plan>

The U.S. Small Business Administration (SBA) is an independent agency of the federal government to aid, counsel, assist, and protect the interests of small business concerns, to preserve free competitive enterprise and to maintain and strengthen the overall economy of our nation. The SBA helps Americans start, build, and grow businesses, through an extensive network of field offices and partnerships with public and private organizations.

- Alabama Small Business Development Center: [www.asbdc.org](http://www.asbdc.org)
- Mississippi Small Business Development Center: [www.mssbdc.org](http://www.mssbdc.org)

## **Alabama Oyster Aquaculture**

- <https://alaquaculture.com>

## **Seafood Safety**

- Alabama Department of Public Health - Seafood and Shellfish Safety  
<https://www.alabamapublichealth.gov/foodsafety/seafood-and-shellfish.html>
- Alabama Department of Environmental Management  
<https://adem.alabama.gov/default.cnt>
- Mississippi Department of Marine Resources Shellfish Bureau  
<https://dmr.ms.gov/shellfish>
- Mississippi Department of Environmental Quality <https://www.mdeq.ms.gov>
- Interstate Shellfish Sanitation Conference (ISSC) <https://www.issc.org>
- National Shellfish Sanitation Program (NSSP)  
<https://www.fda.gov/food/federalstate-food-programs/national-shellfish-sanitation-program-nssp>

The National Shellfish Sanitation Program (NSSP) is the federal/state cooperative program recognized by the U. S. Food and Drug Administration (FDA) and the Interstate Shellfish Sanitation Conference (ISSC) for the sanitary control of shellfish produced and sold for human consumption. The purpose of the NSSP is to promote and improve the sanitation of shellfish (oysters, clams, mussels and scallops) moving in interstate commerce through federal/state cooperation and uniformity of state shellfish programs.

## **Workforce Development and Training**

- Online Off-Bottom Oyster Farm Training for the Gulf of Mexico <https://oyster-culture.teachable.com>
- Storm and Hurricane Preparedness for Off-Bottom Oyster Aquaculture in the Gulf of Mexico <https://shellfish.ifas.ufl.edu/hurricane-resources>
- Gulf of Mexico Sea Grant College Programs [www.gulfseagrant.org](http://www.gulfseagrant.org)

## **Crop Insurance and Assistance Information**

- Group Risk Plan <https://www.rma.usda.gov/Fact-Sheets/National-Fact-Sheets/Aquaculture-Oysters-Clams-WFRP>

- Noninsured Crop Disaster Assistance Program [https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdfiles/FactSheets/noninsured\\_crop\\_disaster\\_assistance\\_program-nap-fact\\_sheet.pdf](https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdfiles/FactSheets/noninsured_crop_disaster_assistance_program-nap-fact_sheet.pdf)
- Emergency Assistance for Livestock, Honey Bees, and Farm-raised Fish (ELAP) <https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/emergency-assist-for-livestock-honey-bees-fish/index>

### **Marketing Planning**

- Creating a Marketing Plan for your Business (with templates) <https://www.indeed.com/hire/c/info/creating-a-marketing-plan#4>
- A Step-By-Step Guide To Your 2022 Marketing Planning <https://www.statsocial.com/2022-marketing-planning-guide>
- What is a Marketing Plan & How to Write One [+Examples] <https://blog.hubspot.com/marketing/marketing-plan-examples>

### **Business Planning**

- FishBizPlan <https://fishbizplan.org>
- University of Minnesota AgPlan <https://agplan.umn.edu/>

### **Mapping and Forecasting**

- Mississippi Hydrological Monitoring Stations <https://dmr.ms.gov/hydrological-monitoring>
- Mobile Bay Salinity Forecast Guidance <https://bit.ly/3qWpHo>
- Mobile River at Barry Steam Plant <https://bit.ly/3dBgHS7>
- Alabama Real-Time Coastal Observing System <https://arcos.disl.org>
- Harmful Algal BloomS Observing System (HABSOS) <https://habsos.noaa.gov>
- USGS Coastal Mississippi Current Conditions by Station <https://bit.ly/3DIIVVG>
- National Hurricane Center <https://www.nhc.noaa.gov>
- Mississippi Beach Monitoring Program <https://opcgis.deq.state.ms.us/beaches/closures.php>
- Alabama Beach Monitoring Program <https://www.alabamapublichealth.gov/environmental/beach-monitoring.html>
- Testing laboratories (certified by ISSC/state agencies) (can provide a list of locations in Gulf or serve Gulf) to reduce closure time
  - ISSC Laboratory List <https://www.issc.org/laboratory-1>

### **Mississippi-Alabama Sea Grant Resilience Indices**

<https://masgc.org/coastal-storms-program/resilience-index>

### **Federal Emergency Management Agency**

<https://www.fema.gov/>

FEMA's mission is to support our citizens and first responders to ensure that as a nation we work together to build, sustain and improve our capability to prepare for, protect against, respond to, recover from and mitigate all hazards.

## **Ready**

[www.ready.gov](http://www.ready.gov)

A program of The Department of Homeland Security and the Federal Emergency Management Agency, Ready is a national campaign designed to educate and empower Americans to prepare for and respond to emergencies including natural and man-made disasters. The goal of the campaign is to get the public involved and ultimately to increase the level of basic preparedness across the nation.

[www.ready.gov/business](http://www.ready.gov/business)

Ready Business will assist businesses in developing a preparedness program by providing tools to create a plan that addresses the impact of many hazards. This website and its tools utilize an "all hazards approach."

**Suggested Citation:**

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## **Appendix C: Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico: Workboats Guide**



# Oyster AQUACULTURE

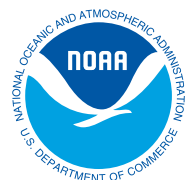
**Rusty Grice**  
**Leslie Sturmer**  
**Bill Walton**  
**Erik Lovstrand**  
**Natalie Simon**  
**Brian Callam**

These fact sheets for the off-bottom oyster aquaculture industry in the Gulf of Mexico provide guidelines and suggested safety procedures in preparing for tropical storms and hurricanes:

- **Introductory Planning Guide**
- **Adjustable Long-Line Farms**
- **Floating Bag Farms**
- **Floating Cage Farms**
- **Land-based Operations**
- **Workboats**

To access all of the fact sheets in this series, visit the National Sea Grant Library at [nsgl.gso.uri.edu](http://nsgl.gso.uri.edu). Using the "search the catalog" function, search "Oyster Aquaculture Hurricane Preparedness Series."

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## Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico **Workboats Guide**

Boats are one of the most valuable assets belonging to an oyster grower, and protective measures should be taken before, during, and after a hurricane, tropical storm, or severe weather event. This fact sheet provides guidance related to planning and preparation, as well as precautionary suggestions, for boat owners. Following these guidelines does not exempt you from being held responsible should your boat cause damage to another's property. Also, acquisition of safety equipment and following the suggested procedures does not necessarily assure that your boat will not be damaged in a storm. This fact sheet is part of a series, which provides an overview of storm preparation and planning for oyster aquaculture operations in the Gulf of Mexico region.



Photo courtesy of Boonedocks Oyster Company

### **PRIOR TO HURRICANE SEASON**

Develop a plan of action to secure your boat by trailering it from the threatened area. If your boat cannot be trailered, determine in advance whether to secure at a marina, dry storage facility, mooring, or hurricane refuge in a protected cove or upriver. A checklist of equipment and supplies needed for any of these options should be prepared in advance. Following are important considerations.

- Maintain an inventory list of all boat equipment. Note items you will remove from the boat and those you will leave on board. Items of value should be marked so that they can be readily identified.
- Take photographs or video with a time stamp of your boat and its associated gear.
- Consolidate all documents including

insurance policies, boat registration, engine numbers, equipment inventory, lease agreement with marina or storage area, photographs, and telephone numbers of appropriate authorities, such as the harbor master, U.S. Coast Guard, National Weather Service, insurance agent, etc. Keep these documents in your possession in a locked waterproof box.

- Check with marine and law enforcement organizations for local plans.
- Make sure your insurance policy is current. Your policy may contain helpful information relative to what you should and should not do if there is loss or damage to your boat. Understand coverages, exclusions, and your duties as a boat owner.
- Keep your boat in sound condition. This includes the hull, motor, hardware, and electronics.
- Check that lifesaving and firefighting equipment are in good condition and readily accessible.
- Check that radio equipment for receiving weather information is in working order.
- Plan how to remove and/or secure all boat gear, including radios, antennas, deck boxes, bimini tops, davits, booms, winches, tumblers, etc.
- Purchase necessary supplies ahead of time, such as additional mooring lines (preferably nylon for strength and stretch, and minimum size of 5/8"), additional anchors (should be oversize, 25 pounds or heavier), fenders, fender boards, chafing gear, and screw anchors. These items may not be readily available during hurricane season.

- Make sure that fuel tanks are full, fuel filters are clean, batteries are charged, and bilges are clean throughout the season.
- Determine how long it will take to implement your plan so you will have an accurate estimate of time and work involved.

#### **Non-trailerable Boats:**

- Check your lease or rental agreement with the marina or dry storage area. Know your responsibilities and liabilities, as well as those of the marina or dry storage area.
- Locate hurricane moorings in advance and obtain permission from appropriate persons.
- Inspect your boat's deck hardware and assess the size and structural attachment of the primary cleats and other hardware. These high load/high stress points should have substantial backing plates and be secured with bolts of adequate size.

### **DURING HURRICANE SEASON**

A tiered approach to preparation, which has been adopted in each fact sheet, allows growers to stage tasks based on the storm or hurricane's track forecast. The authors developed the following color codes to address increasing levels of concern and action.

#### **CODE YELLOW**

Once a hurricane or tropical storm has formed in the Gulf of Mexico or has a chance of entering the Gulf, it is time to begin preparations for securing your boat. Note that the timeline is fluid and will depend on the storm's speed



Photo courtesy of Alan Youngblood, Gainesville Sun

and track. Because your boat will be needed to implement the storm plan for your oyster farm, it is important to address as many of these activities in advance.

**Trailerable Boats:**

- Determine the requirements to load and haul your boat to a safe area.
- Make sure your tow vehicle is capable of properly moving the boat.
- Check the condition of your trailer, tires, bearings, and axle. Too often a flat tire, frozen bearings, or broken axle can prevent an owner from moving a boat.

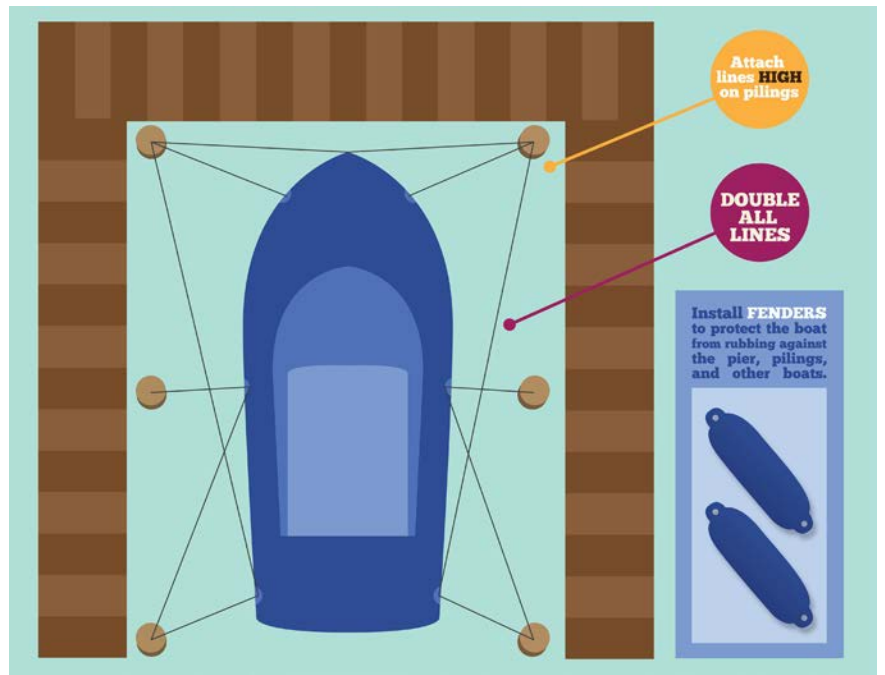
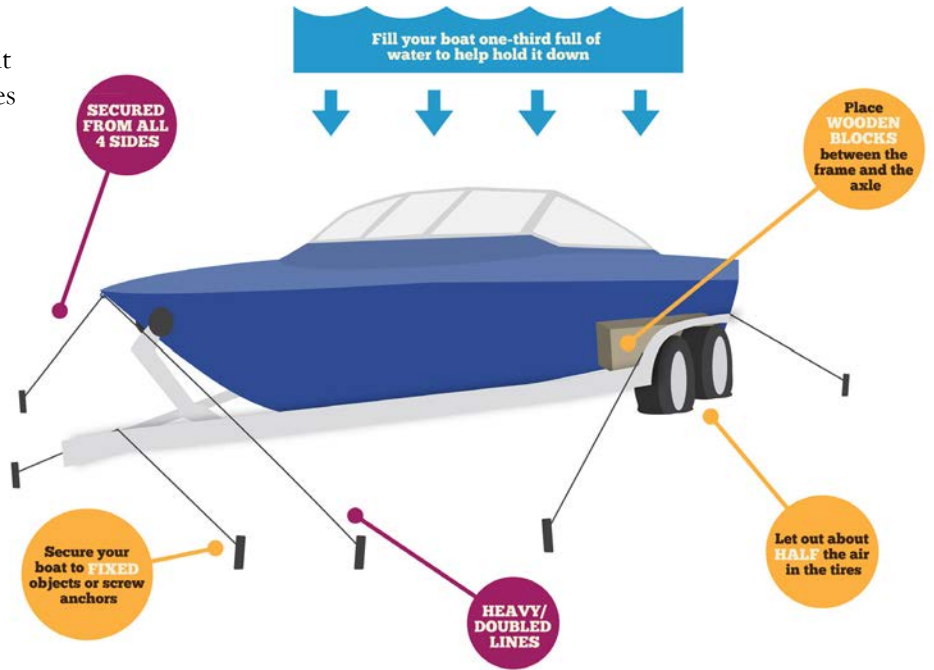
**Non-trailerable Boats:**

If your boat will be moored at a dock or in a marina, a storm surge could cause your boat to bang against the dock or become impaled on the pilings.

- Install heavy-duty fender boards (2"x6") on a bare wood center piling to prevent damage if your boat must remain dockside at a private dock or marina. In addition, acquire fenders of adequate size and strength (for example, old tires are good) to secure to your boat for protection.
- Put some type of preventer at the top of pilings so lines cannot slip off; for example, attach a 2" by 4" wooden board perpendicularly to the piling.
- Have adequate rope available for storm moorings, whether at dock or otherwise. Use double lines. The second set of lines should be at least one size larger than the normal lines, including spring lines at a dock. Note that nylon line will stretch 5-10% of its length.
- Have adequate materials on hand, such as tape, rags, rubber or vinyl hoses, to cover all lines at rough points and prevent chafing of mooring lines.
- Check bilge pumps to be sure they are in working order.

**CODE ORANGE**

Once a hurricane or tropical storm watch has been issued and gear on your oyster farm has been secured, it is time to implement your plan to secure your boat. If your plan calls for trailering your boat, move it at least 36 hours before the hurricane is estimated to strike the area as there may be possible road closures. In the case of a fast-moving storm, it is recommended that you proceed with tasks associated with final stages of preparation.



**FIGURE 1.** Diagrams illustrating how to secure a boat and trailer on land (top) and a non-trailerable boat at a marina or dock (bottom). Images courtesy of Florida Sea Grant.

**Trailerable Boats:**

- Store your boat in a garage or building if you can. If not, place your boat in a location away from power lines, trees, or other objects that can fall on it.
- Lash your boat to the trailer, and place blocks between the frame members and the axle inside each wheel (Figure 1).
- Secure your boat with heavy lines to fixed objects. Because hurricane winds rotate and change direction, try to pick a location that allows you to secure the boat from four directions. It can be tied down to screw anchors secured in the ground (Figure 1).

- Remove the battery to eliminate the risk of fire or other damage.
- Consider letting out about half the air in the tires for lightweight boats and fill your boat one-third full of water to help hold it down. You may also install drain plugs so rainwater can accumulate in the boat.

#### **Non-trailerable Boats:**

- Secure your boat at a marina by doubling all lines and rig spring lines to cross fore and aft (Figure 1).
- Attach lines high on pilings to allow for tidal rise or surge, and make sure lines will not slip off pilings. Inspect pilings, and choose those that seem strongest and tallest and are properly installed.
- Provide chafing protection for all lines to protect them from wear at contact points.
- Check that batteries are fully charged and can run automatic bilge pumps for the duration of the storm. Consider backup batteries, and turn off all other devices consuming electricity.
- Remove all movable equipment, and lash down everything that cannot be removed.
- Do not raft boats together at moorings or docks, especially if larger and smaller boats are involved. The probability of damage to boats is greater if they are rafted together.
- If placing your boat in dry storage, lash your boat to its cradle with heavy lines. Remove drain plugs so accumulated water will drain and prevent the lift from collapsing. Never leave a boat in davits or on a hydro-lift.

#### **CODE RED**

When a hurricane or tropical storm warning has been issued, you must finalize your preparations if, and only if, you can accomplish them safely. Growers and employees must make a series of personal risk assessments. If a final inspection of your oyster farm is necessary, there will be limited time to secure your boat.

- Make sure all preparations are in place, and immediately take measures to secure your boat after checking the farm.

This information was modified from *The Disaster Handbook* published by the University of Florida/ Institute of Food and Agricultural Sciences, IFAS publications DPR-0718, DPR-0719, and DPR-0726, August 2005. To learn more about how to secure your boat during a hurricane, browse the following resources used in this fact sheet:

- **The BoatU.S. Guide to Preparing Boats & Marinas for Hurricanes**  
[www.boatus.com/hurricanes/HurricaneWarning.pdf](http://www.boatus.com/hurricanes/HurricaneWarning.pdf)
- **Hurricane Preparedness for Boat Owners, University of Florida/IFAS**  
[www.flseagrant.org/wp-content/uploads/DPR-0718-web.pdf](http://www.flseagrant.org/wp-content/uploads/DPR-0718-web.pdf)

- Do not stay aboard any boat during a hurricane or tropical storm. If you have taken all the precautions previously outlined, you have done all that can be done in anticipation of the storm.
- Stay in a protected and safe place. Stay tuned to news broadcasts and weather advisories concerning the storm so that you will know when the danger has passed.

#### **POST-STORM RECOVERY**

Oyster growers must be ready to take care of their farms as soon as it is safe and reasonable to do so. After a storm has passed, the following tasks should be considered.

- Check the condition and security of your boat before attempting to move, start, or operate it. If damage has occurred, document with photographs and contact your insurance agent.
- Check with local information sources regarding access to boat ramps in the vicinity of your farm. Authorities may limit access in heavily damaged areas.
- Assess the risks of inspecting your oyster farm, and proceed when safe. Watch carefully for obstructions and loose debris in the water. Markers and other aids to navigation may be missing.

This fact sheet is the result of a collaborative effort among shellfish aquaculture extension specialists in the Sea Grant programs of Florida, Mississippi-Alabama, and Louisiana. For further information, contact:

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The views expressed herein do not necessarily reflect the views of any of these organizations.

The information and checklists provided in this series of fact sheets are meant as guides only. Following these guidelines and suggested safety procedures does not assure that damages will not occur to oyster crops, gear, or facilities.

## **Appendix D: Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico: Floating Bag Farms Guide**



# Oyster AQUACULTURE

**Bill Walton**  
**Leslie Sturmer**  
**Brian Callam**  
**Erik Lovstrand**  
**Natalie Simon**  
**Rusty Grice**

These fact sheets for the off-bottom oyster aquaculture industry in the Gulf of Mexico provide guidelines and suggested safety procedures in preparing for tropical storms and hurricanes:

- **Introductory Planning Guide**
- **Adjustable Long-Line Farms**
- **Floating Bag Farms**
- **Floating Cage Farms**
- **Land-based Operations**
- **Workboats**

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This publication was supported by Florida Sea Grant, the Mississippi-Alabama Sea Grant Consortium, and Louisiana Sea Grant. GOMSG-H-20-006



## Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico Floating Bag Farms Guide

Many oyster growers in the Gulf of Mexico region use the floating bag system, an off-bottom culture gear. This fact sheet provides guidance related to storm preparation and planning for this gear type. It is part of a series providing an overview of storm preparation and planning for other oyster aquaculture operations, including adjustable long-line farms, floating cage farms, land-based operations, and workboats.

The floating bag system uses a series of bags, typically buoyed by twin floats. The bags are attached to a main line that is anchored at either end, but anchoring configuration can vary by site. The floats may have removable caps, allowing a farmer to fill the floats and sink the bag to the sea bottom, but many float designs do not have this capability. Bags are flipped to allow for partial air drying, which provides some control of biofouling.



Photo courtesy of Orlando Sentinel

### INSTALLATION

During installation of the floating bag system, there are several important considerations.

- Assess the site’s exposure to storms as a primary factor in site selection.
- Orient main lines parallel to prevailing winds and waves.
- Choose an anchoring system suitable to the bottom type.
- Install substantial, durable anchors (buried to at least 5 feet depth) that will hold in the farm’s bottom substrate in the strongest storms (see Figure 1 for some options).



**FIGURE 1.** Two types of anchors used to secure floating cage main lines: helical screw anchor (left) and arrowhead anchor (right). Photos courtesy of Auburn University Shellfish Lab

- Bury anchors (typically helical metal screw anchors) fully in the sediment to reduce projection above the sea floor, corrosion, and tangling hazard.
- Invest in durable main line that meets the supplier's recommendation with some protection from chafing at friction points (e.g., anchor attachment).
- Allow sufficient spacing between lines to ensure bags do not collide in bad weather.
- Use a system that will reinforce the bag to reduce chafing at friction points (see Figure 2 for one example).
- If floats have removable caps, invest in and practice with a system, such as a mechanical davit or a compressor to fill floats with air (with a back-up system in place), that allows for safe and efficient sinking and re-floating of bags.
- Place identifying tags on each bag.

### PRIOR TO HURRICANE SEASON

Prior to the onset of hurricane season, oyster farmers should take these steps to reduce the risk of losses.

- Check stocking densities and reduce as necessary (though some farmers have had success by overstocking bags to achieve neutral buoyancy just prior to a storm).
- Check biofouling and control on a routine basis.
- Check all lines for chafing (especially near the clips) and repair as needed.
- Check all bag clips are secured and in good condition at attachment points.

- Have crew conduct timed practices to gauge time needed per line to prepare for a storm.
- For shoreside operations, pick up loose pieces of equipment and secure bags to reduce loss from flooding and wind.
- Review storm plan with crew and family so they can account for personal preparations alongside farm preparations.

### DURING HURRICANE SEASON

A tiered approach to preparation, which has been adopted in each fact sheet, allows growers to stage tasks based on the storm or hurricane's track forecast. The authors developed the following color codes to address increasing levels of concern and actions.

#### CODE YELLOW

Once a hurricane or tropical storm has formed in the Gulf of Mexico or has a chance of entering the Gulf, it is time to begin preparations according to the farm's plan. Note that the timeline is fluid and will depend on the storm's speed and track.

- Re-check stocking densities and reduce as necessary. If opting to overstock bags to achieve slightly positive buoyancy, ensure stocking is appropriate.
- Farmers opting to sink their bags below the surface but still float off the bottom by overstocking bags should consider taking this step now.
- Re-check all lines for chafing (especially near the clips) and repair as needed.
- Ensure all bag clips are secured and in good condition.
- Secure any empty bags on shore or on lines.

- Document the condition of the farm with dated photographs and notes.
- Document the numbers of various sizes of oysters.
- Review workboat(s) plan.

### CODE ORANGE

Once a hurricane or tropical storm watch has been issued, final preparations should begin. In the case of a fast-moving storm, proceed with tasks associated with final stages of preparation.

- Sell product as market allows.
- Track the storm's progress frequently and carefully. When assessing whether to sink bags, keep in mind the amount of time necessary to carry out the sinking operation. Farmers should also weigh the risks of bags and oysters being buried in the substrate.
- Remember that the day before the storm is to make landfall, farmers should not plan to be on the water. They will need that day for other preparations and the weather will likely not allow for it.
- If weather conditions do not warrant sinking bags, consider adding slack to anchor lines to allow for storm surge. Alternatively, some farmers opt to tighten their mainlines to pull bags under the water surface.
- If weather conditions warrant sinking bags, remove both floats from bags and allow them to rest on the

bottom or remove one float or alternate floats to partially or completely submerge the bags to keep them just above the bottom. Store floats safely onshore.

- For systems that have floats with caps, remove caps from floats or alternate floats and ensure all air from floats is removed when sinking.
- Some growers suggest replacing caps on floats (once all air is removed) to prevent sediment from filling the floats (though this may depend on sediment type). This adds considerable time to preparations.
- If allowed by state regulations, some farmers opt to tow floating bags to more protected areas.
- Prepare to implement workboat(s) plan.

### CODE RED

When a hurricane or tropical storm warning has been issued and there is a high probability of being in the path of the storm, farmers must conclude final preparations if and only if they can be accomplished safely. Farmers will make a series of personal risk assessments.

- Conduct last check of farm.
- Implement workboat(s) plan.
- Get to safety.

### POST-STORM RECOVERY

Oyster growers and their employees must be ready to take care of the needs of the farm as soon as it is safe and reasonable to do so. After a storm has passed, the following tasks should be considered.

- Assess risk of returning to farm, and proceed only when safe.
- Patrol the area upstream and downstream of the farm for significant debris that could entangle or dislodge gear once it is raised, and remove or secure debris.
- Document the condition of the farm with dated photographs and notes.
- Refloat bags as soon as practically possible by adding flotation and/or reducing stocking densities.
- If caps were removed from floats, use systems designed for this task, with bags lifted from reinforced points, allowing water to drain out the end caps and being careful to work any bags out of the sea floor if necessary.
- If necessary, use an on-board washdown hose to rinse sediment off the bags or out of floats and recap once washed down.



**FIGURE 2.** Use of a PVC pipe bar to reinforce bag and reduce friction where clips attach as one example of a method to reduce chafing. Photo courtesy of Outlaw Oyster Company

- Assess and document oyster survival, gear condition, and losses.
- Once mortality risk has passed, resume normal biofouling regimen.
- Communicate with public agencies about closures and effects of the storm.

- Communicate with buyers and suppliers to provide situation and outlook reports.

### ACKNOWLEDGMENTS

*We are grateful for discussions and input from several commercial growers using floating bags that greatly improved this fact sheet.*



Photo courtesy of Pelican Oyster Company

This fact sheet is the result of a collaborative effort among shellfish aquaculture extension specialists in the Sea Grant programs of Florida, Mississippi-Alabama, and Louisiana. For further information, contact:

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## **Appendix E: Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico: Floating Cage Farms Guide**



# Oyster

## AQUACULTURE



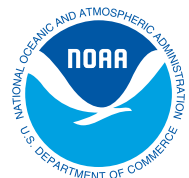
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## Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico

### Floating Cage Farms Guide

Many oyster growers in the Gulf of Mexico region use the floating cage system, an off-bottom gear. This fact sheet provides guidance related to storm preparation and planning for this gear type. It is part of a series providing an overview of storm preparation and planning for other oyster aquaculture operations, including adjustable long-line farms, floating bag farms, land-based operations, and workboats.

The floating cage system uses a series of cages that hold multiple bags of oysters (typically 6), buoyed by twin floats. The cages are typically attached by lateral lines to a main line that is anchored at either end, but anchoring configuration can vary by site. The floats have removable caps, allowing a farmer to fill the floats and sink the cage to the sea bottom. The cage may be raised later, emptying the floats of water to have them floated again. Cages that are flipped on top of the floats allow for air drying, which controls biofouling.



Photo courtesy of Mark Wallheiser

#### INSTALLATION

During installation of the floating cage system, there are several important considerations.

- Assess the site’s exposure to storms as a primary factor in site selection.
- Orient main lines parallel to the prevailing wind and waves.
- Choose an anchoring system suitable to the bottom type
- Install substantial, durable anchors (buried to at least 5 feet depth) that will hold in the farm’s bottom substrate in the strongest storms (see Figure 1 for options).



**FIGURE 1.** Two types of anchors used to anchor the floating cage mainlines: helical screw anchors (top) and arrowhead anchors (bottom). Photos courtesy of Auburn University Shellfish Lab

- Bury anchors (typically helical metal screw anchors) fully in the sediment to reduce projection above the sea floor, corrosion, and tangling hazard.
- Invest in durable anchor line with some protection from chafing at friction points (e.g., anchor attachment).
- Allow sufficient spacing between lines to ensure cages do not collide in bad weather.
- Invest in and practice with a system, such as a mechanical davit or a compressor to fill the floats with

air (with a back-up system in place), that allows for safe and efficient sinking and re-floating of cages. (Figure 2)

- Place identifying tags on each cage or bag.

### PRIOR TO HURRICANE SEASON

Prior to the onset of hurricane season, oyster farmers should take these steps to reduce the risk of losses.

- Maintain appropriate stocking densities so that cages are not crowded and heavy.
- Air dry cages to control biofouling on a routine basis.
- Make it a habit to check bridles and lines when flipping to ensure lines do not get tangled.
- Check all lines for chafing, and repair as needed.
- Check all door closures to ensure that the attachments are secure and not worn.
- Have extra caps on hand in workboat.
- Remove empty cages from the line, as these are prone to come off the line in bad weather.
- Have crew conduct timed sinking practices (including in less than ideal weather conditions) to gauge time needed per line to correctly sink cages.
- For shoreside operations, pick up loose pieces of equipment, and secure cages and bags to reduce loss from flooding and wind.



**FIGURE 2.** A mechanical davit used to raise sunken floating cages from the sea floor after the storm has passed. Photo courtesy of Jason Rider



Photo courtesy of Grand Isle Sea Farms

- Review storm plan with crew and family so they can account for personal preparations alongside farm preparations.

## DURING HURRICANE SEASON

A tiered approach to preparation, which has been adopted in each fact sheet, allows growers to stage tasks based on the storm or hurricane’s track forecast. The authors developed the following color codes to address increasing levels of concern and actions.

### CODE YELLOW

Once a hurricane or tropical storm has formed in the Gulf of Mexico or has a chance of entering the Gulf, it is time to begin preparations according to the farm’s plan. Note that the timeline is fluid and will depend on the storm’s speed and track.

- Re-check stocking densities and reduce as necessary, taking special care with any bags of seed as the smaller mesh can produce more water resistance.
- Re-check all lines for chafing and repair as needed.
- Re-check that all bridles and pucks are in good condition.
- Re-check that all bag and cage closures are in good condition.
- Consider consolidating all small seed (e.g., seed held in 2 mm bags) to one section of cages so that you can re-float those cages first once the threat has passed.

- Secure any empty bags and cages on shore or on lines.
- Document the condition of the farm with dated photographs and notes.
- Document the numbers of various sizes of oysters.
- Review workboat(s) plan.

### CODE ORANGE

Once a hurricane or tropical storm watch has been issued, final preparations should begin. In the case of a fast-moving storm, proceed with tasks associated with final stages of preparation.

- Sell product as market allows.
- Track the storm’s progress frequently and carefully. When assessing whether to sink cages, keep in mind the amount of time necessary to carry out the sinking operation.
- Remember that the day before the storm is to make landfall, farmers should not plan to be on the water. They will need that day for other preparations, and the weather will likely not allow it.
- If weather conditions do not warrant sinking cages based on personal judgment, consider adding slack to anchor lines to allow for storm surge.
- If weather conditions warrant sinking cages, ensure that cages sit “float down” on the bottom, with the wire mesh off the bottom (though this may depend on sediment type).

- Ensure all air from floats is removed when sinking, and walk or dive over the cages to be sure the pontoons are down, with adjustments made as needed.
- Some growers suggest replacing caps on floats (once all air is removed) to prevent sediment from filling the floats (though this may depend on sediment type). This adds time to preparations.
- Prepare to implement workboat(s) plan.

### CODE RED

When a hurricane or tropical storm warning has been issued and there is a high probability of being in the path of the storm, farmers must conclude final preparations if and only if they can be accomplished safely. Farmers will make a series of personal risk assessments.

- Conduct last check of farm.
- Implement workboat(s) plan.
- Get to safety.

### POST-STORM RECOVERY

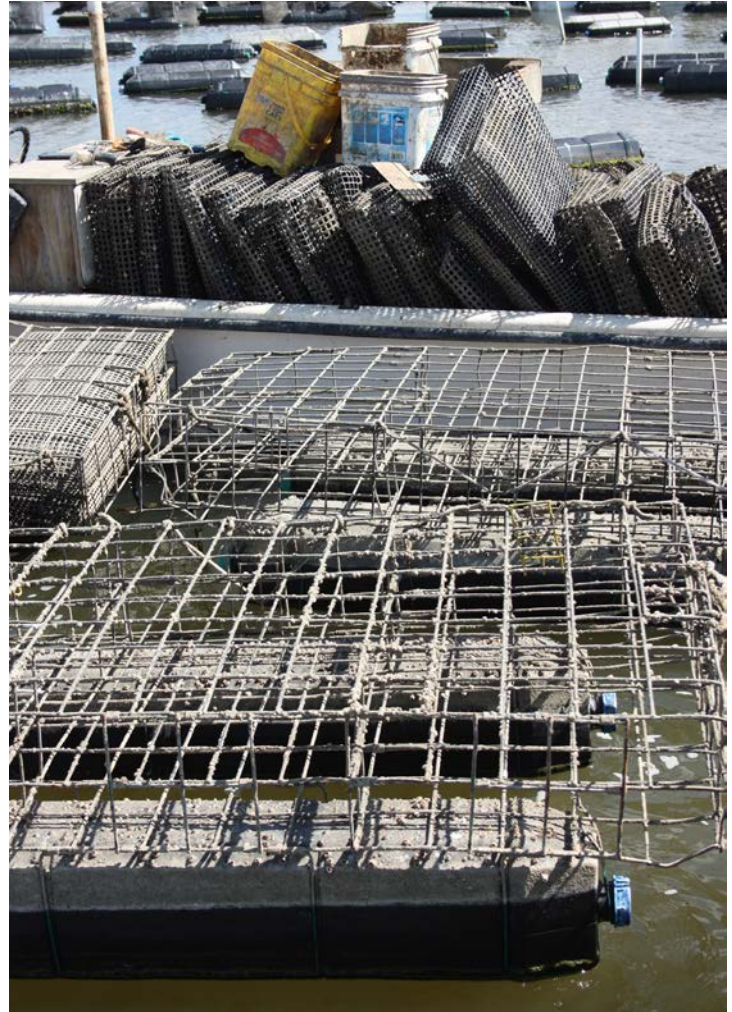
Oyster growers and their employees must be ready to take care of the needs of the farm as soon as it is safe and reasonable to do so. After a storm has passed, the following tasks should be considered.

- Assess risk of returning to farm and proceed only when safe.
- Patrol the area upstream and downstream of the farm for significant debris that could entangle or dislodge gear once it is refloat, and remove or secure debris.
- Document the condition of the farm with dated photographs and notes.
- Refloat cages as soon as practically possible, using the systems designed for this task, with cages lifted from reinforced points, allowing the water to drain out the end caps and being careful to work any cages out of the sea floor if necessary.
- If necessary, use an on-board washdown hose to rinse sediment out of floats, and recap once washed down.
- Assess and document oyster survival, gear condition, and losses.

- Once mortality risk has passed, resume normal biofouling regimen.
- Communicate with public agencies about closures and effects of the storm.
- Communicate with buyers and suppliers to provide situation and outlook reports.

### ACKNOWLEDGMENTS

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## **Appendix F: Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico: Adjustable Long-Line Farms Guide**



# Oyster

## AQUACULTURE

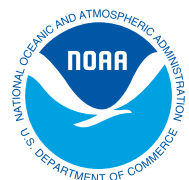
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## Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico

### Adjustable Long-Line Farms Guide

Many oyster growers in the Gulf of Mexico region use the adjustable long-line system (ALS), an off-bottom culture gear. This fact sheet provides guidance related to storm preparation and planning for this gear type. It is part of a series providing an overview of storm preparation and planning for other oyster aquaculture operations, including floating cage farms, floating bag farms, land-based operations, and workboats.

The ALS system uses a tensioned monofilament line strung between anchored pilings with riser posts placed at uniform intervals allowing adjustment of the baskets' height in or above the water column. This guidance is primarily for intertidal operations.



Photo courtesy of USDA Risk Management Agency

#### INSTALLATION

During installation of the ALS system, there are several important considerations.

- Assess the site's exposure to storms as a primary factor in site selection.
- Orient lines perpendicular to the prevailing wind and waves, if possible.
- Invest in durable line that meets the supplier's recommendation with some protection from chafing, such as an outer sleeve.
- Invest in basket-to-line clips that secure the baskets in position on the line.



**FIGURE 1.** Two types of tensioning systems that allow adjustment of line tension in the adjustable long-line system: the donut tensioner (left) and the turnbuckle (right). Photos courtesy of Auburn University Shellfish Lab

- Be sure lines are taut. Some growers opt to use a donut tensioner or other system to adjust tautness (Figure 1).
- Install pilings and riser posts and allow to set prior to storm season.
- If using a sliding sleeve with a clip, install a top pin to ensure that the sleeve cannot come off the riser post top (Figure 2).
- Limit distance between riser posts to about 8-9 feet, with enough room for no more than three baskets.
- Bury riser posts at least one-third of their length.
- Bury at least 50% of the end pilings in the sediment, leaving enough length for at least 3-4 feet to extend above mean high water.
- Include one “storm position” clip in the adjustable clip system, where baskets are suspended just above the bottom during storm events, beneath the heavy wave action.
- Place identifying tags on each basket.

### PRIOR TO HURRICANE SEASON

Prior to the onset of hurricane season, oyster farmers should take steps to reduce the risk of losses.

- Check stocking densities and reduce as necessary.
- Check biofouling and control on a routine basis.
- Check all lines for chafing (especially near the clips) and repair as needed.
- Check for good tension on lines.
- Ensure all basket clips are secured and in good condition.

- Ensure all clips on riser posts are in place, holding the line as intended, and clear of fouling.
- Check for fouling on the riser posts and remove barnacles, oysters, and other hard organisms that could wear the line.
- Have crew conduct timed practices to gauge time needed per line to correctly lower baskets.
- For shoreside operations, pick up loose pieces of equipment and secure baskets to reduce loss from flooding and wind.
- Review storm plan with crew and family so they can account for personal preparations alongside farm preparations.

### DURING HURRICANE SEASON

A tiered approach to preparation, which has been adopted in each fact sheet, allows growers to stage tasks based on the storm or hurricane’s track forecast. The authors developed the following color codes to address increasing levels of concern and actions.

#### CODE YELLOW

Once a hurricane or tropical storm has formed in the Gulf of Mexico or has a chance of entering the Gulf, it is time to begin preparations according to the farm’s plan. Note that the timeline is fluid and will depend on the storm’s speed and track.

- Re-check stocking densities and reduce as necessary, taking special care with any baskets of seed as the smaller mesh can produce more water resistance.
- Re-check all lines for chafing (especially near the clips) and repair as needed.

- Ensure all bag clips are secured and in good condition.
- Ensure all clips on riser posts are in place and holding the line as intended.
- Secure any empty baskets on shore or on lines.
- Document the condition of the farm with photographs and notes.
- Document the numbers of various sizes of oysters.
- Review workboat(s) plan.

### CODE ORANGE

Once a hurricane or tropical storm watch has been issued, final preparations should begin. In the case of a fast-moving storm, proceed with tasks associated with final stages of preparation.

- Sell product as market allows.
- Track the storm's progress frequently and carefully. When assessing whether or not to lower baskets, keep in mind the amount of time necessary to carry out the operation. Remember that the day before the storm is to make landfall, you should not plan to be on the water. You will need that day for other preparations and the weather will likely not allow it.
- If weather conditions warrant lowering baskets based on your judgment, lower all bags to the storm position on the riser clips.

- Prepare to implement workboat(s) plan.

### CODE RED

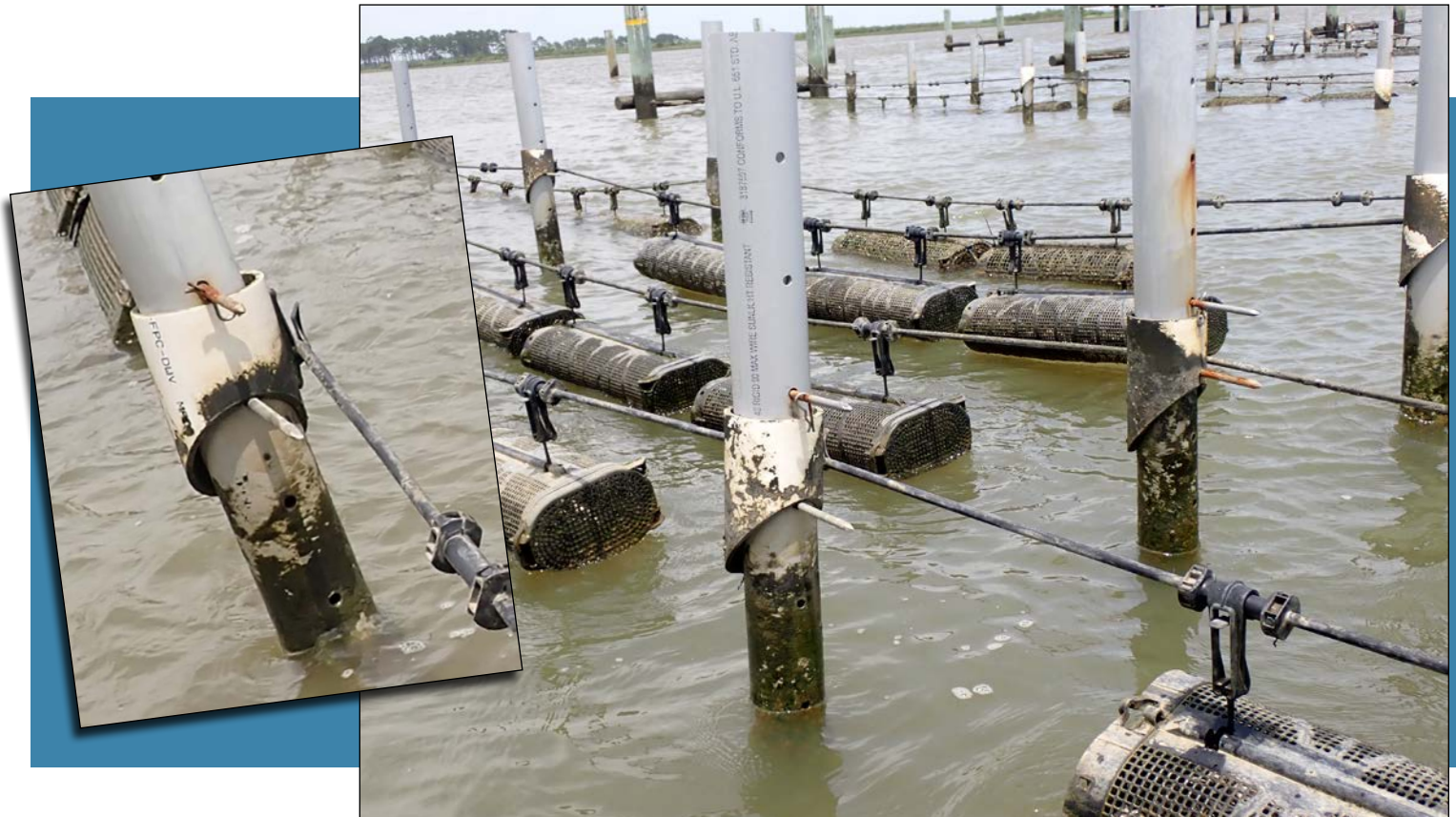
When a hurricane or tropical storm warning has been issued and there is a high probability of being in the path of the storm, farmers must conclude final preparations if and only if they can be accomplished safely. Farmers will make a series of personal risk assessments.

- Conduct last check of farm.
- Implement workboat(s) plan.
- Get to safety.

### POST-STORM RECOVERY

Oyster growers and their employees must be ready to take care of the needs of the farm as soon as it is safe and reasonable to do so. After a storm has passed, the following tasks should be considered.

- Assess risk of returning to farm and proceed only when safe.
- Patrol the area upstream and downstream of your farm for significant debris that could entangle or dislodge your gear once it is raised, and remove or secure debris.
- Document the condition of the farm with photographs and notes.
- Return baskets to customary clip height on riser posts.



**FIGURE 2.** Adjustable long-line sleeve that allows the sleeve (with one clip) to be adjusted up or down the riser pole. Photo courtesy of Auburn University Shellfish Lab

- Assess and document oyster survival, gear condition, and losses.
- Once mortality risk has passed, move lines to high setting to prevent oyster and barnacle set that may occur after storms.
- Communicate with public agencies about closures and effects of the storm.
- Communicate with buyers and suppliers to provide situation and outlook reports.

## ACKNOWLEDGMENTS

*Leon Stott (oyster farm consultant, Australia) and other industry members contributed input for this fact sheet.*



Photo courtesy of Auburn University Shellfish Lab

This fact sheet is the result of a collaborative effort among shellfish aquaculture extension specialists in the Sea Grant programs of Florida, Mississippi-Alabama, and Louisiana. For further information, contact:

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The views expressed herein do not necessarily reflect the views of any of these organizations.

The information and checklists provided in this series of fact sheets are meant as guides only. Following these guidelines and suggested safety procedures does not assure that damages will not occur to oyster crops, gear, or facilities.

## **Appendix G: Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico: Land-Based Operations Guide**



# Oyster

## AQUACULTURE

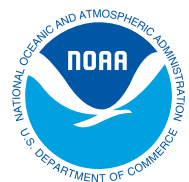
**Brian Callam**  
**Rusty Grice**  
**Leslie Sturmer**  
**Bill Walton**  
**Erik Lovstrand**  
**Natalie Simon**

These fact sheets for the off-bottom oyster aquaculture industry in the Gulf of Mexico provide guidelines and suggested safety procedures in preparing for tropical storms and hurricanes:

- **Introductory Planning Guide**
- **Adjustable Long-Line Farms**
- **Floating Bag Farms**
- **Floating Cage Farms**
- **Land-based Operations**
- **Workboats**

To access all of the fact sheets in this series, visit the National Sea Grant Library at [nsgl.gso.uri.edu](http://nsgl.gso.uri.edu). Using the "search the catalog" function, search "Oyster Aquaculture Hurricane Preparedness Series."

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 GOMSG-H-20-002



## Tropical Storm and Hurricane Preparedness for Off-bottom Oyster Aquaculture in the Gulf of Mexico

### Land-Based Operations Guide



Photo courtesy of Emily Colson, University of Florida/IFAS

Land-based oyster operations that are vulnerable to hurricanes, tropical storms, or severe weather events include seed production facilities and processing plants. This fact sheet provides guidance related to storm planning and preparation, as well as precautionary suggestions, for seed suppliers and wholesale dealers. It is part of a series providing an overview of storm preparation and planning for oyster aquaculture operations in the Gulf of Mexico region.

As the primary source of seed, hatcheries and nurseries are critical components of oyster aquaculture. These facilities are typically located on waterfront property and are at risk to coastal flooding and storm surge. Inside the hatchery, adult oysters (broodstock) are spawned to create oyster larvae that are grown in tanks and fed

cultured microalgae. Oysters complete the larval stages of their lifecycle in the hatchery and are then moved to a nursery setting to be grown large enough for the farm.

Market-size oysters are harvested and delivered by growers to a dealer's processing plant where they are washed, cleaned, sorted, packaged, and stored in a refrigerated cooler prior to distribution. Processing facilities are not necessarily located in flood-prone coastal areas but can be affected by power outages associated with high winds.

#### SITE SELECTION AND FACILITY DESIGN

There are several important considerations in preparing for storms through proper siting, designing, and constructing of land-based facilities. Buildings and structures used in



**FIGURE 1.** Filtration equipment installed on a trailer with quick disconnect and union fittings at the Louisiana Sea Grant Oyster Research Hatchery in Grand Isle, Louisiana. Photo courtesy of University of Florida/IFAS Shellfish Extension

processing shellfish must meet applicable federal and state regulations for sanitary operation; these requirements are not reviewed in this fact sheet.

- Assess vulnerability of the site to flooding and access to roads during flooding.
- Evaluate reliability of critical infrastructure (e.g., power, communications, etc.).
- Construct permanent structures to meet a minimum wind rating of 130 mph (178 km/hr) and comply with Federal Emergency Management Agency (FEMA) regulations pertaining to elevation in flood plain areas.
- Use concrete walls and metal roofing in your building design as these materials are considered the best construction option for hurricane resistance.
- Use breakaway walls for temporary structures or below elevated buildings.
- Use swales and/or berms to direct surface water flow around property and stabilize exposed soils. Criteria for surface water control techniques can be obtained from Soil and Water Conservation district offices.
- Provide adequate floor drainage in areas where tank drawdowns occur or shellfish are stored, as well as work areas that are routinely rinsed.
- Install backflow preventers to prevent contamination of potable water supply.
- Install generators with a capacity to operate critical facility components during power loss for 3 to 5 days (e.g., aerators, pumps, refrigerated coolers, etc.).
- Set up ground-level components for rapid disconnection to move inland in anticipation of storm surge or coastal flooding. For example, use quick disconnect or union fittings on pumps and filters or permanently install equipment on trailers or pallets (Figures 1 & 2).
- Maintain grounds around buildings to be free from conditions that may result in shellfish contamination, such as inadequate drainage, or accumulated shell.

- Identify alternate location(s) where equipment can be easily moved to avoid flooding and wind damage.
- Maintain access pathways to equipment that may be removed prior to a storm.

## PRIOR TO HURRICANE SEASON

Prior to hurricane season, seed suppliers and wholesalers should take steps to reduce the risk of losses.

- Develop and review a storm plan detailing personnel responsibilities and chain of command, primary and emergency contact information, and equipment evacuation designations based on storm strength (i.e., what gets removed from the site when a storm gets to a certain strength).
- Inform employees that if a storm approaches, they will be needed to prepare and implement the storm plan.
- Have a plan for assessing employees' availability after the storm.
- Develop and review a post-storm recovery plan including contact information and procedures, relevant local emergency and government contacts, insurance contact information and claim procedures, etc.
- Obtain civil defense or other identification documents for essential personnel to immediately return after an evacuation.
- Purchase and maintain a stockpile of storm preparation supplies (e.g., tarps, plywood, sandbags, etc.).
- Identify an inland off-site storage location that is accessible and able to receive equipment.
- Make sure generators are in working condition and fuel reserves are adequate.
- Clean up loose items around buildings and structures to reduce storm preparation workload.
- Have employees conduct at least one timed run-through of preparation activities to gauge the amount of time needed to implement the storm plan.
- Maintain inventory of oyster stocks to be able to quickly review needs during hurricane season.

## DURING HURRICANE SEASON

A tiered approach to preparation, which has been adopted in each fact sheet, allows seed suppliers and wholesalers to stage tasks based on the storm or hurricane's track forecast. The authors developed the following color codes to address increasing levels of concern and actions.

### CODE YELLOW

Once a hurricane or tropical storm has formed in the Gulf of Mexico or has a chance of entering the Gulf, it is time to begin preparations according to the facility's plan. Note that the timeline is fluid and will depend on the storm's speed and track.

- Re-check that all employees have received the storm plan and emergency contact information.

- Check that storm preparation supplies, including generator fuel reserves, are adequate and easily available.
- Document the pre-storm condition of the facility and equipment with dated photographs and notes.
- Make sure the off-site storage location is ready for receiving equipment and remove items that are not necessary for continued operation.

**Hatchery and nursery facilities:**

- Inventory and prioritize in-house larvae, post-set, seed, and broodstock. For example, larvae are the least expensive to produce, so efforts may be minimal in securing these stocks.
- Purchase algal concentrates that can be used to feed oyster stocks if algae cultures crash.
- Keep several bags of synthetic sea salt or rock salt on hand as storms can result in excessive rainfall, lowering salinities of inshore waters.

**Processing plant:**

- Inventory in-house product and pending oyster purchases and sales.
- Prepare to ship out orders sooner than the normal distribution schedule.
- Notify suppliers of the storm plan so shipments do not arrive at your facility.

**CODE ORANGE**

Once a hurricane or tropical storm watch has been issued, final preparations should begin. In the case of a fast-moving



**FIGURE 2.** Filtration equipment installed on a pallet with quick disconnect and union fittings at the Louisiana Sea Grant Oyster Research Hatchery in Grand Isle, Louisiana. Photo courtesy of John Supan

storm, proceed with tasks associated with final stages of preparation.

**Hatchery and nursery facilities:**

- Prepare generator for operation in the event of power loss or evacuation.
- Perform routine cleaning of systems that will be maintained in the hatchery through evacuation (e.g., algal stocks, broodstock holding/conditioning system, etc.).
- Add broodstock not held in conditioning or holding tanks into these systems or return them to the farm.
- Move or prepare to move spare pumps, filters, hoses, and other items to secure storage location (based on predicted storm strength, items may be stored onsite or at an inland location).
- Fill empty tanks onsite at least half full of water to prevent moving from wind or flooding. Place loose gear inside the tanks.
- Secure outdoor raceways and weller tanks with rope, straps, or bungee cords to the tank support system.
- Move nursery drum silos and FLUPSY wellers to higher ground or inland site.

**Processing plant:**

- Locate an alternative storage cooler for remaining inventory or load into a refrigerated truck or trailer if required temperature can be maintained.
- Remove all shell and other materials that may spoil from the facility and grounds to prevent attracting pests and vermin.

**CODE RED**

When a hurricane or tropical storm warning has been issued, final preparations must be concluded if and only if they can be accomplished safely. A series of personal risk assessments must be made.

If the facility is not able to withstand predicted wind speeds or storm surge, vital equipment should be removed and transported to a designated inland location for safeguarding.

**Hatchery and nursery facilities:**

If your hatchery can withstand predicted wind speeds and storm surge, conduct the following activities to reduce losses until employees can return to the facility.

- Feed broodstock oysters heavily, and make sure broodstock sumps are full of seawater.
- Drop the water volume of larval tanks and feed extra algae.
- Swirl any stock algal cultures and transfer darker cultures.
- Drain seawater lines and fill with freshwater if time permits.
- Activate recirculating systems if the facility has the capability to do so.
- Confirm the generator is operating and all critical equipment are connected.

- Hook up a small single-phase blower to the generator to provide aeration to tanks containing oyster larvae, post-set, and broodstock.

If the nursery is vulnerable to storm surge and coastal flooding, conduct the following activities to reduce losses of seed and equipment.

- Shut off electricity to pumps and nursery facility at the breaker box.
- Pull and secure pumps so they do not become submerged.
- Store nursery seed in seawater-dipped towels or drain sock material and place in a cooler to keep damp and cool. Within 2-3 days, seed will need to be placed back into the water.
- Transport nursery seed (if feasible) to another in-state growing area that likely will not be affected by the storm event.
- Stock nursery seed large enough into small mesh (2 mm) bags and secure on farm with other culture gear.

#### **Processing plant:**

- Document storage temperature of cooler (if product remains onsite) with a recording thermometer device, such as Therman Blue®.
- Sandbag the cooler and exterior doors to minimize storm surge or flood waters from entering the building.
- Transport inventory via refrigerated truck or temperature-controlled trailer to a predetermined location that is less likely to experience flooding and extended power outages.

## **POST-STORM RECOVERY**

Seed suppliers, wholesalers, and their employees must be ready to take care of the needs of the land-based facilities as soon as it is safe and reasonable to do so. After the storm has passed, the following tasks should be considered.

- Assess risk of returning to the facility and proceed only when safe.
- Notify employees to return to the site for post-storm maintenance and activities.
- If damage occurred, document condition of facility and equipment with dated photographs and notes.

- Return all equipment from alternative off-site storage location.
- Communicate with buyers to provide situation and outlook reports.

#### **Hatchery and nursery facilities:**

- Return water flow to tanks stocked with oysters as quickly as possible.
- Drain, clean, and refeed tanks as soon as clean seawater is obtainable.
- Create a brine with synthetic sea salt or rock salt and add to static tanks to increase salinities if necessary (this is a temporary measure until incoming waters return to normal salinities).
- Assess and document oyster survival and condition.

#### **Processing plant:**

- Take photos to verify the status of the facility in case the local shellfish plant inspector is delayed from visiting the facility.
- If the facility was not flooded, inform the plant inspector and continue with business as usual.
- If the facility was flooded but waters did not reach the cooler and power was not interrupted, clean and sanitize flooded areas and inform the plant inspector. If product is remaining in the cooler, distribute after inspection.
- If flood waters permeated the cooler or power was disrupted and shellstock remaining in cooler exceeded critical temperature limits in the Hazard Analysis Critical Control Point (HACCP) plan, then product is adulterated and must be properly disposed.
- Check with the inspector to find out if potable water at the plant must be tested prior to reopening.

## **ACKNOWLEDGMENTS**

*Scott Rickard (Auburn University Shellfish Lab), John Supan (oyster hatchery consultant), and Florida Department of Agriculture and Consumer Services contributed input for this fact sheet.*

This fact sheet is the result of a collaborative effort among shellfish aquaculture extension specialists in the Sea Grant programs of Florida, Mississippi-Alabama, and Louisiana. For further information, contact:

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The views expressed herein do not necessarily reflect the views of any of these organizations.

The information and checklists provided in this series of fact sheets are meant as guides only. Following these guidelines and suggested safety procedures does not assure that damages will not occur to oyster crops, gear, or facilities.

## **Appendix H: Storm preparedness guide for suspended shellfish aquaculture in Atlantic Canada**

# Storm Preparedness Guide for Suspended Shellfish Aquaculture in Atlantic Canada



## PRIOR TO HURRICANE SEASON

Growers can make preparations to minimize losses due to extreme weather

- Continuous monitoring and regular control of **biofouling** on all suspended gear and infrastructure
- Evaluate lines, bridles, and cages throughout regular operations to **ensure integrity**
- Review **storm preparedness and post-recovery plans** with employees

## HURRICANE SEASON GUIDELINES

Hurricane season occurs between June 1 to November 30

### PRE-HURRICANE PREPARATIONS

High likelihood of hurricane tracking to Atlantic Canadian waters

- **Examine condition of gear, lines, and infrastructure**, replace or repair where needed. Ensure all bag and cage closures are in working order
- **Secure any loose gear** (i.e., collectors, empty cages, and bags) to the grid or store on land, protected from wind, waves, and flooding.
- **Re-examine stocking densities**, redistribute stock to minimize uneven load or overstock bags to increase positive buoyancy, if able to do so.
- Consider **combining oyster seed and early juveniles** to one section of the farm.
- Depending on site inventory, growers **should identify areas to prioritize sinking**, in part or fully to the bottom (i.e., seed or market-sized stock).
- **Determine feasibility of sinking gear**, fully to the bottom or partially, for all or a portion of the farm.
- **Document site status** with dated photographs and inventory (i.e., biomass)
- **Review storm preparedness plan** for workboats and land infrastructure with employees.

These guidelines are a compilation of best practices to reduce damages and losses incurred by shellfish aquaculture farms due to weather events.

# Storm Preparedness Guide for Suspended Shellfish Aquaculture in Atlantic Canada



## HURRICANE SEASON GUIDELINES

Hurricane season occurs between June 1 to November 30

### TROPICAL STORM OR HURRICANE WATCH ISSUED

- **Continuous tracking of the storm** to evaluate next actions
- **Harvest product** if market permits or **transfer harvestable product** to a “storm-proof” storage facility
- If regulations permit, **tow bags** to area(s) that are expected to have less impacts (i.e., another lease)
- **Lower surface gear or sink the gear**, in part or fully to the bottom by removing bags from the floats, remove or fill one float with water, or fill both floats with water
- Prepare to **execute storm preparedness plan** for workboats and land infrastructure. **Review post-storm recovery plan** with employees
- **Prepare emergency gear** (i.e., charge long range radio or cell phones, verify working operation of generators, and obtain fuel/diesel)

### PRIOR TO LANDFALL

- **Visually inspect farm** (> 24 hr anticipated landfall)
- **Execute storm preparedness plan** for workboats and land infrastructure
- Focus on **personal preparations and protection**

### POST-STORM RECOVERY

- **Contact employees** to evaluate personal availability and mobilization risk (i.e., road damage or flooding)
- **Assess accessibility of the farm** only return if conditions (i.e., wind or waves) allow
- On the water, **tour all accessible waters** surrounding the farm, remove or secure debris
- **Take pictures or video footage** and make detailed notes on the status of the farm
- **Return gear / stock to surface**, prioritizing seed and early juveniles
- **Communicate extent of damages** to associations and government bodies

## **Appendix I: Storm preparedness guide for land based aquaculture activities in Atlantic Canada**

# Storm Preparedness Guide for Land based Aquaculture Activities in Atlantic Canada



## PRIOR TO HURRICANE SEASON

Operators of processing plants and hatchery / nursery facilities can make preparations to minimize losses due to extreme weather

- Evaluate the site for **potential flooding** and identify areas to move equipment / gear to avoid flooding
- Evaluate **critical assets** (i.e., cell coverage and electricity)
- **Remove outside debris and store** essential gear and equipment in temporary or permanent structures
- **Evaluate and secure storm supplies** (i.e., fuel, potable water, and algal concentrates)
- **Install and maintain generators** for critical operations (i.e., pumps, coolers, and refrigerators)

## HURRICANE SEASON GUIDELINES

Hurricane season occurs between June 1 to November 30

### PRE-HURRICANE PREPARATIONS

High likelihood of hurricane tracking to Atlantic Canadian waters

- **Re-evaluate and secure storm supplies** (i.e., fuel, potable water, synthetic sea salt, and algal concentrates)
- **Evaluate generator(s)** to ensure proper operation
- **Secure any loose gear** (i.e., collectors, empty cages, and bags) or debris in temporary or permanent structures
- **Document condition of the land-based facility** with dated photographs and inventory (i.e., biomass)
- Processing plants: inquire with distributors about **sending out shipments earlier**
- **Review storm preparedness and post-recovery plans** with employees

# Storm Preparedness Guide for Land based Shellfish Aquaculture in Atlantic Canada



## HURRICANE SEASON GUIDELINES

Hurricane season occurs between June 1 to November 30

### TROPICAL STORM OR HURRICANE WATCH ISSUED

- **Continuous tracking of the storm** to evaluate next actions
- **Clean all systems** to be in operation during a hurricane (i.e., tanks and algal culture)
- **Move redundant but crucial equipment** (i.e., pumps and filters) to another location
- Processing plants: identify potential locations for **alternate storage coolers**
- Prepare to **execute storm preparedness** plan for workboats and land infrastructure. **Review post-storm recovery plan** with employees
- **Prepare emergency gear** (i.e., charge long range radio or cell phones, verify working operation of generators, and obtain fuel/diesel)

### PRIOR TO LANDFALL

- **Visually inspect infrastructure**
- **Execute storm preparedness plan** for land infrastructure
- Focus on **personal preparations and protection**

### POST-STORM RECOVERY

- **Contact employees** to evaluate personal availability and mobilization risk (i.e., road damage or flooding)
- **Assess accessibility of the infrastructure**, only return if conditions (i.e., wind or waves) allow
- **Remove or secure debris**; return all **equipment** from off-site storage location
- **Take pictures or video footage** and make detailed notes on the status of the farm
- **Evaluate and document stock or product loss**; **clean** equipment and tanks
- **Communicate to distributors** expected operations and supply

**Appendix J: Storm preparedness guide for marine vessels**

# Storm Preparedness Guide for Marine Vessels



## PRIOR TO HURRICANE SEASON

Growers can make preparations to minimize losses due to extreme weather

- Ensure **insurance is current and review** policy for coverage. Update if needed
- **Maintain vessel and trailer** in working order. Maintain extra supplies (i.e., batteries)
- **Combine, duplicate, and secure vessel documents** (i.e., insurance, boat registration, engine details)
- Compile an **inventory list** to be maintained on vessel and updated as items are removed
- **Consolidate important phone numbers** (i.e., insurance, Coast Guard, and RCMP)
- **Review storm preparedness and post-recovery plans** with employees

## HURRICANE SEASON GUIDELINES

Hurricane season occurs between June 1 to November 30

### TROPICAL STORM OR HURRICANE WATCH ISSUED

Continuous tracking of the storm to evaluate next actions. Growers should avoid being on the water < 24 hr prior to landfall. After all on the water preparations are made, prepare vessels:

#### Trailerable Vessels

- **Haul vessel, secure** vessel to trailer, and **store** vessel / trailer in a building or an area absent of trees or debris
- **Remove batteries** from vessel and tow vehicle to reduce fire risk
- **Place blocks** at the trailer's tongue jack / wheel and fore / aft each wheel
- **Remove or secure movable equipment / gear** off the vessel, noting in inventory list to ensure supplies are replenished
- Using lines / ropes to **secure vessel / trailer** to fixed objects or anchors

# Storm Preparedness Guide for Marine Vessels



## HURRICANE SEASON GUIDELINES

### TROPICAL STORM OR HURRICANE WATCH ISSUED

#### Non-Trailerable Vessels

- **Double lines** to mooring or wharf; **add anchors (360°)** – **do not raft with other vessels**
- **Evaluate battery function**; consider installation of a secondary battery
- Ensure vessel's **fuel is maximized** and **remove moveable gear / equipment**

### PRIOR TO LANDFALL

- **Turn on automatic bilge pump(s)** (marine moored); **remove drain plugs** (land based)
- **Purchase and safely store diesel** for post storm recovery
- Focus on **personal preparations** and **protection**
- **Document vessel condition** with dated photographs or video

## POST-STORM RECOVERY

- **Assess accessibility of the vessel** only return if conditions (i.e., wind or waves) allow
- **Turn off automatic bilge pump(s)** (marine moored); **return drain plugs** (land based)
- **Take pictures or video footage** and make detailed notes on the vessel condition
- **Return gear / equipment** removed during storm preparations
- **Remove anchors and lines**; launch vessel if conditions allow (i.e., functional ramp, wind, or waves)
- **Communicate extent of damages** to associations and government bodies

**Appendix K: Generic design recommendations for Atlantic Canadian oyster and mussel farms (DSA Ocean report)**

Document Title	<b>Engineering recommendations for Atlantic Canada oyster and mussel farms to build-back stronger post Hurricane Fiona</b>
File	DSA-CMAR-23PDR-R01-RevA.4 -- Shellfish Design Recommendations.docx
Revision	A
Prepared for	Leah Lewis-McCrea; CMAR
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Document Title	Engineering recommendations for Atlantic Canada oyster and mussel farms to build-back stronger post Hurricane Fiona			
Revision	A	Date Created	2023-04-28	
DSA Project No.	CMAR-23PDR	Client Project No.	N/A	

## Revision history

Revision	Date last revised	Summary of changes / Comments	Revisions by	Checked by	Approved for release by	Issued to / Distribution	Engineering review status (IFI / IFR / IFC)
A	2023-04-28	Report release	BGW	WT	DMS	Leah Lewis-McCrea; CMAR	IFI

### Engineering review status acronyms


IFI – Issued for Information

IFR – Issued for Review

IFC – Issued for Construction

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Document Title	Engineering recommendations for Atlantic Canada oyster and mussel farms to build-back stronger post Hurricane Fiona			
Revision	A	Date Created	2023-04-28	
DSA Project No.	CMAR-23PDR	Client Project No.	N/A	

## Executive summary


Hurricane Fiona occurred in September 2022 and caused extensive damage to the shellfish industry in Atlantic Canada, resulting in significant economic loss for the farmers. DSA Ocean has been contracted by the Centre for Marine Applied Research (CMAR) to develop guidelines and recommendations that would aid shellfish farmers to build-back infrastructure to better withstand extreme weather events. The proposed guidelines will reduce the risk of incurring impact from future storms.

Hurricane Fiona was determined to have wind speeds which fall within a 50-year storm value in the Maritimes which is common to design to as per industry engineering standards. It is clear that previous systems were not properly design to withstand such conditions; proper engineering for future systems would reduce the risk for substantial damage in similar storms.

A typical engineering design process as per aquaculture standards was discussed, and approximate costs for various levels of engineering design options have been provided. A key requirement for proper engineering design consists of evaluating site specific met-ocean conditions and determining extreme storm conditions, evaluating seabed composition to select appropriate anchors, and assessing tidal range.

Generic recommendations for each future site were provided, which include considerations for site selection based on met-ocean conditions, orienting the lines inline with the predominant met-ocean directions, anchoring considerations based on the seabed composition the site, and the importance of documenting installed components and any maintenance performed was discussed.

One recommendation which would greatly benefit the shellfish industry as a whole would be to perform a sensitivity study for a generic design provided by the industry which would indicate how line sizes change based on combinations of load conditions. DSA Ocean could complete this study with suppliers and industry partners. A set of predetermined current speeds and wave heights can be developed as inputs for the sensitivity study. Required line and anchor sizes for a standard design can be produced for each load case. This would prevent the need for a full engineering analysis to be performed for each site if its met-ocean conditions fall within the predetermined load cases. Completing a sensitivity study would reduce the time and engineering costs associated for future sites, however a check would still be required for each site to determine if the load cases chosen for the sensitivity study are applicable to the given site, to assess the seabed composition and select an anchoring technology to be used etc.

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## 1 Introduction

Hurricane Fiona passed through Atlantic Canada on September 23, 2022 and significantly damaged shellfish farms in Nova Scotia (NS) and PEI. The strong winds and waves associated with the storm resulted in parted lines, dislodged anchors, and damaged marine shellfish structures. Due to the extent of the damage to the industry, it is clear that these shellfish farms were not designed to withstand these extreme storm conditions.

This report provides engineering recommendations to help the industry “build-back better” and reduce future risk based on DSA Ocean’s experience in the finfish and shellfish aquaculture industries. DSA has extensive experience assessing site-specific current, wind and wave (met-ocean) conditions, in addition to engineering aquaculture systems to withstand extreme storm conditions based on industry standards.

## 2 Abbreviations and acronyms


DSA	Dynamic Systems Analysis Ltd.
CMAR	Centre for Marine Applied Research
ADCP	Acoustic Doppler Current Profiler
MBL	Minimum Breaking Load

## 3 Reference documents and drawings

[1]	“Norwegian Standard NS9415:2021: Floating aquaculture farms. Site survey, design, execution and use,” Standards Norway, 2022.
[2]	Marine Scotland, “A Technical Standard for Scottish Finfish Aquaculture,” Ministerial Group for Sustainable Aquaculture’s Scottish Technical Standard Steering Group, 2015.
[3]	“ISO 16488:2015: Marine finfish farms -- Open net cage -- Design and operation,” International Organization for Standardization, 2015.
[4]	Nova Scotia Fisheries and Aquaculture Map, “ <a href="https://www.arcgis.com/apps/OnePane/basicviewer/index.html?appid=c21a2f45160d4c3189b85fa6c6015317">https://www.arcgis.com/apps/OnePane/basicviewer/index.html?appid=c21a2f45160d4c3189b85fa6c6015317</a> ”
[5]	PEI Aquaculture Leases Map, “ <a href="https://www.arcgis.com/home/webmap/viewer.html?webmap=16aa8830c7084a8a92ce066b525978b4">https://www.arcgis.com/home/webmap/viewer.html?webmap=16aa8830c7084a8a92ce066b525978b4</a> ”
[6]	Environment and Climate Change Canada, Historical Climate Data: “ <a href="https://climate.weather.gc.ca/historical_data">https://climate.weather.gc.ca/historical_data</a> ”
[7]	Centre for Marine Applied Research, Exposure Modeling Atlas, “ <a href="https://cmar.ca/exposure_modeling/">https://cmar.ca/exposure_modeling/</a> ”

## 4 Background

Shellfish aquaculture is an important industry in the Maritimes. The shellfish farms are typically built in bodies of water with water depths ranging from a few meters to 20 meters. In the Maritimes, there are two types of shellfish aquaculture farms – mussels and oysters. The farms are typically constructed of long-line ropes (sometimes referred to as main-lines) with anchors at each end to secure these lines to the seabed. The shellfish product typically grows vertically from these long-lines (mussels) as shown in Figure 1 and Figure 2, or in cages attached to the long-lines (oysters) as shown in Figure 3. A series of buoys or floats are attached to keep the


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long-lines and shellfish near the water surface. One example of an oyster long-line system is shown in Figure 3, which utilizes OysterGro floats and cages which contain the oysters. The rope sizes provided by suppliers are currently based on anecdotal evidence. Farmers generally follow these types of recommendations; however, systems are typically not assessed to ensure the as-built design is sufficient to withstand extreme conditions. The length of the long lines varies, as does the size of flotation. Screw anchors and concrete blocks are commonly used for anchors.



Figure 1: Mussel farm<sup>1</sup>

<sup>1</sup> [Mussel Farming - Mussel Seed - PEI Mussel Harvesting - PEI Mussel Processing](#)

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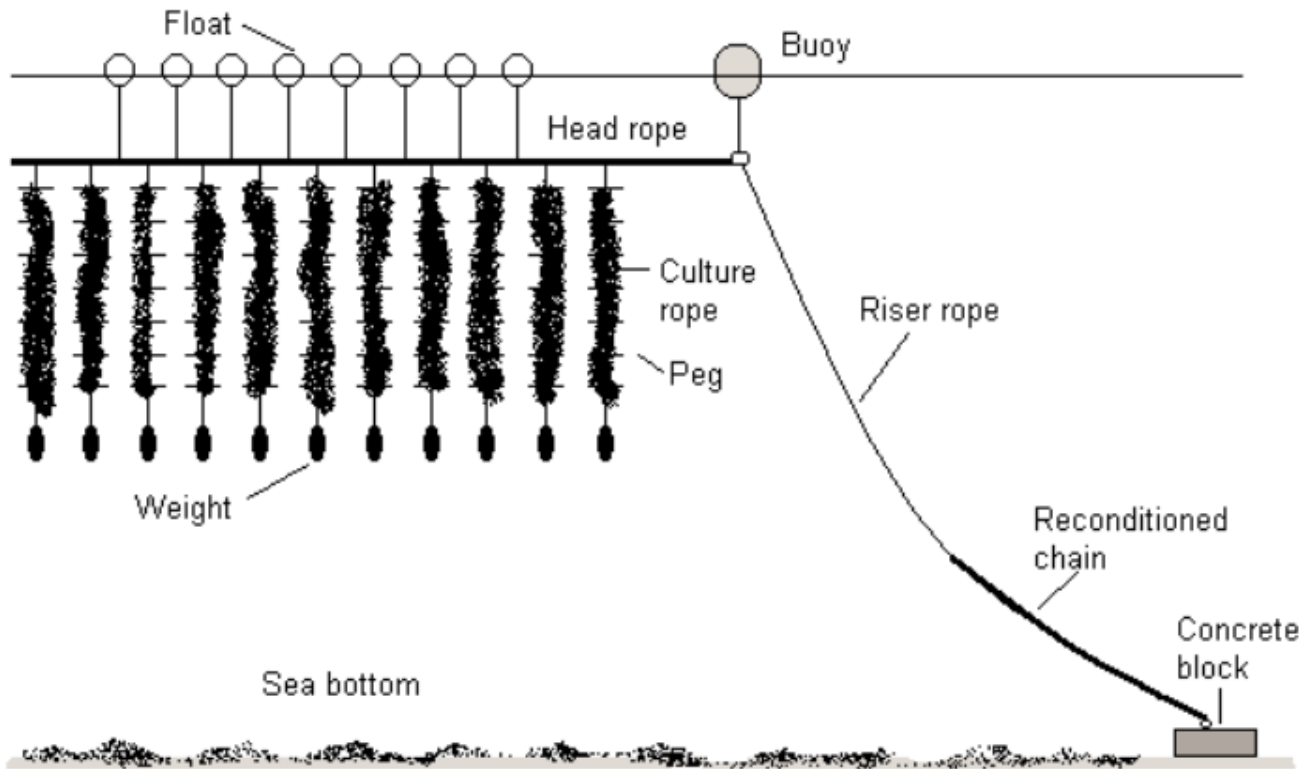



Figure 2: Typical mussel farm design<sup>2</sup>



Figure 3: OysterGro oyster farm<sup>3</sup>

<sup>2</sup> [\(PDF\) Growth And Production In Long-Line Cultivated Mediterranean Mussel \(Mytilus Galloprovincialis\) In Sinop, Black Sea \(researchgate.net\)](#)

<sup>3</sup> [OysterGro® Aquafarming - OysterGro®](#)

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An image showing all shellfish leases throughout Nova Scotia (NS) is provided in Figure 4 and an image showing all aquaculture (finfish and shellfish) leases in Prince Edward Island (PEI) is shown in Figure 5. Most leases in Atlantic Canada are not exposed to open ocean swell (i.e., larger, more-powerful waves which travel large distances). The leases tend to be protected by headlands and islands. Examples are shown for NS and PEI in Figure 6 and Figure 7, respectively. However, these leases are typically exposed to strong winds, and waves are generated from these winds. The stronger the wind, and the longer the fetch (distance over the water that the wind blows), the larger the waves. Determination of the expected extreme wind and wave conditions at a site is important for developing site designs which are fit for purpose.

In these coastal areas, ocean currents vary greatly depending on ocean circulation, bathymetry, and coastal hydrodynamics. In many cases, the principal loads on the shellfish farms will be due to the strong currents. Knowledge of the maximum expected current speeds is important for engineering design, in addition to wind and wave conditions.

#### Nova Scotia Fisheries and Aquaculture

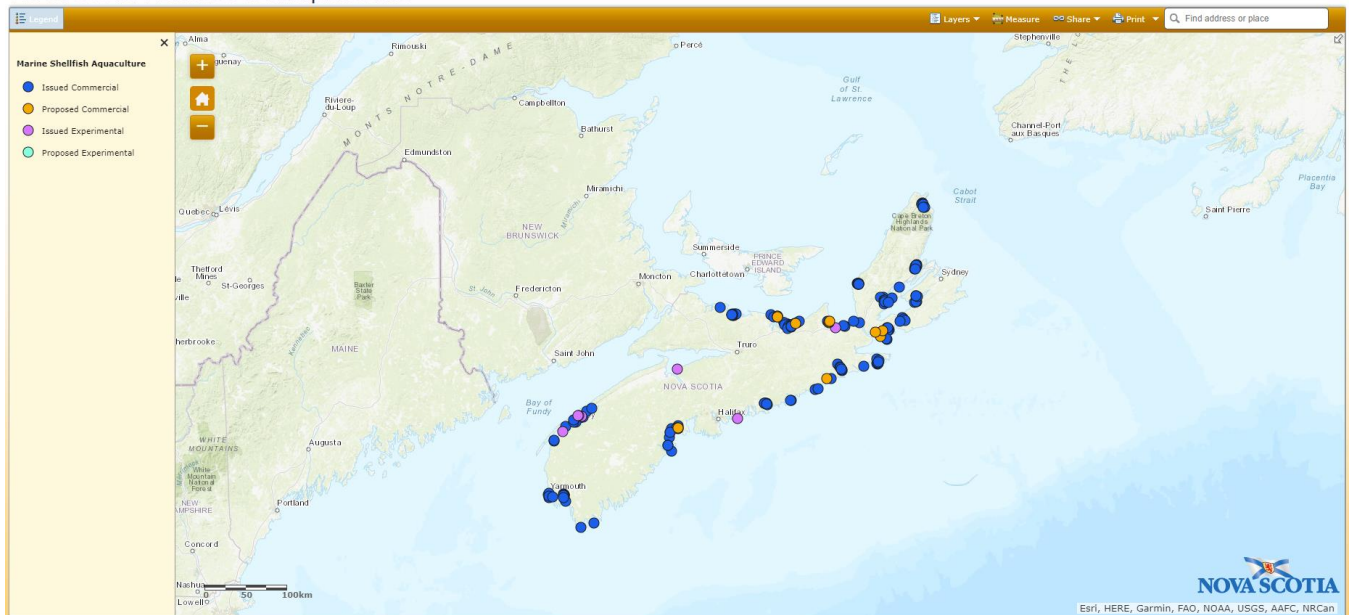



Figure 4: Nova Scotia Fisheries and Aquaculture Map – shellfish leases [4]

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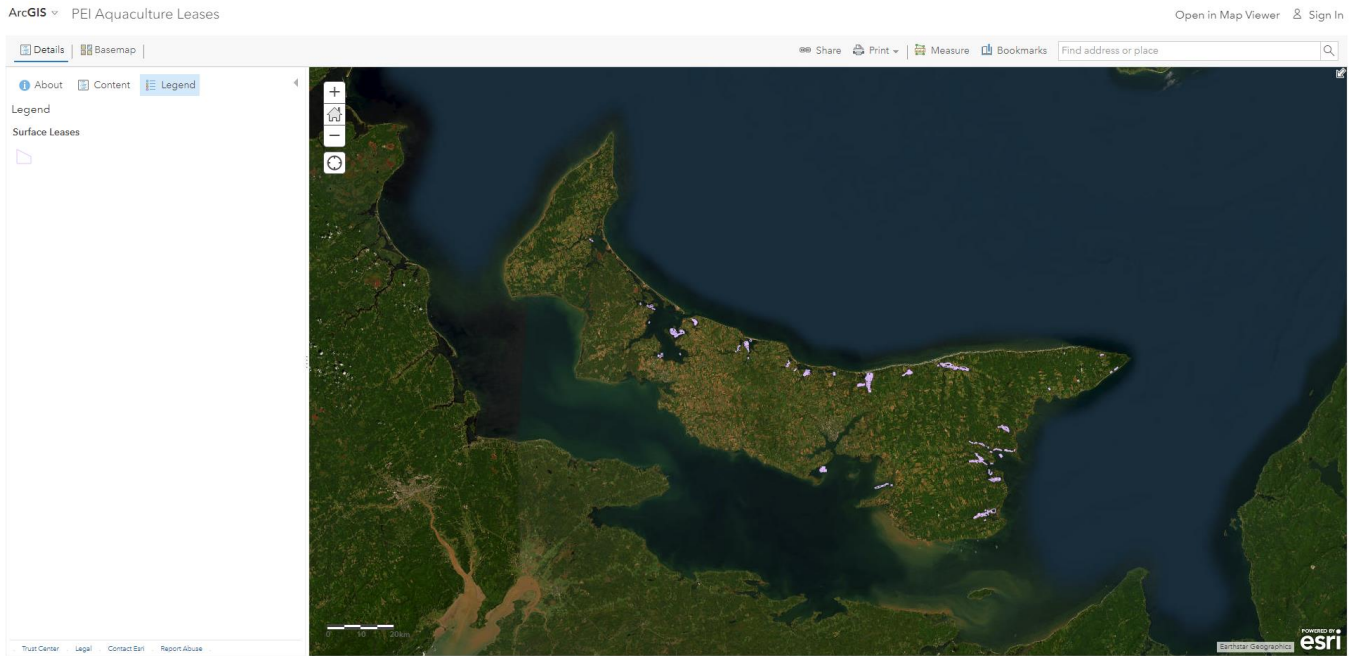


Figure 5: PEI Aquaculture Leases Map [5]

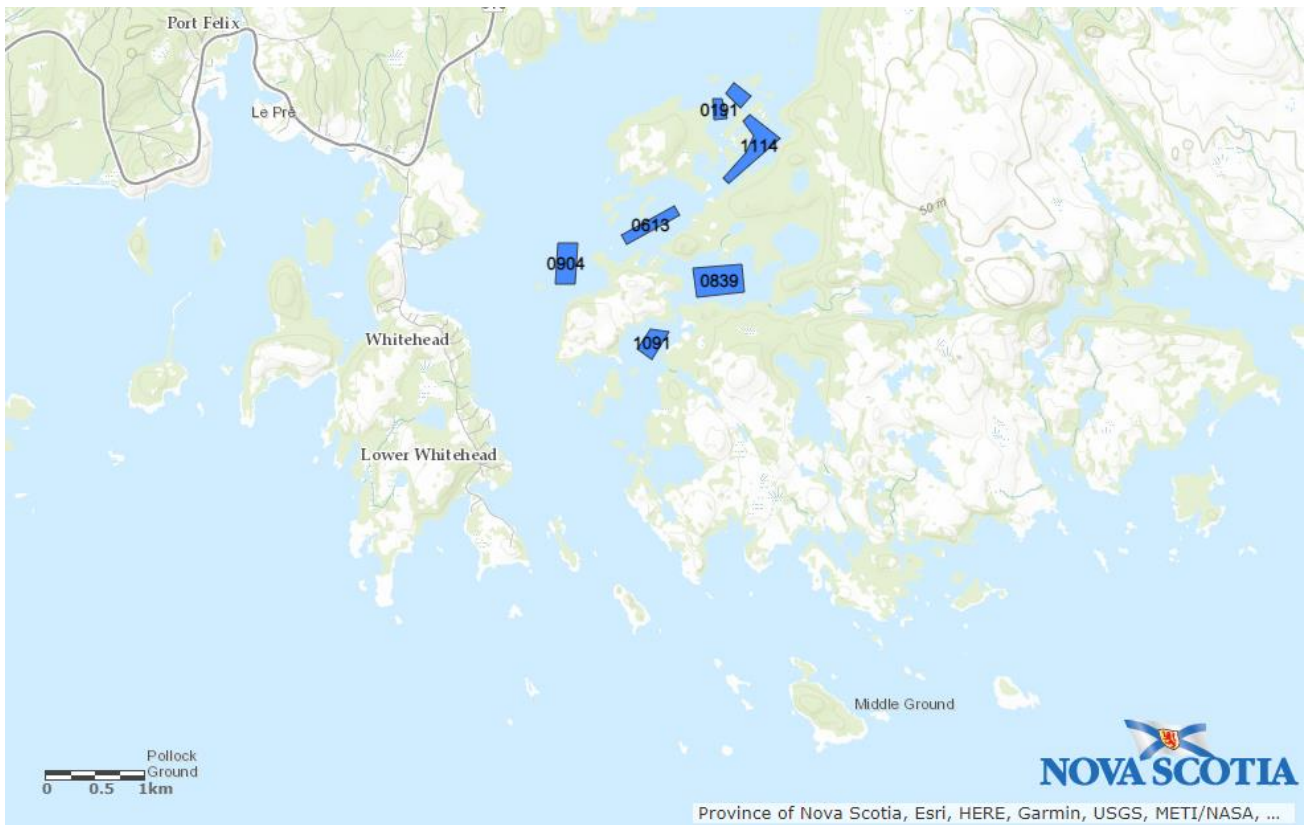



Figure 6: Examples of shellfish leases in NS which are generally protected from offshore swell, which would propagate from the south for this area.

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**Figure 7: Examples of shellfish leases in PEI which are generally protected from offshore swell. As shown here, these leases would only have wind generated waves present, and likely low currents.**


There are currently no formal regulations for engineering shellfish aquaculture systems in NS or PEI. The latest finfish regulations in NS and Newfoundland both require assessment of structures by a Professional Engineer, but these do not apply to shellfish farms. Shellfish equipment is typically installed based on experience and support from equipment suppliers (e.g., oyster cage suppliers, rigging shops). It is not common practice to size components to withstand extreme storms that have a low probability of occurrence, based on calculations or analysis.

It appears that documentation of the equipment which is deployed at leases is not typically available. The lack of documentation of the equipment that has failed (e.g., what rope size, shackle size or anchor weight) – makes it difficult to assess how to precisely improve a design after an incident.

Another important issue which is impacting shellfish growers is that climate change has resulted in higher frequency of occurrence of large storms, such as Fiona. Marine conditions are changing over time. This means that experienced-based equipment specifications may not be sufficient for future hurricanes and storms.

Based on DSA’s experience in engineering of marine structures, aquaculture designs must comprehensively consider many factors to reduce the likelihood of their failure:

- met-ocean conditions (wind, waves, currents, and tides)
- seabed composition
- lease size / orientation

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- operations
- accident cases


As part of CMAR’s support to NS and PEI provinces, CMAR is 1) developing and supplying tools for evaluating storm-damage claims and 2) providing recommendations for more resilient design of shellfish sites. DSA has been contracted by CMAR to support the development recommendations that will enable building back of shellfish systems that are more resilient of extreme weather events such as Hurricane Fiona.

## 5 Engineering design process

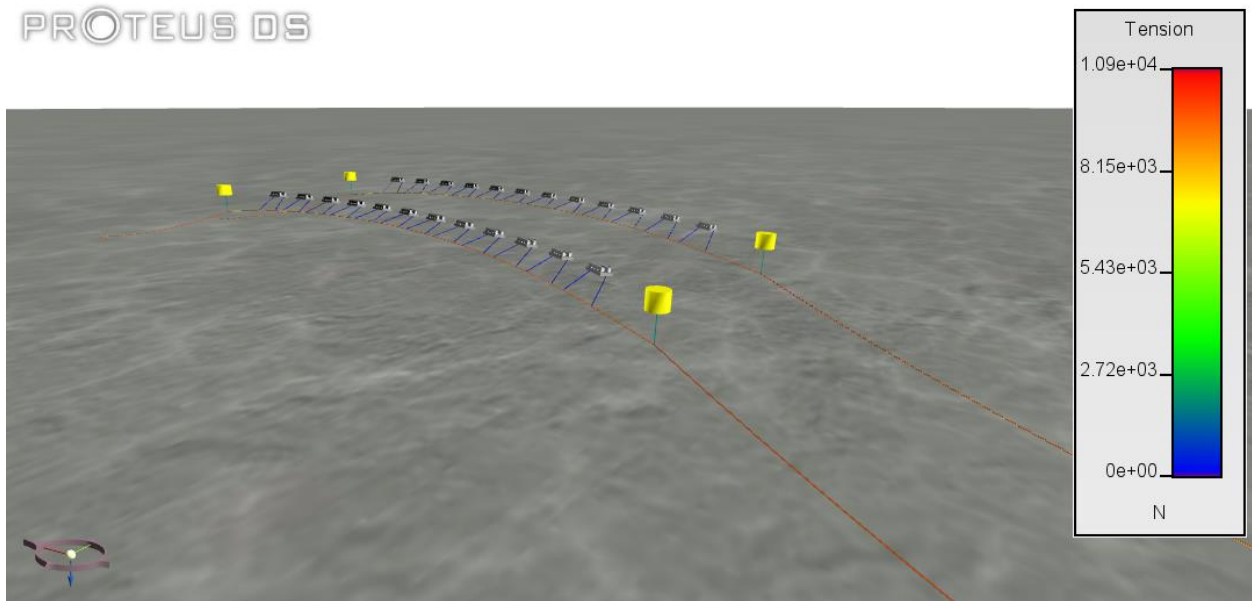
DSA Ocean has experience with engineering aquaculture systems to withstand expected extreme conditions. Engineering standards are used to inform design decisions across the industry. Although these standards were typically created for finfish aquaculture systems, the concepts such as predicting extreme (storm) environmental conditions and material safety factors can be applied to shellfish aquaculture as well. The following aquaculture standards are common in the industry:

- Norwegian Standard NS9415:2021: Floating aquaculture farms. Site survey, design, execution and use [1]
- Marine Scotland, “A Technical Standard for Scottish Finfish Aquaculture,” [2]
- ISO 16488:2015: Marine finfish farms -- Open net cage -- Design and operation [3]

As per the industry standards, a dynamic analysis of the aquaculture system to be deployed at a specific site must be performed. For example, DSA has developed a dynamic analysis software called ProteusDS to design aquaculture systems through simulations. An example of two OysterGro lines simulated in current, wind, and waves with ProteusDS is shown in Figure 8.

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PROTEUS DS




**Figure 8: OysterGro lines modeled in current with ProteusDS. The loads exerted on the anchors and lines are calculated based on drag forces, wave forces and wind loads.**

The software enables prediction of environmental loads for each component based on the input wind, wave, and current conditions. Using these loads with the corresponding safety factors provided in the industry standards, each component of the system can be specified.

As DSA’s standard procedure for aquaculture system design, the following steps are performed as per specific site conditions:

1. Determine maximum expected extreme wind, wave, and current conditions at the specific site.
2. Extrapolate met-ocean conditions to predict expected worst-case conditions (often for a storm that occurs every 10 or 50 years on average).
3. Develop load cases with extreme storm conditions for multiple directions around the compass rose (typically > 8 load case directions at ordinal and cardinal directions).
4. Design the proposed system and perform dynamic analysis to predict loads in lines and predict buoy submergence and anchor loads (simulate the system in extreme wind, wave, and current conditions – e.g., see Figure 8).
5. Process loads in each component and apply safety factors as per industry standards to determine required minimum breaking loads and anchor holding capacities.
6. Develop engineering site plan and hardware specifications to meet industry standard safety factors.
7. Review and certification of design by a suitably experienced and trained professional engineer.
8. Farmer to construct site as per specifications.
9. Review of as built components, anchor locations and overall construction by engineer. Verification that as-built system is in accordance with the analysis. Memo issued certifying that site is built and constructed as per best practice.

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10. [As necessary] Assess future component changes and repairs throughout a project’s life (e.g., deviations from the issue for construction site plan, changes in length, and changes in anchor position).

## 6 Expected extreme met-ocean conditions for shellfish farms in the Maritimes

The first step in building-back stronger shellfish farms is to develop the design basis for the farms. Namely, the designs must consider the expected extreme environmental conditions (steps 1-3 above). Towards this end, a review of environmental conditions in PEI and NS was performed. The likely extreme wind conditions to be used for engineering design of shellfish aquaculture structures were determined. A discussion of how to determine current and wave design conditions is presented.

### 6.1 Wind Conditions

Wind data has been gathered by CMAR across Atlantic Canada for four previous hurricanes, namely Hurricane Juan (2003), Hurricane Earl (2010), Hurricane Dorian (2019), and Hurricane Fiona (2022) to compare their relative impact. The location of each data point considered is shown in Figure 9. Results for each weather station and buoy compiled are shown in Table 1 and Table 2.

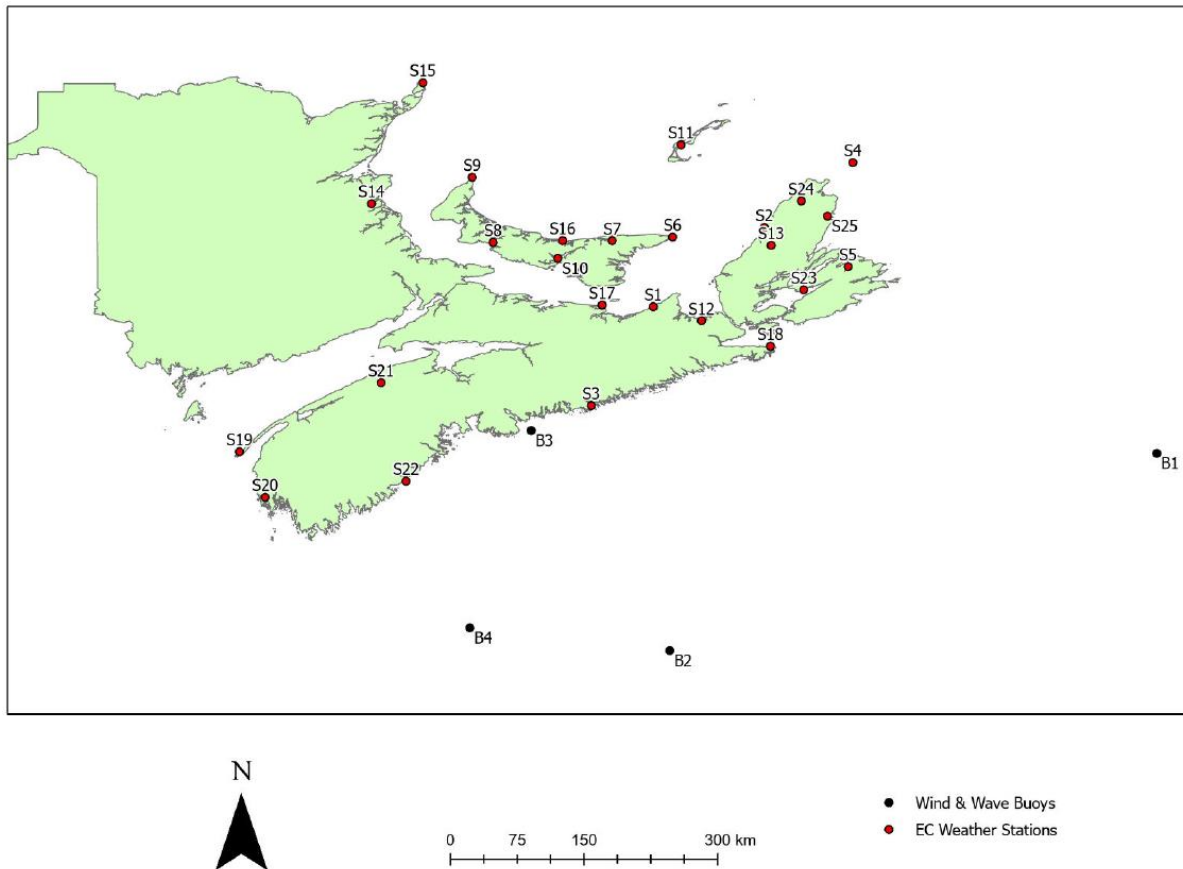



Figure 9: Location of buoys and Environment Canada (EC) weather stations collecting wind and wave data during hurricane events [6]

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**Table 1: Recorded wind gusts and sustained winds during select named hurricanes from weather stations and buoys in Atlantic Canadian waters [6]**


Location	Site/Buoy	Number	Fiona (2022)		Dorian (2019)		Earl (2010)		Juan (2003)	
			Gust (km/h)	Sustained (km/h)	Gust (km/h)	Sustained (km/h)	Gust (km/h)	Sustained (km/h)	Gust (km/h)	Sustained (km/h)
NS	Arisaig	S1	179	121	No Data	No Data	No Data	No Data	No Data	No Data
	Grand Etang	S2	167	94	155	75	No Data	72	No Data	65
	Beaver Island	S3	160	126	145	106	135	104	131	95
	St. Paul Island	S4	158	123	No Data	No Data	130	100	109	78
	Sydney	S5	149	96	87	72	85	63	70	46
	Tracadie	S12	136	91	96	60	93	56	83	54
	Margaree	S13	75	91	82	60	No Data	56	No Data	54
	Caribou Point	S17	146	103	122	95	107	76	119	No Data
	Hart Island	S18	128	86	126	88	109	78	89	69
	Brier Island	S19	98	80	110	85	69	41	No Data	39
	Yarmouth	S20	89	57	98	75	69	43	32	22
	Greenwood	S21	91	68	104	63	65	50	56	35
	Western Head	S22	70	42	88	54	98	70	70	43
	Eskasoni	S23	125	96	113	82	No Data	No Data	No Data	No Data
	North Mountain	S24	127	72	111	68	No Data	65	No Data	41
Ingonish Beach	S25	89	47	90	46	89	43	67	35	
PEI	East Point	S6	149	112	120	95	98	69	96	67
	St. Peters	S7	141	79	99	52	72	46	107	59
	Summerside	S8	140	89	117	86	70	50	83	61
	North Cape	S9	136	101	122	91	85	67	89	69
	Charlottetown	S10	131	73	107	69	78	48	139	82
NB	Stanhope	S16	131	89	92	55	No Data	No Data	No Data	No Data
	Kouchibouguac	S14	70	39	66	36	No Data	No Data	No Data	No Data
Miscou Island	S15	113	83	106	80	74	46	56	43	
Magdalen Islands	Isles de la Madeleine	S11	126	83	117	82	91	69	107	74
Ocean	44139	B1	107	81	81	61	59	50	No Data	No Data
	44137	B2	10	9	107	94	89	70	88	73
	44258	B3	115	91	112	90	121	84	135	99
	44150	B4	100	79	121	97	122	84	49	41

**Table 2: Maximum and sustained wind recorded from ocean buoys during select named hurricanes [6]**

Buoy Name	Number	Fiona (2022)		Dorian (2019)		Earl (2010)		Juan (2003)	
		Max (km/h)	Significant (km/h)	Max (km/h)	Significant (km/h)	Max (km/h)	Significant (km/h)	Max (km/h)	Significant (km/h)
44139	B1	30.3	13.4	18.5	9.1	12.5	6.6	No Data	No Data
44137	B2	23.5	11.9	27.1	15.2	17.9	10.3	12.5	6.9
44258	B3	7.3	4.2	23.5	9.5	23.3	10.1	19.9	9
44150	B4	13.7	8.2	27.7	13.6	24.6	13.1	2.6	1.4


Wind measurements at four weather stations around Atlantic Canada during Hurricane Fiona were processed further by DSA Ocean to determine the maximum wind speeds and estimate the expected return value of the storm. Details for each weather station are as follows [6]:

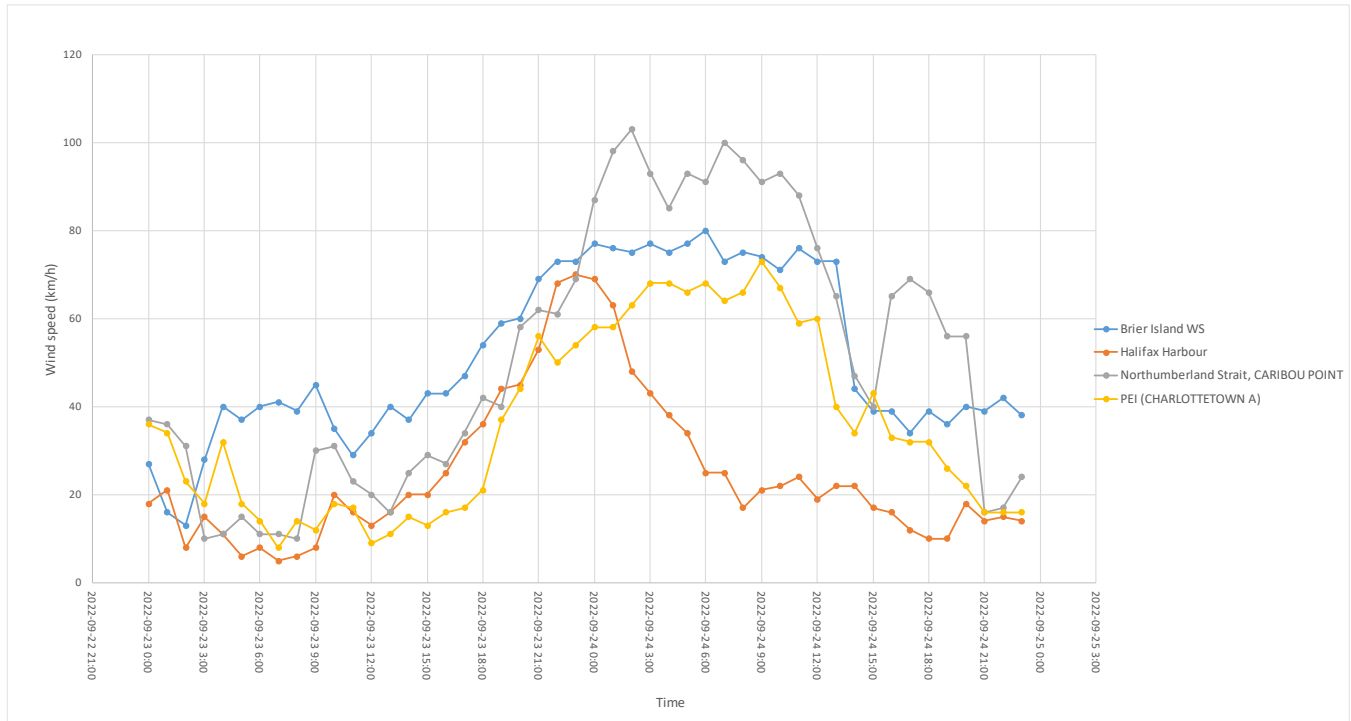
**1. Brier Island weather station (S19 in Figure 9):**

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- Elevation: 15.8m
  - Latitude: 44°17'09.000" N; Longitude: 66°20'48.000" W
  - Climate ID: 8200604
2. **Halifax Dockyard weather station:**
- Elevation: 3.8m
  - Latitude: 44°39'19.000"N; Longitude: 63°34'36.000" W
  - Climate ID: 8202240
3. **Caribou Point weather station (S17 in Figure 9):**
- Elevation: 2.4m
  - Latitude: 45°46'00.000"N; Longitude: 62°41'00.000" W
  - Climate ID: 8200774
4. **Charlottetown A weather station (S10 in Figure 9):**
- Elevation: 50.9m
  - Latitude: 46°17'21.000" N; Longitude: 63°07'09.000" W
  - Climate ID: 8300301

A plot of the wind speeds during Hurricane Fiona (1-hour mean) is provided in Figure 10.

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**Figure 10: Wind speeds during Hurricane Fiona**

A maximum wind speed of 103 km/hr (28.6 m/s) was measured at the Northumberland Strait weather station. Based on DSA’s experience, a 30 m/s wind speed (1 hour mean speed at 10m elevation) is an approximate maximum estimated 50-year storm condition in Atlantic Canada. This data shows that Hurricane Fiona was a significant storm with an approximately 50-year return period. Aquaculture standards including NS9415 [1], the Scottish Standard [2], and ISO 16488 [3] require designing a system to a 50-year storm (see Section 6 for more details), as such a wind speed of 30 m/s could be considered an appropriate design condition for systems to withstand future storms of this magnitude. It’s possible to perform a more detailed analysis of local wind conditions at each site which may arrive at lower design wind speeds. However, if the industry moved forward with an assumed extreme wind speed such as 30 m/s for all site designs, it would reduce the effort and cost of the farmers and their suppliers in performing detailed met-ocean analyses for each site.

## 6.2 Wave Conditions

It is important to assess wave conditions for aquaculture design at each individual site as wave conditions are affected by a variety of factors including wind speeds, distance of open water in which waves can propagate (fetch), and seabed depths. Sites that are generally protected from offshore waves will have significantly different design requirements than those that are exposed to ocean swell. With knowledge of sustained wind speeds, fetch, and water depth, extreme wave conditions can be accurately predicted. This is a limitation in engineering design; long-term inshore wave data is generally not available for predicting long-term extreme wave conditions, and therefore wind-driven fetch calculations are often used to predict wave conditions. With knowledge of the fetch, and the design wind speed (e.g., 30 m/s), it is possible to calculate design wave conditions for shellfish aquaculture design.

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Using the wave calculations described above, DSA Ocean has collaborated with CMAR to develop a wind-generated wave exposure atlas around the coast of NS as part of an “Exposure Modeling” project [7]. This atlas can be used to assist in selecting sites which are less likely to be affected by extreme waves. A similar project could be completed by DSA and CMAR for the province of PEI which would potentially reduce the effort of evaluating site-specific waves at future sites.

### 6.3 Current Conditions

Current is typically a driving factor for loads on aquaculture systems based on DSA’s experience. Further, current speeds are extremely difficult to predict based on modeling or using existing data. It is best practice to measure current at a shellfish lease with an Acoustic Doppler Current Profiler (ADCP) or similar instrumentation. Often anecdotal estimates of current speed underestimate the maximum current speed throughout the water column, and does not capture peak values or extreme events. Therefore, it is important to deploy an ADCP and measure currents at a specific site for at least 30 days to determine current speeds to be considered for aquaculture design.

In absence of current meter deployment, a design current speed must be carefully selected by a qualified and experienced oceanographer that is familiar with the region of interest. Based on DSA’s experience, currents around Atlantic Canada are highly variable. For example, current speeds can be >2 m/s in many areas of the Bay of Fundy. In the Bay of Fundy, DSA always recommends a current meter deployment. In some regions such as the Northumberland Strait, it may be possible to use circulation models (e.g., FVCom) and ADCP data to determine an upper design current speed.


Circulation models predict current speeds for defined regions which may be appropriate for analysis and site design. Due to uncertainty in circulation models, and variability of currents from one site location to another, a very conservative value of design current speed would likely be required for many regions and may result in unnecessarily large rope and anchor sizes being specified. As a result, although there is an upfront cost for deploying an ADCP (typically on the order of \$10,000), the more accurate evaluation of local currents would likely result in substantial savings in reduced equipment sizes over the life of the lease.

For leases in enclosed bodies of water without currents, wind-induced currents can also be calculated based on wind speed.

## 7 Considerations for the robust design of shellfish farms

There are various factors to consider when designing an aquaculture site. As discussed above, met-ocean conditions (current, winds, waves), seabed type and depth, lengths and sizes of each rope and chain component, pretensions, buoyancy etc., will all influence the performance of the system in typical and extreme conditions. Based on the engineering process presented above, a proposed shellfish system design needs to be checked against the met-ocean conditions present at a lease.

When considering the change of any individual component, the entire system must be considered as a whole. As an example, a farmer may increase the length of their long-lines to maximize production on their lease. The


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system may hold up under typical conditions, but in extreme conditions the loads may cause anchors to move or lines to part because drag increases with longer lines. Then, a larger diameter rope is justified to handle this increase of loads, however, if a larger diameter rope is used the drag loads will be increased further. As a result, sizes of other components in the system (shackles, anchors etc.) may need to be increased as well. In general, it is easy to unintentionally increase loads. Engineering analysis would quantify the increase in loads for any change, and ensure that at equivalent level of safety is maintained from one shellfish farm to the next.

Based on DSA’s experience in the finfish industry, it is difficult to design a generic mooring system for aquaculture systems. Mooring load analysis is unique for every technology because of the unique combinations of wind, current, wave, tidal elevation, and seabed type at each site. In the finfish industry a load analysis is conducted on every site to ensure that a given equipment’s rated load is not exceeded.

Even if a site-specific engineering analysis is not completed, the following considerations will aid shellfish farmers in installing more robust structures:

- During the site selection process, the sites exposure to extreme weather conditions (storms) must be considered
- It is extremely important to document the as-built design components. Inspection and maintenance procedures are to be followed and documented. If components are replaced, they must be replaced with components that meet or exceed (within reason – again, larger component sizes will increase loads) the original specification.
- Main lines are to provide protection from chafing at friction points such as against cages/bags, anchor points etc.
- Sinking rope is preferred for lines near the surface (main lines) which has the potential of coming in contact with cages or other surface equipment.
- It is advised to align the system in-line (or parallel) to the predominant current directions throughout the water column to reduce loads. As the predominant current direction at the surface may be different from the current direction at depth, the specific current profile at the site must be understood.
- Sufficient spacing between lines must be used to ensure cages do not contact each other in extreme conditions
- At sheltered sites, where high currents (above 0.5 m/s) and extreme waves are not expected, generic components recommended by the equipment manufacturer may potentially be used with minimal risk. Even at these sheltered sites, careful consideration must be used to justify the use of manufacture specified components, and these designs should never be blindly applied.
- Anchoring technology to be selected depends on specific site conditions including the seabed composition and tidal range:
  - o In general, screw anchors may be used in calm (relatively low current) environments with an insignificant tidal range if seabed composition permits
    - Screw anchors are to be buried in the sediment to provide maximum holding power, reduce corrosion, and reduce tangling hazards

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- For sites with extreme currents and/or a high tidal range, drag anchors with a section of anchor chain are commonly used in the industry. The weight and length of anchor chain can be lifted up as the tide rises to provide tidal compliance and keep the system at the surface throughout the tidal range, while providing adequate pretension at low tide
- Concrete anchor blocks may potentially be used with a section of anchor chain to provide tidal compliance; however, concrete is very inefficient in water (concrete’s mass is reduced by approximately 40% in water) and therefore the concrete mass required to adequately hold the system in place is often not feasible.
- During installation, anchors should be pull tested to the rated load of the anchor for at least 15 minutes
- Long line systems can easily become too long and loads massively increased. Calculations should always be performed to ensure that the drag loads on the long lines and shellfish product (e.g., mussel lines or oyster cages) do not result in the line parting. When drag calculations are performed, a safety factor must be applied to the estimated loads to determine the required Minimum Breaking Load (MBL) for each component. A minimum safety factor of 1.67 is reasonable, if the met-ocean conditions are well-known and a dynamic analysis technique is used for the analysis.

## 8 Estimate of engineering costs

As outlined above, proper consideration of met-ocean conditions in engineering design is the first step towards building back better for the shellfish industry. Next, a review of loads and equipment should be completed to ensure that equipment is fit for purpose for a site. A given long line setup for example needs to be checked to ensure that it meets MBL requirements to support the expected loads in extreme conditions.

The following design tier options with estimated order of magnitude of cost that may be performed by DSA Ocean are provided below. These are not quotations, as each individual lease and the amount of time required for analysis can vary depending on technology and if a similar analysis has been completed previously.

1. Minimum
  - a. Shellfish farmer provides previously determined design current speed, ideally obtained by an ADCP at or very near the lease for a duration of at least 30 days; or via a known current atlas produced for the area.
  - b. DSA Ocean evaluates wind and wave conditions at the site and determines extreme storm values to be used in the analysis as per engineering standards.
    - i. A 50-year return wind speed of 30m/s will be used
    - ii. This wind speed will be applied with fetch calculations to determine design wave heights
  - c. Farmer provides proposed design to DSA Ocean.
    - i. DSA reviews proposed design
    - ii. Site visit


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- d. DSA performs analysis of proposed design and provides a report specifying Minimum Breaking Load (MBL) requirements for each component, anchor selection, and buoy size based on standard design (this assumes the technology is conventional long-line equipment setup).
  - e. Farmer documents its equipment documentation/drawings (e.g. final anchor placement, water depths, equipment used/deployed)
  - f. DSA review drawings / schematics.
  - g. DSA issues memo referencing all materials above, and provides engineering certification for site construction.
  - h. Approximate cost: \$7500
2. Intermediate
- a. All steps in 1 will be followed
  - b. DSA will deploy and process ADCP data and determine extreme current values for analysis.
  - c. Approximate cost: \$17,500
3. Standard
- a. All steps in 2 would be followed, except that the equipment set up would be optimized or adjusted as per the farmer's needs.
  - b. Design would be adjusted as per the farmer's requirements (ex. Maximize grow area within the lease, or minimize equipment cost etc.)
  - c. Alternative designs may be considered for optimization, ex. a grid system may provide benefits such as increasing grow area/production in a smaller footprint vs. using individual long-lines.
  - d. Site design documentation (meeting requirements of engineering standards) will be provided to the farmer in the form of engineering drawings
  - e. Approximate cost: \$25,000

A summary of the design levels is provided in Table 3.

**Table 3: Tiers for engineering analysis**

<u>Level</u>	<u>Approx. Cost</u>	<u>Current, wind and wave conditions</u>	<u>General Design</u>	<u>Deliverables</u>
Basic	\$7,500	Provided by shellfish farmer and reviewed by DSA	Proposed by shellfish farmer / equipment supplier	DSA to provide report with required minimum breaking loads, anchor size, buoy size etc. As-built components to be documented by farmer. After install, DSA to provide memo to report compliance with standards.
Intermediate	\$17,500	Determined by DSA, DSA to deploy ADCP	Proposed by shellfish farmer / equipment supplier	DSA to provide report with required minimum breaking loads, anchor size, buoy size etc. As-built components to be documented by farmer. After install, DSA to provide memo to report compliance with standards.

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Optimized	\$25,000	Determined by DSA, DSA to deploy ADCP	To be optimized by DSA	DSA to provide report with required minimum breaking loads, anchor size, buoy size etc. DSA to provide engineering construction drawings documenting what was installed. After install, DSA to provide memo to report compliance with standards.
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## 9 Conclusions & recommendations for next steps

This report provides key recommendations that would ensure that shellfish aquaculture systems in Atlantic Canada have increased resiliency in extreme storm conditions and reduce financial and environmental risk for the shellfish sector as a whole.


Hurricane Fiona was determined to have wind speeds which fall within a 50-year storm value in the Maritimes which is common to design to as per industry engineering standards. Proper engineering for future systems would reduce the risk for substantial damage in similar storms.

A typical engineering design process as per aquaculture standards was discussed, and approximate costs for various levels of engineering design options have been provided. A key requirement for proper engineering design consists of evaluating site specific met-ocean conditions and determining extreme storm conditions, evaluating seabed composition to select appropriate anchors, and assessing tidal range.

Generic recommendations for each future site were provided, which include considerations for site selection based on met-ocean conditions, orienting the lines inline with the predominant met-ocean directions, anchoring considerations based on the seabed composition the site, and the importance of documenting installed components and any maintenance performed was discussed.

A key issue which made it difficult to provide practical advice for the industry to improve, is that there was no documentation for "as-built structures" that were damaged by Hurricane Fiona. If recommendations are implemented from this report for future sites (i.e., proper documentation of as-built structures); DSA Ocean could assess damages incurred by future storms and determine reasons for failure to provide key recommendation for site design.

One recommendation which would greatly benefit the shellfish industry as a whole would be to perform a sensitivity study for a generic design provided by the industry which would indicate how line sizes change based on combinations of load conditions. DSA Ocean could complete this study with manufactures and industry partners. A set of predetermined current speeds and wave heights can be developed as inputs for the sensitivity study. Required line and anchor sizes for a standard design can be produced for each load case. This would prevent the need for a full engineering analysis to be performed for each site if its met-ocean conditions fall within the predetermined load cases. Completing a sensitivity study would reduce the time and engineering costs associated for future sites, however a check would still be required for each site to determine if the load

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cases chosen for the sensitivity study are applicable to the given site, to assess the seabed composition and select an anchoring technology to be used etc.

Another future recommendation would be to develop a wind-generated wave exposure atlas around the coast of PEI. As discussed in Section 6.2, DSA Ocean and CMAR completed a similar project for NS. Developing a similar atlas for the province of PEI which would potentially reduce the effort of evaluating site-specific waves at future sites.