# Best Practices- Design, Construction, and Operation of Oyster Nursery Systems in Nova Scotia

**Prepared for: Centre for Marine Applied Research (CMAR)**

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## Executive Summary

Oyster nursery systems are a core risk-management component of modern oyster aquaculture. In Nova Scotia, where environmental variability, labour constraints, and chronic disease pressures—particularly *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo)—directly affect farm performance, effective nursery capacity is essential to both long-term biological sustainability and economic viability. The nursery phase bridges hatchery production and field grow-out, representing the single greatest opportunity to reduce avoidable losses and improve production performance.

Well-designed and properly operated nursery systems routinely reduce early-stage mortality by 20–40% compared to direct stocking. They also improve growth uniformity, increase the predictability of field performance, and enable more efficient use of labour. Across operations, the nursery phase consistently delivers higher usable output per million seed input, fewer field losses, and tighter size distributions at stocking—outcomes that directly improve lease productivity, harvest planning, and profitability.

This guide presents a best-practice framework for the design, construction, and operation of oyster nursery systems suited to Nova Scotia conditions, including floating flow-through upwelling systems (FLUPSY), land-based flow-through systems, hybrid land-based and floating systems, and partial or full recirculating aquaculture system (RAS) nurseries. The focus is intentionally practical and operational, emphasizing flow dominance over density, labour-efficient layouts, biosecurity-aware design, and modular scalability rather than complex or capital-intensive solutions.

The transition from hatchery to the field is the most biologically vulnerable stage of oyster production. Nursery systems mitigate this risk by maintaining high dissolved oxygen concentrations and waste removal, allowing conservative stocking densities, enabling regular grading to manage size variability, and conditioning seed to local environmental conditions prior to stocking. These practices reduce stress, improve survival, and produce a more consistent product.

Disease pressure from MSX and Dermo is treated in this guide as a chronic, stress-mediated risk rather than an episodic event. Effective nursery design reduces disease risk by prioritizing strong and uniform water flow, avoiding overstocking, capacity for observation and contingency holding, enabling rapid response to adverse environmental conditions, and supporting seed traceability and quarantine. While no system eliminates disease risk, land-based and hybrid nurseries provide internal control points that substantially reduce losses relative to direct stocking or fully exposed floating systems.

Labour availability and cost are critical constraints for Nova Scotia oyster operations. Accordingly, best-practice nursery systems are designed to maximize daily operational efficiency, safety, and manageability by small teams. This includes concentrating early, high-intensity nursery stages in accessible shore-based facilities, minimizing manual handling, enabling rapid visual assessment of system performance, reducing weather-dependent work, and allowing expansion without proportional increases in labour demand.

While no single nursery model is appropriate for all sites, hybrid nursery systems—combining land-based flow-through nurseries for early stages with floating FLUPSY systems for later bulk growth—are increasingly considered best practice in Nova Scotia. These systems concentrate biological risk where control is highest and production volume where efficiency is greatest, delivering strong performance across biological, labour, and economic metrics. For medium- and large-scale operations, hybrid approaches consistently provide the most resilient and scalable solution.

This guide is intended to support oyster growers, community groups, regulators, and funders by providing clear design principles grounded in Nova Scotia conditions, practical construction and operational guidance, realistic assessments of cost and labour requirements, and a common reference framework for permitting, funding, and project evaluation. Well-designed nursery systems are not simply infrastructure investments—they are foundational risk-reduction tools that underpin sustainable oyster aquaculture development in Nova Scotia.

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# 1. Purpose and Role of an Oyster Nursery

An oyster nursery is an intermediate grow-out system that receives hatchery-produced oyster spat (typically 1–3 mm shell length) and grows them to a robust juvenile size (generally 6–15 mm) before transfer to grow-out leases.

In Atlantic Canada, hatchery capacity is a limitation for the industry at the present time. Few hatcheries with limited capacity requiring transfer of early-stage seed to other facilities.

The nursery phase functions as a biological conditioning and risk-buffering stage between the controlled hatchery environment and the variable conditions of marine grow-out leases. This transition point is where the greatest avoidable losses typically occur if seed is placed directly into the field without intermediate conditioning.

## 1.1. Core Functions of an Oyster Nursery

**Oyster Nursery Benefits:**
- Improves survival between hatchery and lease
- Accelerates early growth and shell development
- Biologically conditions the seed to local conditions
- Mitigates disease pressure
- Improved biosecurity
- Reduces field performance variability
- Buffers production against environmental and operational risks
- Supports farm planning and management

Nursery systems provide continuous water exchange that improves dissolved oxygen and delivery of phytoplankton throughout the system, creating conditions that maximize feeding efficiency and metabolic performance. Consistent upwelling flow prevents localized depletion of food and dissolved oxygen, while controlled stocking densities reduce competition and energy expenditure associated with overcrowding. Overall, these conditions reduce stress and mortality during the most vulnerable early life stages, significantly increasing the proportion of hatchery seed that survives for lease stocking.

As a result, seed allocates a greater proportion of available energy to shell accretion and tissue growth rather than stress response. Faster early growth shortens the time required to reach a stockable size, thereby reducing exposure to environmental stressors, fouling, and disease pressure. Improved shell development at the nursery stage increases resistance to handling damage and reduces desiccation and transport stress during grading and deployment. Robust juveniles are better able to withstand initial stocking and adapt rapidly to lease conditions, resulting in higher survival and more consistent grow-out performance.

Routine grading and density management in the nursery reduce size dispersion and competitive suppression. More uniform seed translates into improved spacing, synchronized growth, and more predictable harvest timing in the field. Gradual exposure to local temperature, salinity, and plankton regimes under controlled conditions enhances physiological resilience. It also prepares juveniles for the variability they will encounter on grow-out leases, resulting in better post-stocking performance.

Nursery capacity further provides a critical buffering function, allowing operators to hold, stabilize, or delay deployment in response to adverse conditions such as storms, heat events, harmful algal blooms, or disease stress. This buffering function protects both seed investment and lease performance. Nurseries support production planning and farm-scale management. Since nurseries decouple hatchery delivery schedules from field deployment constraints, operators can receive seed when hatcheries have availability rather than when field conditions are ideal. Additionally, operators can build an inventory of conditioned juveniles to support stage-wise development for optimizing grow-out capacity, labour capacity, lease readiness, and market timing.

Additionally, while nursery systems cannot eliminate the presence of MSX (*Haplosporidium nelsoni*) or Dermo (*Perkinsus marinus*), they significantly reduce disease expression by minimizing stress through strong flow, appropriate stocking densities, and controlled handling. Land-based and hybrid nursery configurations provide capacity for observation, quarantine, and contingency holding, allowing operators to delay field deployment during high-risk periods and reduce the likelihood of stress-mediated disease impacts.

# 2. Environmental and Regional Considerations (Nova Scotia)

The design and operation of oyster nursery systems in Nova Scotia must account for a unique combination of environmental, seasonal, and biological factors that directly influence system performance, survivability, and biosecurity. Systems optimized solely for peak summer growth conditions are unlikely to perform reliably across the full production season or under adverse weather events commonly observed in the province.

## 2.1 Water Source Options for Oyster Nurseries

Oyster nursery systems in Nova Scotia may utilize either direct seawater intake from the marine environment or groundwater (well water) as a primary or supplemental water source. Each option presents distinct advantages, limitations, and design implications. In some cases, hybrid approaches may be appropriate.

### 2.1.1. Direct Ocean (Seawater) Intake

Direct intake of ambient seawater is the most common water source for oyster nurseries in Nova Scotia. When properly sited and designed, ocean intake systems provide natural plankton availability, stable water chemistry, and low operating complexity.

**Key Advantages**

- Continuous supply of naturally occurring phytoplankton and dissolved nutrients
- Minimal need for filtration beyond coarse screening
- Lower operational cost compared to treated or recirculated systems
- Regulatory familiarity and acceptance for flow-through nursery designs

**Design / Operational Considerations**

- Intake depth selection to avoid surface freshwater lenses, ice, debris, and to consider tidal action
- Screening to prevent entrainment of predators, larvae, debris
- Exposure to environmental variability (i.e., temperature, salinity, dissolved oxygen, HABs)
- Seasonal operational constraints during extreme weather or ice

**Ocean Intake Systems are Best Suited For:**

Open coastal/well-flushed estuarine environments ▪ Suites with stable salinity regimes ▪ Flow-through or hybrid nurseries

### 2.1.2. Well Water (Groundwater) Sources

If brackish aquifers can be identified, wells could be drilled to provide water that may be used as a sole source or contingency supply for oyster nurseries, particularly in land-based systems. In Nova Scotia, well water is typically cold, stable, and free from plankton and many biological stressors. Industry may access the Centre for Marine Applied Research's (CMAR) Resource Map to identify water sources (i.e., wells, saltwater intrusion, and surficial aquifers) in the province.

Well water is most effective when:

- Blended with seawater to moderate temperature or salinity
- Used seasonally during winter or harmful algal bloom (HAB) events
- Applied to early-stage seed holding or quarantine systems

**Key Advantages**

- Highly stable temperature and salinity
- Absence of harmful algal blooms, parasites, and fouling organisms
- Reliable winter operation where surface intakes are ice-impacted
- Valuable contingency water source during adverse marine conditions

**Design / Operational Considerations**

- Lack of natural plankton, requiring supplemental feeding or blending
- Potentially low alkalinity or altered pH requiring buffering
- Yield limitations depending on aquifer capacity
- Permitting and hydrogeological assessment requirements

**Well Water is Most Effective When**

Blended with seawater to moderate temperature/salinity ▪ Used seasonally during winter or HABs event ▪ Applied to early-stage seed holding or quarantine systems

## 2.2. Water Source Decision Matrix

The following decision matrix compares the two primary water source options used in oyster nursery systems in Nova Scotia: direct ocean (seawater) intake and groundwater (well water). This matrix is intended to support site selection, system design, and regulatory justification. Operational blending may still occur in practice, but only the two base water sources are evaluated below (Table 1).

Table 1. Water source decision matrix comparing direct ocean intake versus well water.

| DECISION FACTOR | DIRECT OCEAN INTAKE | WELL WATER (GROUNDWATER) |
|---|---|---|
| **Temperature Profile** | Seasonally variable; tracks ambient marine conditions | Highly stable; typically cold year-round |
| **Salinity Stability** | Site-dependent; influenced by rainfall and runoff | Very stable; unaffected by precipitation |
| **Natural Food Availability** | Yes – ambient phytoplankton present | None – requires supplemental feeding or limited use |
| **HAB Exposure** | Possible in some regions and seasons | None |
| **Biosecurity Risk** | Moderate; open connection to the marine environment | Low; isolated from marine pathogens |
| **Fouling Pressure** | High during the summer months | Minimal |
| **Infrastructure Complexity** | Low–moderate; simple screened intake | Moderate; requires well development and pumping |
| **Operating Cost Profile** | Low energy cost; minimal treatment | Moderate; pumping and possible conditioning |
| **Best Use Cases** | Primary nursery grow-out during productive seasons | Quarantine, winter holding, contingency supply |

Selection between direct ocean intake and well water should be based on site exposure, seasonal operating goals, biosecurity risk tolerance, and regulatory context. Many nursery designs prioritize one primary source while maintaining the ability to temporarily rely on an alternate source during high-risk environmental conditions.

Capital cost considerations differ materially between water source options. Well water systems generally involve higher upfront capital expenditure due to hydrogeological assessments, well drilling, casing, pump installation, electrical supply, and long-term yield testing. In contrast, direct ocean intake systems typically involve lower initial capital costs, relying primarily on screened intakes, piping, and basic pumping infrastructure. These capital cost differences should be explicitly considered during project planning, particularly for small- to medium-scale nursery developments.

## 2.3. Seasonal Temperature and Plankton Dynamics

Nova Scotia coastal waters exhibit strong seasonal variability, with water temperatures ranging from near freezing in winter to peak summer temperatures exceeding 20 °C in some nearshore areas. Plankton abundance and composition also fluctuate significantly throughout the year, influencing natural food availability for seed oysters.

Nursery systems must therefore be designed to:

- Maintain adequate flow and oxygenation during cold-water shoulder seasons
- Support early spring and late fall operations when growth rates are reduced
- Avoid reliance on peak summer conditions for system viability

## 2.4. Ideal Water Depth and Intake Positioning

Water depth is a critical site and design consideration for oyster nursery systems in Nova Scotia, as it directly influences temperature stability, salinity consistency, fouling pressure, ice risk, and intake reliability.

Ideal depth ranges vary by system type, but generally fall within the following guidelines.

Shore-based and land-based intake systems:

- Preferred intake depth: 3–6 m below chart datum
- Avoids surface freshwater lenses during rain and spring runoff
- Reduces temperature extremes and short-term salinity swings
- Minimizes intake of surface debris, ice, and plankton blooms

Floating or dock-mounted nursery systems:

- Operational depth: 2–4 m below surface for upwellers and silos
- Sufficient clearance from the bottom to prevent sediment entrainment
- Ability to adjust depth seasonally is strongly recommended
- Semi-enclosed or low-exchange waterbodies (e.g. lakes, lagoons, long estuaries):
- Deeper intakes (≥ 5 m where available) are preferred
- Depth should be below the dominant freshwater influence during extreme precipitation events
- Continuous salinity monitoring is recommended in these systems

Shallow systems (< 2 m) are generally discouraged due to:

- High exposure to precipitation-driven salinity dilution

- Elevated temperature fluctuations
- Increased ice formation and ice movement risk
- Greater fouling and sediment loading

Where bathymetry or access limits intake depth, system design should compensate through:

- Higher flow rates and redundancy
- Adjustable intake depth or multiple intake elevations
- Conservative stocking densities during high-risk periods

Depth selection should be confirmed through site-specific bathymetric assessment and, where possible, high-resolution, multi-year seasonal monitoring of temperature, salinity, and dissolved oxygen profiles.

### 2.5. Salinity Variability

Salinity levels in Nova Scotia can vary widely, particularly near river mouths, estuarine systems, or in semi-enclosed waterbodies with limited water exchange. In these environments, direct precipitation, snowmelt, and watershed runoff can significantly influence ambient salinity, sometimes resulting in rapid or prolonged reductions.

Such salinity fluctuations can stress juvenile oysters, suppress feeding activity, and increase disease susceptibility, particularly when combined with other stressors such as temperature extremes or handling events.

Nursery systems operating in variable-salinity environments should incorporate:

- Careful site selection that minimizes exposure to extreme freshwater influence where feasible
- Intake placement and flow rates should be sufficient to promote water exchange and dilution
- Operational flexibility to reduce stocking density, suspend grading, or adjust handling schedules during low-salinity events

### 2.6. Degassing

Degassing is a critical component of an effective flow-through oyster nursery, as it removes excess carbon dioxide that would otherwise lower pH consequently inhibits shell growth and calcification. By maintaining optimal water chemistry, degassing supports faster growth rates and improved survival, particularly under higher stocking densities and warmer seasonal conditions. It also stabilizes overall water quality, reducing stress, and disease risk, ensuring more consistent and predictable nursery performance.

### 2.6.1. Causes of elevated CO2 levels

- Stocking density is moderate to high
- Water temp > ~12–15°C (summer NS conditions)
- Intake source has low exchange or variable salinity
- Lower pH during upwelling events
- Variable conditions near shore
- River influence (salinity swings)
- Increased organic load → increases respiration → increases $CO_2$
- Stratified layers

### 2.6.2. Inadequate degassing:

- Slows seed growth (longer nursery phase)
- Results in less uniform size
- Increases higher mortality during stress events
- Reduces feeding efficiency

### 2.6.3. Proper degassing:

- Results in faster progression through mesh sizes
- Increases condition factor
- More predictable output (required for planning)

### 2.6.4. Packed Column Degassing

Packed column degassing is a highly efficient, commercially available systems used in aquaculture to remove dissolved gases—primarily carbon dioxide ($CO_2$)—from water by maximizing air–water contact. Water is distributed at the top of a vertical column filled with plastic packing media (such as bio-balls or structured packing) and allowed to trickle downward as a thin film over a large surface area. At the same time, air moves upward through the column, either passively or with the assistance of a fan, creating a counter current flow that drives gas exchange.

As the water spreads across the packing, $CO_2$ diffuses from the water into the air stream due to the concentration gradient, effectively “stripping” it from the system. This process increases pH, improves carbonate availability for shell formation, and enhances overall water quality. Packed columns are considered the gold standard for degassing because they are simple, energy-efficient, scalable, and capable of handling full system flow rates in commercial nursery operations.

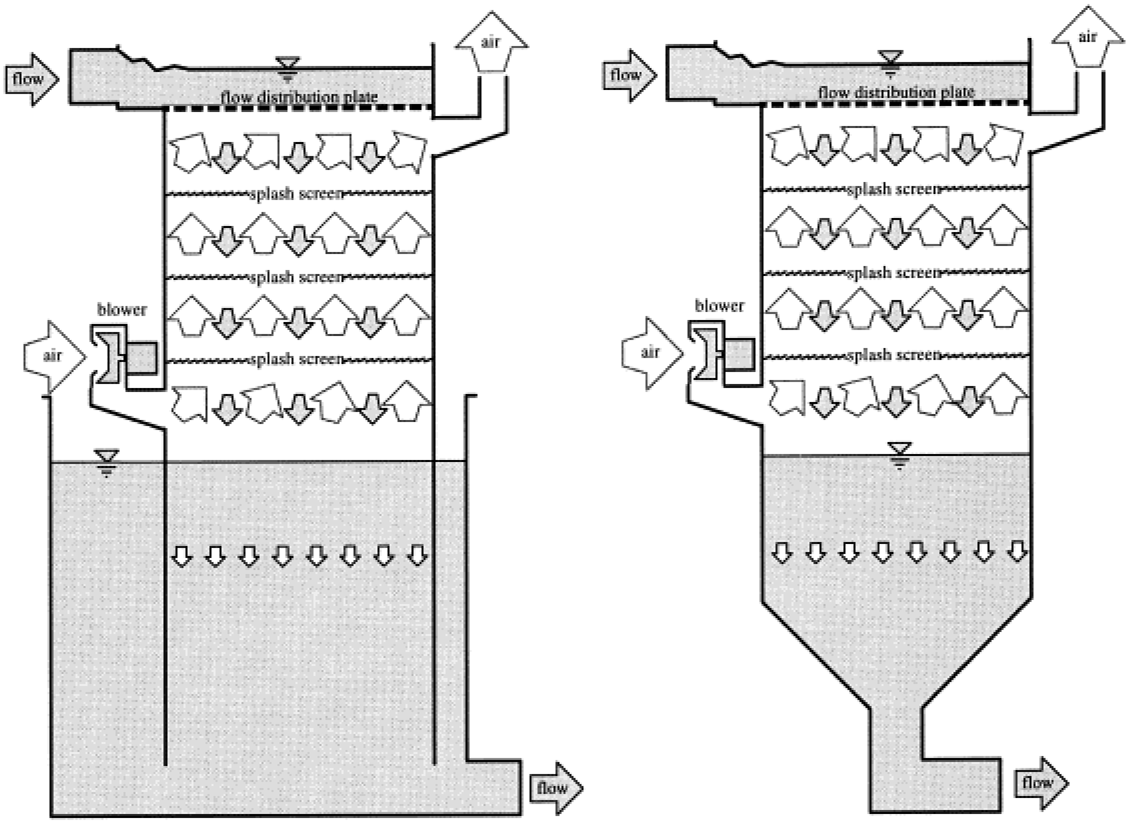

Figure 1. Schematic of a packed column (Source: Summerfelt et. Al (2000))

### 2.6.5. Splash Tray / Spray Bar Degassing

Splash trays or spray bar systems are a simple, low-cost methods of improving gas exchange by exposing water to air as it cascades over a series of trays, plates, or steps. Water is allowed to fall from one level to another, breaking into droplets and thin sheets, which increases its surface area and promotes the release of dissolved gases—primarily carbon dioxide ($CO_2$)—while simultaneously allowing oxygen to enter the water.

As water splashes and tumbles through the air, turbulence enhances mixing and accelerates gas transfer, making this approach effective for basic aeration and partial degassing. These systems are easy to build, require minimal energy, and are often used in small-scale or supplemental applications. However, compared to packed column degassing, splash trays are less efficient at removing $CO_2$, especially at higher flow rates or stocking densities.

Figure 2. Schematic of a typical spray bar (Source: J Nickerson)

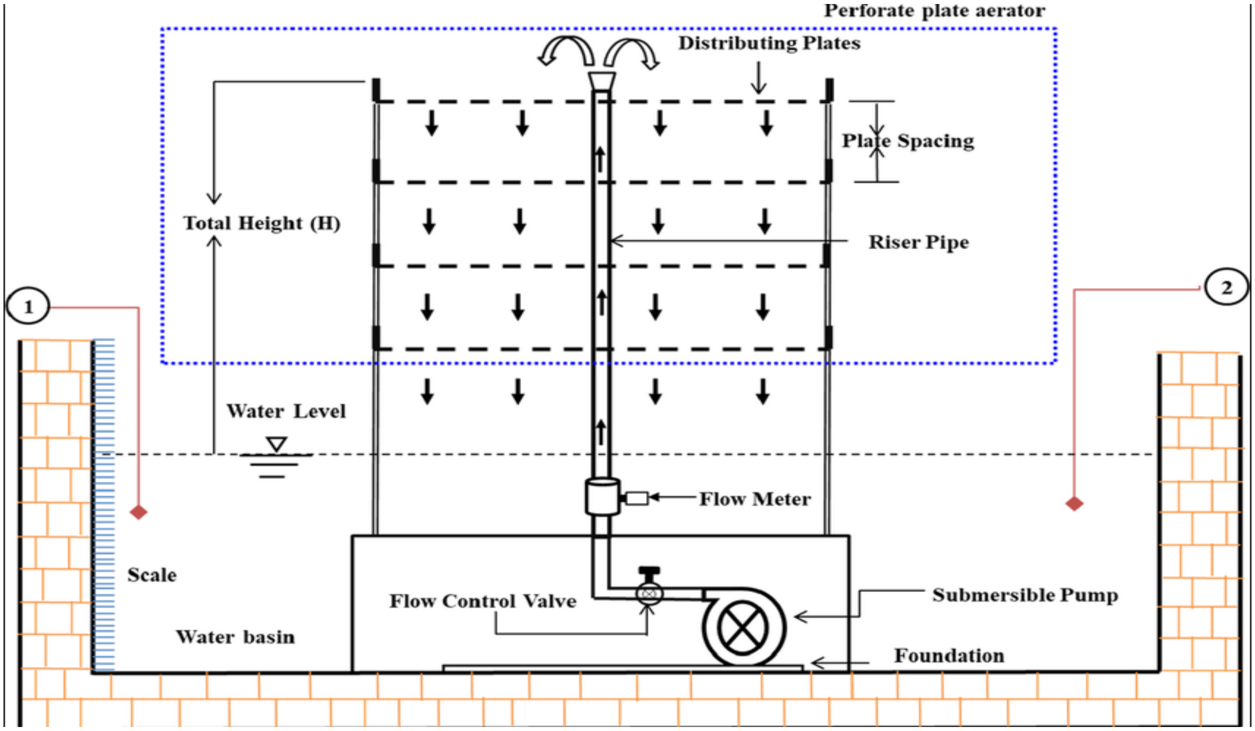

Figure 3. Schematic of a typical splash tray (Source: Roy et al. (2023))

## 2.7. Aquatic Invasive Species and Biofouling

In Nova Scotia, aquatic invasive species (AIS) and biofouling pressure, such as tunicates, algae, bryozoans, and other marine organisms, are the highest during summer months.

Effective nursery designs support:

- Easy removal and cleaning of screens and silos
- Redundant screen inventory to allow drying and rotation
- Adequate flow velocities to reduce fouling settlement
- Ensure the location is not in a high aquatic invasive species zone

The Federal Open Government Portal presents several different data sets identifying the presence of invasive species[1] .

## 2.8. Harmful Algal Blooms (HABs)

Certain regions of Nova Scotia experience episodic harmful algal blooms (HABs), which can impact oyster health and create regulatory and operational risks.

Land-based and hybrid systems provide advantages by:

- Allowing temporary shutdown or intake relocation
- Supporting contingency management during bloom events
- Improving operational control during regulatory advisories

## 2.9. Oyster Diseases (MSX and Dermo)

Oyster diseases such as MSX and Dermo are present in Canada's Maritime waters. Disease expression is closely linked to stress factors.

Nursery system design should emphasize:

- Strong, consistent water flow and oxygenation
- Conservative stocking densities
- Minimal handling during high-stress periods
- Robust record-keeping of seed source, batch identity, and movement history

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[1] Species distribution models and occurrence data for marine invasive species hotspot identification
Updated Species Distribution Models for Marine Invasive Species Hotspot Identification
DFO Maritimes Biofouling Monitoring Program
Gulf Region Aquatic Invasive Species (AIS) Biofouling Monitoring Dataset

### 2.10.Design Philosophy for Regional Resilience

Nursery systems in the Maritimes must be designed for reliability during spring and fall shoulder seasons and resilience during storms, ice events, and temperature extremes. The Nova Scotia aquaculture Coastal Classification System Mapping Tool presents data on cold and heat exposures, drift ice risk, and wind and wave conditions for the entire province

## 3. Overview of Oyster Nursery System Types

Oyster nursery systems can be broadly grouped into four categories based on how water is managed, how much environmental control is needed, the quality of the water, and where biological and operational risks are carried within the production cycle. Each system type reflects a different balance between cost, labour demand, biosecurity, scalability, and exposure to environmental and disease risk.

There is no universally "best" nursery system. The appropriate system and practices depend on site conditions, production scale, labour availability, disease risk tolerance, and the operator's long-term development strategy. Selecting the right approach requires a clear understanding of the purpose of each system and the specific operational challenges it is designed to address.

### 3.1. Floating Flow-Through Upwelling Systems (FLUPSY)

#### 3.1.1 System Description

Floating FLUPSY systems consist of vertical upwelling silos mounted on a floating dock, raft, or barge. Ambient seawater is pumped upward through screened trays containing oyster seed and discharged directly back to the surrounding marine environment without recirculation or treatment (Figure 1).

#### 3.1.2. Advantages

- Low capital cost
- Available for purchase 'off the shelf'
- Minimal hydraulic head and low energy use
- Simple construction and operation
- Modular and easily expandable
- Excellent biological performance under favourable conditions

#### 3.1.3. Limitations

- High exposure to weather, fouling, and HABs
- Limited biosecurity
- Seasonal operational constraints due to temperature and ice
- Reduced operational control
- Access to an adequate electrical supply

### 3.1.4. Typical Use

- Floating FLUPSY systems are well-suited to:
- Small and medium-scale operations
- Community projects
- Seasonal nursery production
- Operators seeking low initial capital investment

### 3.1.5 Principles of Operation

FLUPSYs are nursery platforms that use continuous low-head pumping to move ambient seawater vertically upward through trays of oyster seed. These systems are designed to maximize food delivery, oxygen, and waste removal while minimizing energy use and capital cost.

System Principle:

- Water is drawn from the surrounding waterbody using a submersible pump and introduced at the base of each upweller silo. Water then moves vertically upward through stacked trays containing oyster seed before exiting at the top of the silo and returning directly to the marine environment.
- The vertical upwelling motion gently suspends and tumbles the seed, ensuring:
- Continuous exposure to phytoplankton
- High dissolved oxygen availability
- Rapid removal of metabolic waste
- Prevention of sediment accumulation

Hydraulic Characteristics:

- Since floating systems operate at or near water level, the total dynamic head is typically less than 2 metres. This allows large volumes of water to be moved efficiently using low-power pumps.
- Flow is regulated through a central header and individual branch valves, allowing operators to balance upwelling velocity across all silos.

Biological Function:

- Floating FLUPSY systems perform best once the seed has reached a robust size (generally ≥ 4–6 mm). At this stage, oysters better tolerate environmental variability and can be held on coarser mesh, which reduces fouling risk.
- These systems are most effective as high-throughput biomass production units during favourable seasons.
- Because the system tracks ambient temperature, salinity, and plankton availability, growth rates are often excellent during ideal conditions. However, the same exposure also makes floating systems vulnerable to fouling, harmful algal blooms, and weather events.
- In practice, floating FLUPSY systems function best as high-throughput, low-cost biomass production units once the seed has reached a robust size.

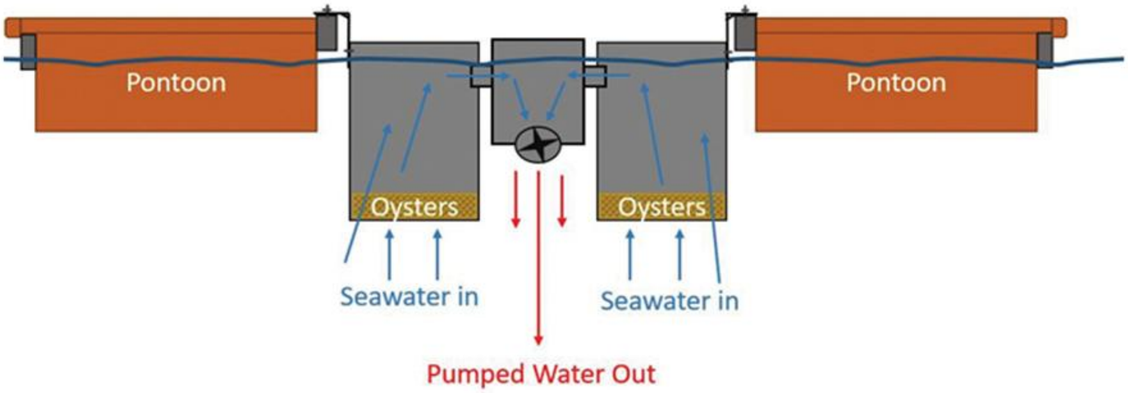

Figure 4. Schematic of a typical FLUPSY (Source: Pump Industry)

## 3.2. Land-Based Flow-Through Upwelling Systems

Land-based flow-through systems are selected when greater control, year-round access, and reduced environmental exposure are required, while still maintaining the simplicity and energy efficiency of flow-through operation (Figure 2; Figure 3).

Operators typically choose land-based systems when:

- Early-stage survival and conditioning are priorities
- Winter or shoulder-season operation is required
- Labour efficiency and worker safety are important
- Exposure to storms or variable water quality conditions (i.e., salinity and temperature) must be reduced
- By relocating the upwelling process into a shore-side facility, land-based systems allow operators to manage flow, stocking density, grading frequency, and observation more effectively. While these systems do not eliminate exposure to ambient water quality or disease, they significantly reduce stress during the most vulnerable life stages and provide critical risk-buffering capacity between hatchery and lease.

### 3.2.1 System Description

Land-based flow-through nurseries locate upwelling silos within a shore-side building or shelter. Raw seawater is pumped from an adjacent marine intake into the facility, distributed through upwellers, and discharged by gravity back to the marine environment.

### 3.2.2 Advantages

- Improved environmental and operational control
- Year-round access and winter operability
- Reduced exposure to storms and ice
- Easier grading, cleaning, and husbandry

### 3.2.3 Limitations

- Higher capital cost than floating systems

- Higher pumping head and energy demand
- Continued exposure to ambient water quality and disease
- Requirement for shore power

### 3.2.4 Typical Use

- Land-based systems are appropriate for:
- Operators requiring year-round access
- Larger commercial nurseries
- Sites with challenging exposure
- Projects prioritizing operational resilience

### 3.2.5 Principles of Operation

Land-based flow-through nurseries apply the same upwelling principles as floating systems but relocate the hydraulic process into a shore-side facility, providing greater environmental control, improved access, and year-round operability.

System Principle:

- Raw seawater is drawn from a nearshore intake and pumped into a nursery building. Water is distributed through a main header and branch lines to individual upweller silos, where it flows upward through trays of oyster seed before exiting via overflow and returning to the marine environment by gravity.
- Hydraulic Characteristics
- Land-based systems operate at a higher hydraulic head (typically 3–6 metres) due to intake depth and building elevation. Pump selection, pipe sizing, and redundancy are therefore critical design considerations.
- Oversized plumbing and individual flow control valves ensure consistent upwelling, even under fouling conditions.

Biological Function:

- Land-based systems are particularly effective for early nursery stages (1–3 mm to 4–6 mm), when the seed is most vulnerable to stress. Fine mesh, conservative stocking densities, and frequent observation support high survival and uniform growth.
- Land-based capacity also provides quarantine and contingency holding capability during adverse environmental conditions.

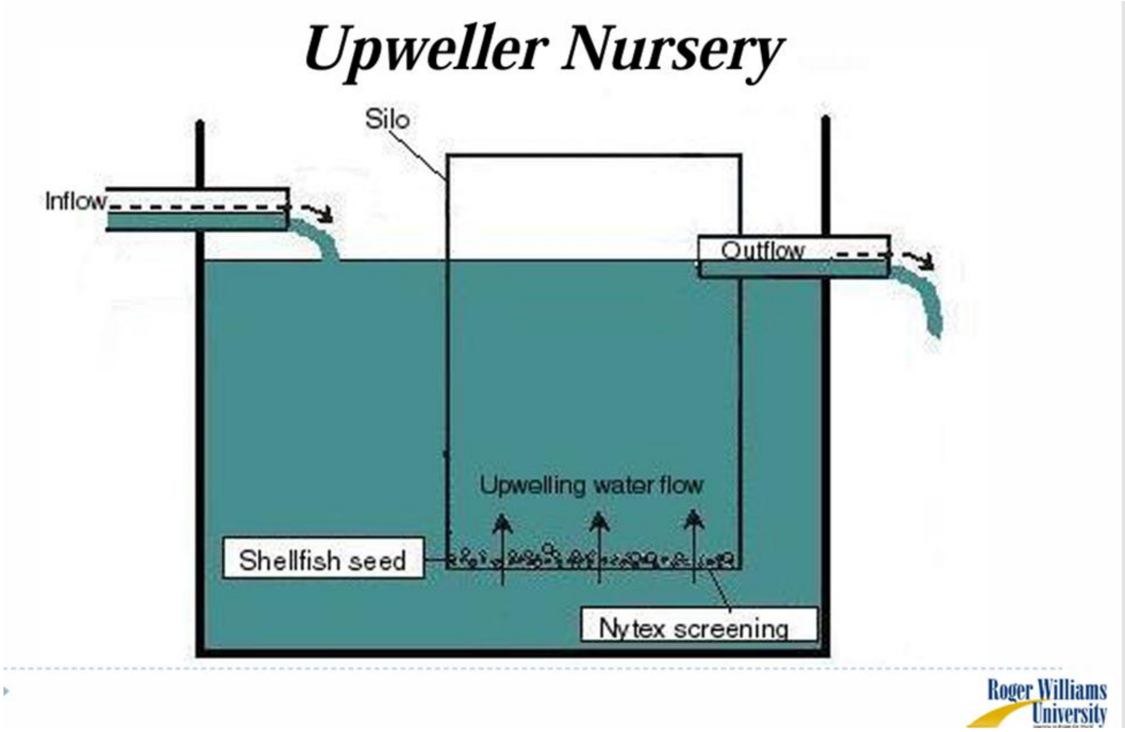

Figure 5. Schematic of a typical shellfish upweller nursery (Source: Roger Williams University)

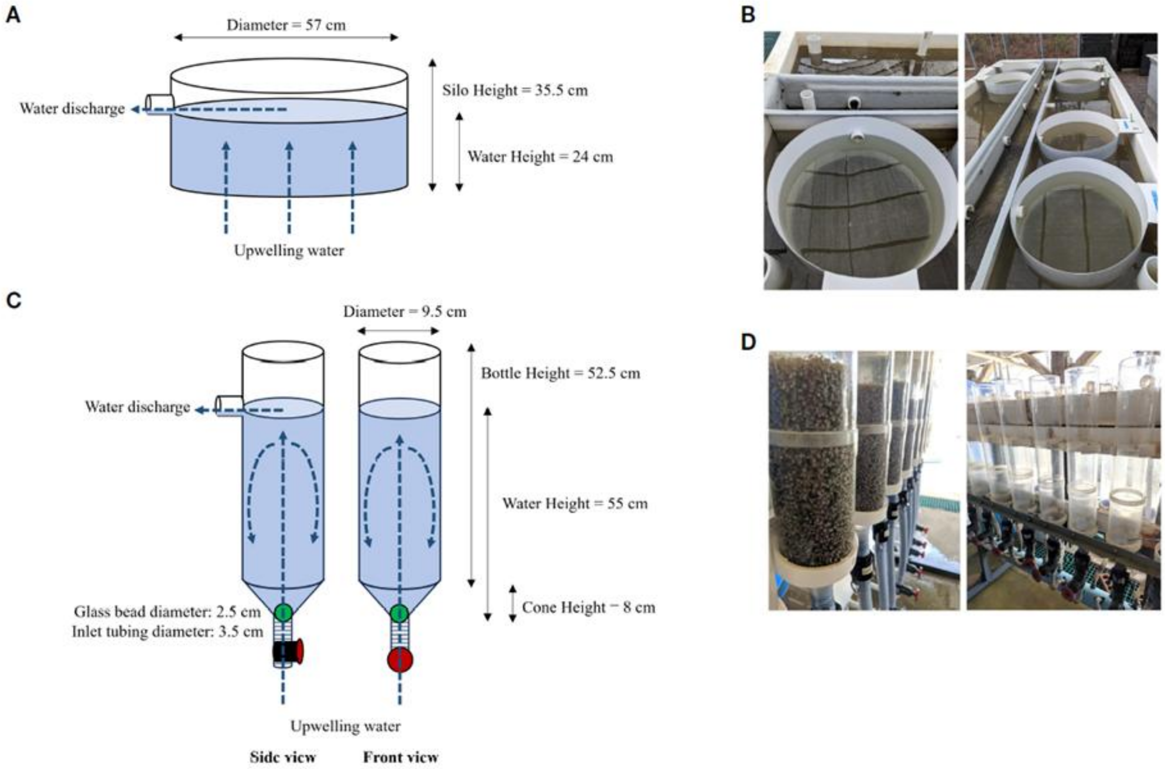

Figure 6. Schematics of shellfish upweller nurseries A/B. silo upweller and C/D bottle upweller[2].

## 3.3. Hybrid Nursery Systems

Hybrid nursery systems deliberately combine land-based and floating components, assigning each system to the production stage in which it performs best. This approach is increasingly considered best practice in Nova Scotia for medium- and large-scale operations.

Operators choose hybrid systems when:

- Reducing early-stage mortality is a priority
- Consistent output and production predictability are required
- Long-term scaling is anticipated
- In hybrid systems, early-stage seed is stabilized and conditioned in a land-based nursery before being transferred to floating FLUPSY units for cost-efficient bulk growth. This structure concentrates biological risk where control is highest and production volume where efficiency is greatest. Hybrid systems provide flexibility, resilience, and strong alignment with funding and regulatory objectives focused on risk reduction and sustainability.

### 3.3.1 System Concept

Hybrid nursery systems combine a land-based flow-through nursery with one or more floating FLUPSY units. Each system is assigned to the production stage where it performs best.

### 3.3.2 Functional Staging

Stage A – Land-Based Nursery

- Intake and stabilization of hatchery seed (1–3 mm)
- Early growth to approximately 4–6 mm
- Fine mesh sizes and conservative stocking
- Grading, observation, and quarantine
- Contingency capacity during adverse conditions
- Stage B – Floating FLUPSY Nursery
- Bulk nursery growth from 4–6 mm to 8–15 mm
- Coarser mesh sizes
- Higher stocking densities
- Cost-efficient biomass production

### 3.3.3 Benefits

- Reduced early-stage mortality

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[2] Tarnecki, A. M., Landry, K., Rikard, S. 2023. Nursery upweller type has minimal impact on subsequent grow-out of Eastern oysters (*Crassostrea virginica*). Front. Aquac. 2:1236346.

- Improved consistency and predictability
- Lower overall production risk
- Optimized capital investment
- Strong alignment with funding and regulatory priorities
- Hybrid systems are increasingly considered best practice for medium- and large-scale oyster nursery operations in Nova Scotia.

### 3.3.4 Principles of Operation

Hybrid nursery systems deliberately combine land-based and floating components, assigning each system to the production stage in which it performs best. The hybrid system works because risk is concentrated where control exists, and volume is concentrated where efficiency exists. This approach consistently produces higher usable output per million seed input than single-system designs.

System Concept
Rather than forcing a single system to manage all nursery functions, hybrid systems separate production into two functional stages:

- Stage A – Control and Stabilization (Land-Based): intake, conditioning, and early growth
- Stage B – Production and Conditioning (Floating): bulk growth and biomass accumulation

Operational Flow
Hatchery seed enters the land-based nursery immediately upon delivery. Here it is held at conservative densities on fine mesh under strong, controllable flow conditions. Once the seed reaches a robust size (typically 4–6 mm), it is graded and transferred to floating FLUPSY units.

The floating system then provides cost-efficient, low-energy growth to planting size (6–15 mm).

Risk Management Logic
Hybrid systems concentrate biological risk where control is highest and production volume where efficiency is greatest. Land-based capacity remains available for:

- Intake of new seed batches
- Contingency holding during adverse water quality events (i.e., temperature, salinity, dissolved oxygen)
- Quarantine or increased observation, if health concerns arise
- This structure consistently reduces early-stage mortality, improves growth consistency, and enhances production predictability. Operationally, the land-based system remains active as:
- Intake capacity for new seed
- Contingency space during storms or heat events

- Grading and redistribution hub

The hybrid system works because risk is concentrated where control exists, and volume is concentrated where efficiency exists. This approach consistently produces higher usable output per million seed input than single-system designs.

## 3.4. Partial and Full Recirculating (RAS) Nursery Systems

Recirculating aquaculture systems (RAS) nursery systems are chosen when maximum biosecurity and environmental control outweigh considerations of capital cost and operational complexity. These systems rely on internal water treatment rather than continuous exchange with ambient seawater.

Operators typically select RAS when:

- Disease exclusion is a primary objective
- Adequate ambient water quality is highly constrained
- Year-round production independent of seasonal cycles is required
- The nursery is directly linked to a hatchery

While RAS offers the highest level of control and isolation from harmful algal blooms and diseases like MSX and Dermo, they require significant technical expertise, continuous monitoring, the capacity and technical capabilities to grow a consistent supply of algae, and robust backup systems. As a result, they are best suited to specialized applications rather than broad industry deployment.

### 3.4.1 System Description

RAS nurseries reuse water through filtration, biological treatment, and disinfection. Partial-RAS combines flow-through operation with filtration or UV treatment, while full RAS operates with minimal water exchange.

### 3.4.2 Advantages

- Maximum biosecurity
- Protection from MSX, Dermo, and HAB exposure
- Stable temperature and water quality
- Year-round production capability

### 3.4.3 Limitations

- High capital and operating costs
- High energy dependency
- Increased technical complexity
- Greater risk of catastrophic failure requiring a high level of technical expertise and redundancy built into the system.

### 3.4.4 Typical Use

- RAS are best suited to:
- Hatchery-linked operations
- Broodstock or high-value seed programs
- Locations with severe water quality constraints

### 3.4.5 Principles of Operation

RAS nurseries operate on a fundamentally different principle than flow-through systems, whereby water quality is controlled internally rather than replaced continuously.

In RAS nurseries, water leaving the nursery tanks or upwellers is treated through mechanical filtration to remove solids, biological filtration to convert dissolved wastes, and disinfection (UV or ozone) before being returned to the system. Only a small percentage of makeup water is added to replace losses and maintain chemistry.

This approach allows operators to:

- Isolate seed from external disease vectors
- Maintain stable temperature and salinity
- Operate independently of ambient plankton cycles
- However, biological success in RAS systems depends on system stability rather than flow dominance. Any interruption to power, filtration, or circulation can lead to rapid degradation of water quality.
- For this reason, RAS nurseries require:
- Continuous monitoring
- High system redundancy
- Trained technical operators
- Reliable backup power

In Nova Scotia, RAS nurseries are most appropriate where biosecurity outweighs cost and complexity, such as hatchery-linked operations or specialized seed programs.

## 3.5 Selecting the Appropriate System

Each nursery type represents a different approach to managing biological and operational risk. The key decision is not which system produces oysters fastest under ideal conditions, but which system produces the most consistent and reliable output under site-specific conditions.

Many successful operations use more than one system type over time, evolving toward hybrid or staged approaches as production scale, labour capacity, and risk tolerance change.

### 3.6 Nursery System Selection – Decision Matrix

This matrix is intended to help operators quickly assess which oyster nursery system type best aligns with production goals, site conditions, labour capacity, disease risk tolerance, and capital availability (Table 2).

Table 2. Decision matrix to support nursery system selection.

| Decision considerations | Floating FLUPSY | Land-Based Flow-Through | Hybrid (Land + Floating) | Partial / Full RAS |
|---|---|---|---|---|
| **Primary Role** | Bulk nursery growth under favourable conditions | Early-stage stabilization and conditioning | Staged risk management + efficient bulk growth | Maximum control and biosecurity |
| **Typical Seed Stage** | 4–6 mm to 8–15 mm | 1–3 mm to 4–6 mm | 1–3 mm → 15 mm (staged) | 1–3 mm onward |
| **Early-Stage Survival** | Moderate | High | Very high | Very high |
| **Growth Consistency** | Moderate | High | High–Very high | Very high |
| **Disease Risk Mitigation (MSX/Dermo)** | Low | Moderate | Moderate–High | High |
| **Environmental Exposure** | High (weather, HABs, fouling) | Moderate | Managed by stage | Very low |
| **Biosecurity Control** | Low | Moderate | Moderate–High | Very high |
| **Labour Efficiency** | Moderate (weather-dependent) | High | High | Moderate–Low (technical) |
| **Operational Complexity** | Low | Low–Moderate | Moderate | High |
| **Scalability** | Modular, seasonal | Modular, site-limited | Highly scalable | Technically scalable, but costly |
| **Seasonality** | Seasonal | Seasonal or year-round | Flexible | Year-round |
| **Best Fit For** | Small or seasonal operations; limited capital | Early-stage protection; winter access | Commercial scale; risk reduction; planning | Hatchery-linked or high-value seed |
| **Key Limitation** | Exposure and limited control | Higher energy and capex than floating | Requires coordination of two systems | Cost, complexity, failure risk |

## 4. System Design and Hydraulic

Flow rates must scale with seed size and stocking density. Adequate flow is essential to maintain consistent access to food, dissolved oxygen levels, waste removal, and uniform growth.

### 4.1 Hydraulic Characteristics

Land-based systems operate at a higher hydraulic head (typically 3–6 metres) due to intake depth and building elevation. Pump selection, pipe sizing, and redundancy are therefore critical design considerations.

Because floating systems operate at or near water level, the total dynamic head is typically less than 2 metres. This enables the efficient movement of large volumes of water using low-power pumps.

Pump selection, redundancy, and fouling tolerance are critical design considerations.

## 5. Operations and Husbandry

Effective nursery performance depends on disciplined husbandry practices that prioritize flow, oxygen, and nutrient delivery, and uniform growth while minimizing stress, labour inefficiency, and disease expression. The following practices are central to achieving consistent biological and economic outcomes.

### 5.1 Stocking Density

Stocking density is one of the most important variables in oyster nursery systems. Density must always be secondary to available flow, as well as dissolved oxygen and nutrient delivery.

Conservation densities during early stages:
Early-stage seed (1–3 mm) has limited tolerance for low oxygen, waste accumulation, and competition. Conservative stocking densities ensure that each individual has consistent access to food and oxygen, reducing stress and early mortality. Overcrowding at this stage often results in slow growth, uneven size distribution, and increased susceptibility to disease expression.

Progressive increases as seed size and flow increase:
As the seed grows and the mesh size increases, densities can be gradually increased, provided that the upwelling velocity and flow per unit biomass are maintained. Density adjustments should be incremental and based on observed seed behaviour (i.e., active tumbling, uniform suspension) rather than fixed targets. Density increases without corresponding flow increases negate nursery benefits and reduce performance. It is recommended to maintain batch integrity by seed source and each nursery unit or tray stack should contain seed from a single hatchery source and delivery batch wherever possible.

Maintaining batch integrity:

- Reduces cross-contamination risk
- Improves traceability for disease management
- Allows performance comparison between sources
- Simplifies decision-making if health or growth issues arise
- Mixing seed from different sources within the same unit is strongly discouraged, particularly during the early stages

## 5.2 Mesh Progression

Mesh selection and progression directly influence flow, food delivery, fouling rates, and labour demand. Mesh should always be selected to balance seed retention with adequate water exchange.

Fine mesh for early seed:
Early-stage seed requires fine mesh to prevent loss and ensure stable positioning during upwelling. Fine mesh should be used only where sufficient flow can be maintained, typically in land-based systems where fouling can be managed, and flow can be adjusted easily.

Gradual transition to coarser mesh:
As seed grows, mesh size should be increased incrementally to reduce hydraulic resistance, improve flow-through, and limit fouling accumulation. Gradual progression prevents sudden changes in hydrodynamics that can stress the seed and disrupt feeding behaviour.

Avoid fine mesh in floating systems:
Fine mesh in floating FLUPSY systems is prone to rapid fouling and flow restriction due to exposure to plankton blooms and suspended debris. Where floating systems are used, seed should be transferred only once it can be retained on a coarser mesh that allows reliable flow and reduces daily maintenance demands.

Mesh progression should always be coordinated with grading schedules and density adjustments to maintain stable upwelling conditions.

## 5.3 Grading and Monitoring

Regular grading and close observation are essential for maintaining uniform growth, preventing density-related stress, and identifying issues before losses occur.

Regular grading to maintain uniformity:
Grading separates fast- and slow-growing individuals, reducing size-based competition and ensuring that flow and density are appropriate for all seed in a unit. Consistent grading improves growth uniformity, simplifies downstream handling, and leads to more predictable field performance.

Recommendations:

- Daily visual inspection of flow and seed behaviour

- Operators should visually confirm daily that:
- Upwelling is uniform across all trays
- Seed is actively tumbling or gently suspended
- No areas of stagnation or compaction are present
- Changes in seed behaviour (i.e., seed tumbling slows or stops, sticks together, concentrates at the bottom of the tray) are often the first indicator of flow restriction, fouling, or oxygen limitation.
- Prompt response to fouling or flow restriction

Any reduction in flow must be addressed immediately through cleaning, screen rotation, density reduction, or flow adjustment. Delayed response to fouling events is a leading cause of avoidable stress, uneven growth, and disease expression in nursery systems.
Consistent monitoring and rapid intervention convert nursery systems from passive holding structures into active biological management tools

## 6. Biosecurity and Disease Management

Disease management in oyster nurseries is fundamentally about stress management, not disease eradication. In Nova Scotia, pathogens associated with MSX and Dermo are present in the environment, and their impacts are driven primarily by the physiological condition of the oyster rather than simple exposure alone.

Nursery systems play a critical role in limiting disease pressure by reducing the intensity, duration, and frequency of stress during early life stages and by shortening the time oysters remain vulnerable.

### 6.1 Stress Pathways and Disease Expression (MSX and Dermo)

MSX and Dermo are stress-mediated diseases. Infection pressure may be present for extended periods, but disease expression and mortality typically increase when oysters experience one or more of the following stressors:

- Low dissolved oxygen
- High salinity
- Inadequate or inconsistent food availability
- Overcrowding and waste accumulation
- Rapid temperature or salinity change
- Repeated or poorly timed handling
- Flow restriction caused by fouling

When stress is elevated, oysters divert metabolic energy away from growth and immune function towards basic survival. This weakens resistance and allows disease processes to progress more rapidly.

Nursery systems that maintain strong, consistent flow and conservative densities directly interrupt this stress–disease pathway by keeping oysters in a high-energy, low-stress physiological state.

## 6.2 Role of Nursery Systems in Disease Mitigation

While nursery systems cannot eliminate MSX or Dermo, they are highly effective at reducing the conditions that allow disease expression to accelerate.

Best-practice nursery designs mitigate disease risk by:
- Maintaining strong water flow and oxygenation
- Continuous upwelling ensures high dissolved oxygen and rapid waste removal, limiting physiological stress and supporting immune function.
- Avoiding overcrowding:

Density is managed relative to flow and seed size, preventing oxygen depletion, waste buildup, and competitive suppression that increase disease susceptibility.

Minimizing handling stress:
Well-designed nursery layouts reduce unnecessary handling and allow grading and transfers to occur at appropriate sizes, limiting cumulative stress exposure.

Rotating and drying screens:
Regular screen rotation and drying interrupts fouling accumulation, maintains flow efficiency, and reduces localized stress conditions within seed trays.

Maintaining detailed seed source and batch records:
Tracking seed origin, delivery dates, and nursery performance allows operators to identify source-related trends, manage risk proactively, and isolate issues if disease concerns arise.

## 6.3 Growth Rate, Exposure Time, and Disease Risk

A critical but often underappreciated benefit of nursery systems is their ability to shorten the growth cycle between hatchery delivery and field planting.

Disease risk increases with duration of exposure, not exposure alone. The longer oysters remain small, stressed, or poorly conditioned, the greater the cumulative opportunity for disease expression.

By accelerating early growth, nursery systems:
- Reduce the duration oysters spend in highly vulnerable size classes
- Move seed more quickly into robust juvenile stages with stronger shells and higher stress tolerance
- Shorten the window during which diseases, like MSX and Dermo, are most likely to progress to clinical expression

In practical terms, faster growth is a disease mitigation strategy. Oysters that reach plantable size sooner experience fewer stress events, fewer handling cycles, and less cumulative exposure to adverse conditions.

### 6.4 System Type and Biosecurity Capacity

Different nursery system types provide different levels of disease risk control:

- Floating systems offer limited biosecurity and rely heavily on maintaining strong flow and appropriate stocking densities.
- Land-based flow-through systems provide improved capacity for observation, early intervention, and stress reduction during vulnerable stages.
- Hybrid systems offer the strongest balance by concentrating early-stage risk management in controlled environments while using floating systems for efficient bulk growth.
- RAS systems provide the highest level of isolation and disease exclusion, but with significant increased cost and complexity.
- Land-based and hybrid systems also provide critical contingency capacity, allowing operators to delay field deployment during high-risk periods such as heat stress events, salinity extremes, storm events, or suspected disease pressure.

### 6.5 Key Principle

Disease management in oyster nurseries is achieved by controlling stress, reducing exposure time, and maintaining biological momentum. Nursery systems that prioritize flow, density control, growth rate, and operational discipline consistently experience lower disease-related losses and more predictable production outcomes.

## 7. Power, Energy, and Backup Systems

Reliable electrical power is mission-critical for oyster nursery operations. Even short interruptions in pumping can result in rapid oxygen depletion, waste accumulation, and acute stress—conditions that can trigger mortality and disease expression (MSX/Dermo), particularly in early-stage seed. Power systems must therefore be designed for continuous operation, redundancy, and rapid recovery. Nova Scotia is notorious for poor power reliability; storms, tropical depressions, and hurricanes typically result in extended periods of time without power, requiring the nursery operator to carefully select the appropriate system(s).

### 7.1 Typical Energy Demand (Indicative Ranges)

Energy demand varies by system type, scale, hydraulic head, and pump efficiency. The ranges below reflect typical Nova Scotia nursery installations operating with low-head, high-flow pumps.

Floating FLUPSY Systems –

- Typical pump size: 0.5–1.5 kW per pump
- Operating head: < 2 m
- Continuous operation (24/7 during season)
- Typical energy use:
  - ~12–36 kWh per day per pump
  - ~4,000–12,000 kWh per season (6–9 months if used for multiple batches)

Land-Based Flow-Through Nurseries –

- Typical pump size: 1.5–5.5 kW per pump (depending on lift and intake distance)
- Operating head: 3–6 m
- Continuous operation (capable for all year-round)
- Typical energy use:
  - ~36–130 kWh per day per pump
  - ~13,000–45,000 kWh per year for small–medium systems (2–5M seed capacity)

Hybrid Systems (Combined land-based + floating demand) –
Typical energy profile:

- Higher winter/shoulder-season load (land-based)
- Lower summer incremental load (floating)
- Hybrid systems often achieve lower energy cost per million seed produced due to improved survival and faster growth.
- Actual consumption should always be verified through pump curves, measured head, and run-time assumptions during design.

## 7.2 Renewable Energy Integration

Renewable energy systems should be incorporated into nursery design wherever feasible, particularly for FLUPSY nurseries, where on-site generation can eliminate the need for underwater electrical cables, reduce operating costs, and improve overall system resilience.

In addition to operational benefits, the integration of renewable energy can significantly enhance project eligibility for financial incentives and grant programs offered by various federal, provincial, and regional agencies. Programs typically prioritize projects that demonstrate improvements in energy efficiency, greenhouse gas emission reductions, and clean technology adoption within the aquaculture sector.

Renewable systems must be designed to support continuous and reliable water flow, with appropriate redundancy and backup provisions to protect stock during adverse weather, low-energy periods, or equipment failure.

### 7.2.1 Solar-Powered Pumping

Solar-powered pumping systems are a proven and widely adopted renewable option for both FLUPSY and land-based flow-through nurseries.

Typical system configurations include:

- Photovoltaic (PV) panels supplying power directly to a DC pump, or
- PV panels connected to an inverter and variable frequency drive (VFD) to operate an energy-efficient AC centrifugal pump.

Battery storage may be incorporated to allow pumping during nighttime hours and periods of reduced solar irradiance, and to smooth short-term fluctuations in power output. Solar systems are particularly well-suited to low-head, high-flow nursery applications and can be scaled to match seasonal production requirements.

### 7.2.2 Tidal-Driven Pumping (Paddle Wheel Systems)

Tidal-driven pumping systems, such as paddle wheel or turbine-based mechanisms, are highly effective for FLUPSY installations located in areas with strong and predictable tidal currents (typically greater than 0.3 m/s).

Key advantages include:

- Continuous energy availability during tidal cycles
- Minimal operating costs,
- Reduced reliance on electrical infrastructure

Tidal pumping systems perform best when integrated into hybrid configurations, typically paired with solar power and limited battery storage to maintain flow during slack tides and low-current periods. As with all nursery pumping systems, tidal-driven designs must incorporate redundancy or auxiliary pumping capacity to ensure uninterrupted water flow and safeguard stock health.

## 7.3 Generator and Backup Power Requirements

All nursery systems should be designed to operate under the assumption that grid power interruptions will occur, particularly during storm events and winter months.

Minimum Generator Requirements

The generator must be capable of supporting:

- All duty pumps operating simultaneously
- Essential lighting and control systems
- Critical monitoring or alarm systems

Sizing Guidance:

- Minimum generator capacity: 125–150% of maximum continuous pump load

*Example*:

2 × 3 kW pumps + controls = ~7 kW load

Recommended generator size: 9–11 kW

Best Practices:

- Automatic transfer switch, where feasible
- Fuel supply sized for 72-96 hours of continuous operation
- Routine test runs under load
- Clear standard operating procedures and staff training for manual startup if automatic systems fail

## 7.4 Credible Failure Scenarios and Consequences

Understanding realistic failure modes is essential for risk management. These include:

- Power Failure (Grid Outage)
- Loss of flow leads to oxygen depletion within minutes to hours, depending on density
- Early-stage seed is particularly vulnerable
- Generator response time is critical
- Pump failure
- Mechanical failure, fouling, or electrical faults
- Without redundancy, failure can result in localized or system-wide losses
- Intake blockage
- Debris, ice, or biofouling can reduce flow even when pumps are operating
- Flow restriction may not be immediately obvious without regular visual evaluation
- Human error
- Incorrect valve positioning
- Missed fouling events
- Inadequate response to alarms
- Poor standard operating procedure training
- Lack of best-practice mitigation
- Duty + standby pumps improperly installed and plumbed
- Lack of daily visual checks confirming upwelling function
- Lack of installation of alarms or flow indicators
- Lack of clear emergency response procedures posted on-site
- Inadequate staff training

## 7.5 Energy-Efficient Design and Operating Practices

Energy efficiency reduces operating costs and improves system resilience by lowering total load during backup operation.

Pump and Hydraulic Efficiency

- Select pumps for operating point, not maximum capacity
- Avoid over-speeding pumps to compensate for poor plumbing design

- Use large-diameter intake and header pipes to reduce friction losses

System Layout
- Minimize vertical lift where possible
- Keep intake runs short and direct
- Avoid unnecessary elbows and restrictions

Operational Efficiency
- Match stocking density to available flow—do not compensate with higher pumping rates
- Increase mesh size as soon as biologically appropriate to reduce head loss
- Clean screens and intakes proactively to maintain pump efficiency

Hybrid Strategy Benefits
- Use land-based systems only when control is required
- Shift bulk growth to floating systems with lower energy demand when conditions allow
- This staged approach often yields the lowest energy cost per unit of usable seed

Renewable and Supplemental Power
- Solar may offset lighting, monitoring, or auxiliary loads
- Solar alone is generally insufficient for continuous pumping, but can reduce peak demand
- Battery-backed alarms and monitoring systems add resilience at low cost

### 7.6 Key Principle

Power systems in oyster nurseries must be designed for failure, not perfection.

Reliable flow, rapid recovery, and conservative loading protect seed health, reduce disease risk, and safeguard production continuity.

## 8. Economics and Scalability

The economic viability of an oyster nursery is driven by both capital efficiency and operational performance over the full production cycle. Economic planning should therefore evaluate nursery systems on a per-million-seed capacity basis, allowing meaningful comparison across different design options and scales.

Key economic considerations include:
- Capital cost per million seed capacity - including pumping, intake infrastructure, silos or upwelling units, electrical systems, and site works;
- Operating costs - such as power consumption, labour requirements, routine maintenance, and consumables.

- Avoided mortality - particularly during early nursery stages, where losses have a disproportionate impact on overall farm productivity.
- Improved growth rates and size uniformity - which reduce nursery residence time and enable more predictable transfer to grow-out systems.
- Phased expansion pathways - allowing systems to scale incrementally as production volumes, markets, and grow-out capacity increase; and
- Alignment with downstream grow-out capacity - ensuring nursery output matches available lease area, equipment, and labour, and avoids production bottlenecks.

Nursery economics should not be evaluated solely on upfront capital cost. Instead, value is realized through reduced biological risk, greater growth consistency, labour efficiency, and production predictability; all of which directly improve farm-level profitability. Well-designed nursery systems can shorten time to market, improve survival through stressful seasonal periods, and reduce variability between cohorts.

Modular nursery designs—such as scalable upwelling arrays, expandable intake systems, and renewable-ready pumping infrastructure—enable producers to transition efficiently from pilot or demonstration scale to full commercial production. This approach reduces initial capital exposure, supports adaptive learning, and allows infrastructure investment to be closely matched to demonstrated performance and market demand.

# 9. Regulatory Pathway (Nova Scotia)

## 9.1 Lease and Licences

The regulatory pathway in Nova Scotia involves multiple Federal and Provincial regulations, depending upon the system and area the nursery is proposed for. Nova Scotia has recently completed an extensive review of its regulatory framework, which will help shellfish applications move more efficiently through the system.

### 9.1.1 Underwater Pipelines, Intakes, and Power Cables

Nova Scotia Department of Natural Resources (NSDNR) is the lead agency, but it is the proponent’s responsibility to contact Transport Canada (TC), Fisheries and Oceans Canada (DFO), and Nova Scotia Department of Environment and Climate Change (NSECC) for any permits and permissions that they may require. Industry should consult CMAR’s Resource Map for information regarding the electricity infrastructure (i.e., electric tower, electric line, electric: transformer, tanks, and ponds).

Table 3. Permit process matrix – Underwater pipeline/electrical cable in Nova Scotia, Canada.

| Regulator | Permit / Approval | Why It's Required | Who Applies | Key Information Reviewed | Typical Outcome |
|---|---|---|---|---|---|
| Nova Scotia Department of Natural Resources and Renewables (NSDNR) | Crown Land Licence of Occupation | Intake/outfall pipeline crosses below the Ordinary High-Water Mark (OHWM) | Proponent | Intake route, seabed interaction | Licence of Occupation issued |
| Nova Scotia Department of Environment and Climate Change (NSECC) | Environment Act Determination or Environmental Approval | Any shoreline works, intake/outfall installation, or marine discharge | Proponent | Intake/outfall design, disturbance footprint | Determination (most common) or approval |
| Transport Canada (TC) | Navigation Protection Program (NPP) Review / Approval | Intake or outfall located in navigable waters | Proponent | Location, burial depth, drawings | NPP approval or determination |
| Fisheries and Oceans Canada (DFO) | Fisheries Act Review | Intake entrainment risk and fish habitat protection | Proponent | Screen size, flow rates, habitat context | Letter of Advice (typical) |
| Nova Scotia Department of Fisheries and Aquaculture (NSDFA) | Biosecurity Review | Disease prevention and seed movement controls | NSDFA | Seed source, quarantine protocols, and records | Conditions applied to the licence |
| NS Power / Utility (if applicable) | Electrical Service Approval | Power supply for pumps, blowers, and heaters | Proponent | Electrical load requirements | Service connection approved |

### 9.1.2 Permits for Land-based Nursery

Nova Scotia Department of Fisheries and Aquaculture (NSDFA) is the lead agency and is responsible for networking the application to other agencies as a Class 3 application.

The proponent is still responsible for obtaining TC and NSDNR approvals for pipelines, etc, and if using well water, permits from NSECC.

Table 4. Permit process matrix – Nova Scotia land-based oyster nursery

| Regulator | Permit / Approval | Why It's Required | Who Applies | Key Information Reviewed | Typical Outcome |
|---|---|---|---|---|---|
| **Municipality** | Development Permit / Building Permit | Land-based buildings, tanks, plumbing, and electrical systems | Proponent | Site plan, building design, zoning compliance | Municipal permits issued |
| Nova Scotia Department of Fisheries and Aquaculture (NSDFA) | Aquaculture License (Nursery) | Authorization to culture oyster seed | Proponent | Species, capacity, biosecurity, water source | Nursery license issued |
| Fisheries and Oceans Canada (DFO) | Fisheries Act Review | Intake entrainment risk and fish habitat protection | NSDFA referral | Screen size, flow rates, habitat context | Letter of Advice (typical) |
| Nova Scotia Department of Environment and Climate Change (NSECC) | Wastewater / Discharge Review | Discharge of untreated seawater back to the marine environment | NSDFA referral | Discharge method and flow | Usually, no approval is required |
| NS Power / Utility (if applicable) | Electrical Service Approval | Power supply for pumps, blowers, and heaters | Proponent | Electrical load requirements | Service connection approved |

### 9.1.3 Permits for FLUPSY on Existing Lease

Nova Scotia Department of Fisheries and Aquaculture (NSDFA) is the lead agency and is responsible for networking the application to other agencies. A Class 2 application is required to add a FLUPSY to an existing lease or to increase the size of an existing lease to accommodate the footprint of the equipment.

The proponent is responsible for getting TC and NSDNR approval for pipelines, etc, and requesting TC for amending an existing license to permit the placement of the FLUPSY and required moorings.

Table 5. Permit Process Matrix – Amendment to Gear Type for Existing Oyster Lease & License in Nova Scotia

| Regulator | Permit / Approval | Why It's Required | Who Applies | Key Information Reviewed | Typical Outcome |
|---|---|---|---|---|---|
| **Nova Scotia Department of Fisheries and Aquaculture (NSDFA)** | Amendment Request (Gear Change) | Change to approved gear type on an existing lease/licence | Proponent | Current licence, proposed gear, rationale | Amendment request accepted for review |
| **Nova Scotia Department of Fisheries and Aquaculture (NSDFA)** | Licence Amendment Review | Licence conditions must reflect the new gear | NSDFA | Gear description, scale, seasonality | Draft amended licence conditions |
| **Fisheries and Oceans Canada (DFO)** | Fisheries Act Screening | Confirm no new risk to fish or fish habitat | NSDFA referral | Gear interaction, habitat context | No objection or advice |
| **Nova Scotia Department of Environment and Climate Change (NSECC)** | Environmental Screening / Determination | Assess whether the gear change alters environmental risk | NSDFA referral | Gear type, intensity, and bottom interaction | No concern or conditions |
| **Transport Canada** | Navigation Review | Ensure the new gear does not affect navigation | Proponent | Surface expression, buoy layout | Clearance or conditions |
| **NSDFA** | First Nations Consultation (if triggered) | Required if gear change alters site use or footprint | NSDFA-led | Description of change | Consultation record completed |

| Regulator | Permit / Approval | Why It's Required | Who Applies | Key Information Reviewed | Typical Outcome |
|---|---|---|---|---|---|
| **NSDFA** | Public Notice / Consultation (if required) | Required only if the change is material or contentious | NSDFA-led | Updated site maps | Comment period completed |
| **NSDFA** | Technical Review Committee Decision | Integrated review of the amendment | NSDFA | All agency inputs | Recommendation to approve, modify, or refuse |
| **NSDFA** | Amended Licence Issued | Formal authorization of new gear | NSDFA | Final conditions | Licence amendment issued |
| **NSDFA (if required)** | Lease Amendment | Only if the gear change alters the lease footprint | NSDFA | Revised boundaries | Amended lease issued |

### 9.1.4 Permits for New Leases

Nova Scotia Department of Fisheries and Aquaculture (NSDFA) is the lead agency and is responsible for networking the application to other agencies as a Class 1B application.

The proponent is responsible for getting TC and NSDNR approvals for pipelines, etc.

Table 6. Permitting Matrix – New shellfish lease and license in Nova Scotia

| Regulator | Permit / Approval | Why It's Required | Who Applies | Key Information Reviewed | Typical Outcome |
|---|---|---|---|---|---|
| Nova Scotia Department of Fisheries and Aquaculture (NSDFA) | Experimental Aquaculture Licence | Authorizes commercial - scale shellfish culture | Proponent | Species, scale, duration, objectives | Experimental licence issued |
| Transport Canada | Navigation Protection Program (NPP) Review / Approval | Floating structure in navigable waters | Proponent | Buoy layout, surface profile | NPP approval or determination |
| Fisheries and Oceans Canada (DFO) | Fisheries Act Review | Intake entrainment and habitat interaction | NSDFA referral | Screen size, flow rates | Letter of Advice (typical) |
| **NSDFA** | First Nations Consultation (if required) | Duty to Consult for new marine activity | NSDFA-led | Site information, maps | Consultation record completed |
| **NSDFA** | Public Notification (if required) | Required if the site is new | NSDFA-led | Lease notice, maps | Comment period completed |
| **NSDFA** | Integrated Technical Review | Consolidate inter-agency feedback | NSDFA | All approvals and advice | Recommendation to proceed |
| **NSDFA** | Licence Conditions & Reporting | Ensure pilot-scale oversight | NSDFA | Monitoring and reporting plan | Time-limited operation authorized |
| **NSDFA** | Decommissioning Requirement | Ensure site restoration after trial | NSDFA | Removal and restoration plan | Mandatory removal at the end of trial |

## 9.2 Regulatory Oversight of Shellfish Transfers

In Canada, shellfish movements are subject to oversight by multiple regulatory bodies. In response to emerging oyster disease concerns in Atlantic Canada, the regulatory framework has continued to evolve as conditions change and new research becomes available.

### 9.2.1 Canadian Food Inspection Agency (CFIA)

In September 2025, CFIA designated Atlantic Canada as a Declared Infected Area (DIA) for Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni*). As a result, CFIA no longer regulates shellfish transfers within Atlantic Canada.

CFIA continues to regulate shellfish transfers into Atlantic Canada from external jurisdictions, including the eastern United States.

### 9.2.2 Nova Scotia Introductions and Transfers Committee (NS I&T Committee)

The Nova Scotia Introductions and Transfers (I&T) Committee is chaired by Fisheries and Oceans Canada (DFO) and includes representation from multiple federal and provincial agencies, including the Nova Scotia Department of Fisheries and Aquaculture (NSDFA).

The Committee is responsible for reviewing and approving shellfish transfers both into Nova Scotia and within the province.

### 9.2.3 Nova Scotia Department of Fisheries and Aquaculture (NSDFA) – Aquatic Animal Health (AAH)

NSDFA Aquatic Animal Health (AAH) staff participate in the NS I&T Committee and are responsible for coordinating and reviewing disease testing requirements prior to any approved transfer.

NSDFA Fish Health also reviews Farm Management Plans (FMPs) to ensure that all conditions associated with an I&T approval are clearly documented and implemented.

Given the evolving disease status in Atlantic Canada and ongoing work by the broader research community, proponents are strongly advised to engage early and maintain regular communication with NSDFA AAH staff when planning any shellfish transfers.

## 10. Final Recommendations

Well-designed oyster nursery systems are foundational to the long-term sustainability, biosecurity, and economic viability of oyster aquaculture in Nova Scotia. To support resilient industry growth in the face of disease-related challenges, the following actions are recommended:

### 10.1 Invest in Industry-Led Best Management Practices (BMPs)

Dedicated resources should be allocated to industry and collaborative partners to regularly update region-specific Best Management Practices for oyster nursery design, construction, and operation.

### 10.2. Design for Nova Scotia’s Full Environmental Range

Nursery systems must be engineered to perform reliably across seasonal extremes—including cold temperatures, variable salinity, ice, and high fouling pressure—rather than being optimized solely for peak summer conditions.

### 10.3 Prioritize Water Flow and Oxygenation Over Stocking Density

Strong, consistent water exchange and dissolved oxygen levels are critical to minimizing stress, reducing disease expression, and maintaining high survival rates. Stocking densities should be scaled to system capacity, not theoretical maximums.

### 10.4 Adopt Modular Designs and Scale Conservatively

Nurseries should be built using modular components that allow for phased expansion. This approach reduces upfront risk, supports adaptive learning, and enables operators to scale production in step with operational capacity and market demand.

### 10.5 Leverage Land-Based Capacity for Risk Management

Land-based or shore-based nursery infrastructure should be used strategically to improve biosecurity, enable quarantine and contingency holding, extend operating seasons, and provide resilience during adverse weather or environmental events.

### 10.6 Maintain Robust Record-Keeping and Biosecurity Protocols

Detailed records of seed source, batch movements, environmental conditions, and handling events are essential for traceability, disease management, and regulatory compliance. Strong biosecurity protocols should be standard practice across all nursery operations.

### 10.7 Climate Change Strategy

Develop and implement a climate change strategy that provides growers with practical guidance on climate-related risks, including Aquatic Invasive Species (AIS), ocean acidification, and other emerging environmental stressors affecting shellfish operations.

# 11. References

University of Connecticut | Video shows how FLUPSY helps the shellfish garden grow

Centre for Shellfish Research | SOLAR FLUPSY project update: Design and Construction Report

Aquatic Supply Centre | Your FLUPSY Circulation Solutions

Prezi | Pacific Oyster FLUPSY

Centre for Marine Applied Research | Storm Preparedness Recommendations for Aquaculture Producers

Centre for Marine Applied Research | Coastal Wind and Wave Exposure Modelling

Centre for Marine Applied Research | Asset Map

Centre for Marine Applied Research | Coastal Monitoring Program

Aquaculture Coastal Classification System - Government of Nova Scotia, Canada

Nova Scotia Aquaculture & Rockweed Map Viewer

Aquaculture Licence and Lease Regulations - Fisheries and Coastal Resources Act (Nova Scotia)

Fisheries and Aquaculture Energy Efficiency Innovation Fund | Efficiency Nova Scotia

Business Energy Rebates | Apply Now | Efficiency Nova Scotia

# Appendix A - Technical Design Rationale

This Appendix provides the technical and biological rationale underlying the nursery system designs described in the main body of this guide. It is intended for engineers and operators seeking a deeper explanation of design choices.

## A1. Flow Dominance as the Primary Design Principle

All successful flow-through oyster nurseries are governed by flow dominance rather than stocking density. Oyster seed performance is maximized when water movement, oxygen delivery, and waste removal exceed biological demand. Systems designed around density targets rather than hydraulic capacity consistently underperform.

Upwelling velocity must be sufficient to:

- Maintain dissolved oxygen at or near ambient levels
- Prevent waste accumulation and boundary-layer stagnation
- Ensure uniform phytoplankton delivery across the seed bed

## A2. Oversizing Plumbing and Hydraulic Resilience

Headers, branch lines, and intake plumbing are intentionally oversized relative to initial flow requirements. This provides resilience against:

- Biofouling and debris accumulation
- Seasonal increases in biological demand
- Incremental system expansion

Oversizing reduces friction losses, improves energy efficiency, and prevents the gradual performance decline commonly observed in undersized systems.

## A3. Uniform Flow Distribution

Uniform flow across all trays within a silo is achieved through bottom plenums and distribution plates. Uneven flow leads to localized stress, uneven growth, and increased disease expression. Individual branch valves allow operators to balance flow and respond to fouling or biomass changes without shutting down the system.

## A4. Flow Per Unit Biomass

Flow requirements scale with biomass, not tray count. As biomass increases through growth or stocking density changes, flow must be adjusted accordingly. Failure to maintain this relationship is a leading cause of slow growth, size variability, and mortality.

# Appendix B - Disease, Stress, and Growth Cycle Detail

This Appendix expands on the biological relationship between stress, growth rate, and disease expression, with specific reference to MSX and Dermo.

## B1. Stress-Mediated Disease Expression

MSX and Dermo are present in the environment in Nova Scotia. Disease expression is driven primarily by cumulative physiological stress rather than single exposure events. Key stressors include low oxygen, overcrowding, inconsistent flow, rapid environmental change, and repeated handling.

When stressed, oysters divert energy from immune function and growth toward basic survival, allowing disease processes to progress.

## B2. Role of Nurseries in Disease Mitigation

Nursery systems interrupt the stress–disease pathway by maintaining strong flow, conservative densities, and controlled handling. Land-based and hybrid systems provide additional capacity for observation, quarantine, and delayed deployment during high-risk periods.

## B3. Growth Rate and Time at Risk

Disease risk increases with time at risk. Faster early growth shortens the duration oysters remain in vulnerable size classes and reduces cumulative exposure to stressors. Accelerated growth is therefore a core disease-mitigation strategy.

## B4. Batch Integrity and Traceability

Maintaining single-source, single-batch segregation improves traceability, supports targeted response if disease issues arise, and allows performance comparison between hatchery sources.

# Appendix C- Economics and ROI Considerations

This Appendix provides additional context for evaluating nursery investments beyond simple capital cost.

## C1. Primary Value Drivers

Avoided early-stage mortality

Improved growth uniformity and field survival

Reduced labour inefficiency and weather dependency

Improved alignment of planting with lease capacity and market timing

## C2. Nursery ROI Logic

The economic value of a nursery is realized through increased usable output per million seed input. Even modest improvements in early survival and growth consistency translate into significant downstream gains in harvest volume and predictability.

## C3. Hybrid System Advantage

Hybrid systems consistently achieve lower cost per usable seed by combining early-stage risk control in land-based systems with low-energy bulk growth in floating systems. This staged approach maximizes return on capital while reducing biological and operational risk

## C4. Land-Based Flow-Through Nursery (2M Capacity)

Indicative Capital Cost Range: $54,900 – $125,900 CAD (Dependant of site specifics)

| COMPONENT | DESCRIPTION | QTY | EST. COST (CAD) |
|---|---|---|---|
| **Intake & Pumps** | 3" HDPE intake, duty + standby pumps | 1 | $6,000–$15,000 |
| **Header & Plumbing** | 3" header, 1" branches, valves | 1 | $3,000–$7,000 |
| **Trays & Mesh** | 60 trays + spares | 1 | $4,000–$10,000 |
| **Drainage & Floor** | Trench drain, piping | 1 | $1,000–$3,000 |
| **Electrical & Alarms** | Panel, GFCI, alarms | 1 | $1,500–$5,000 |
| **Building** | 20’x20’ with pad | 1 | $25,000-$50,000 |

| COMPONENT | DESCRIPTION | QTY | EST. COST (CAD) |
|---|---|---|---|
| **Civil Work** | Site prep | 1 | $2,000-$7,500 |
| **Generator & Transfer** | ~10 kW standby | 1 | $7,000–$14,000 |

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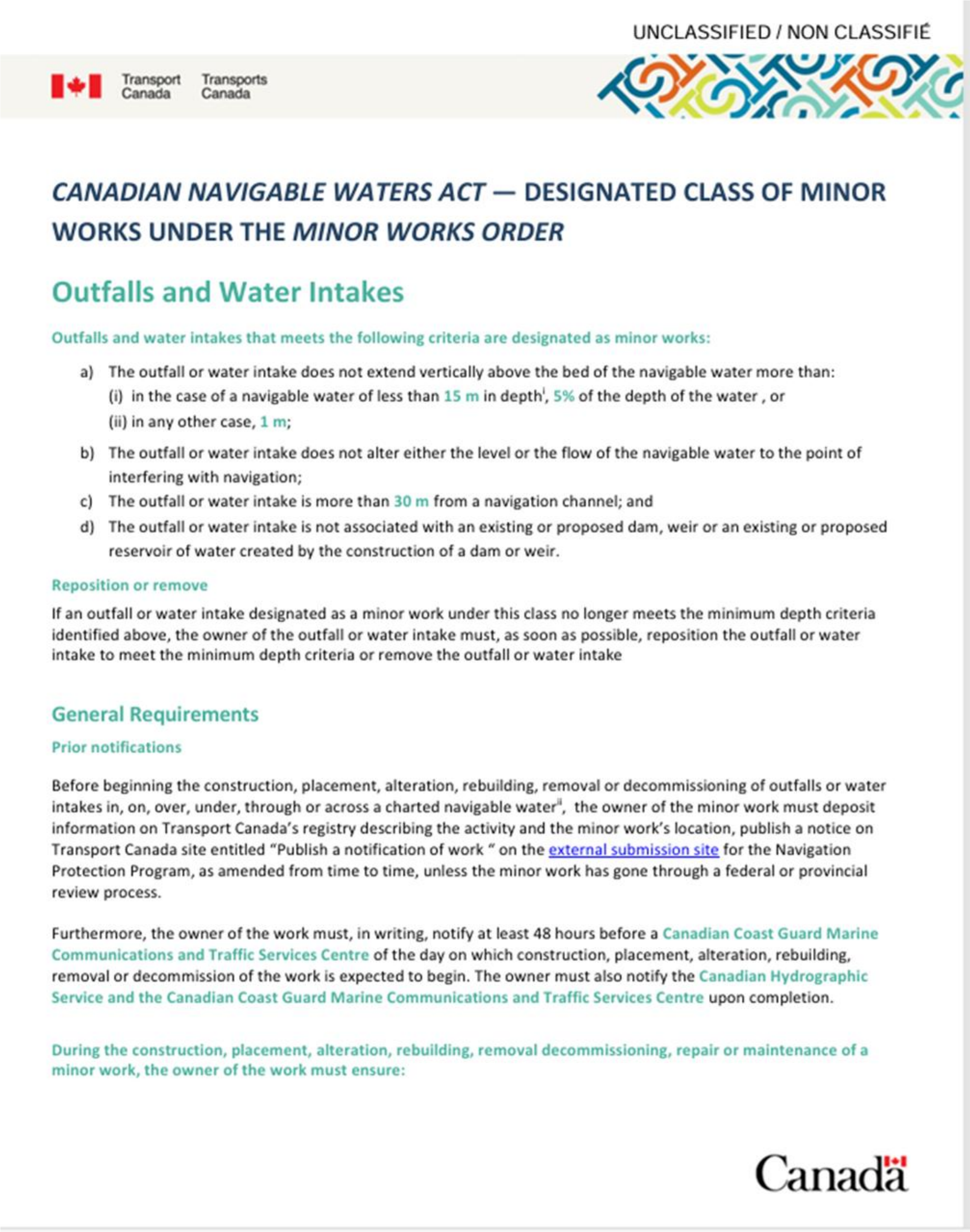
## C5. Floating FLUPSY Nursery (2M Capacity)

Indicative Capital Cost Range: $35,900 – $90,300 CAD (moderate exposure site)

| COMPONENT | DESCRIPTION | QTY | EST. COST (CAD) |
|---|---|---|---|
| **Floating Dock** | Modular HDPE dock | 1 system | $5,000–$8,000 |
| **Mooring System** | Anchors, chain, lines | 1 set | $3,000–$10,000 |
| **Pumps & Intake** | Duty + standby pumps | 2 | $3,500–$15,000 |
| **Manifold & Plumbing** | Header, branches, valves | 1 | $1,500–$3,500 |
| **Silos** | 18–24" dia HDPE | 12 | $5,400–$14,400 |
| **Generator & Transfer** | ~10 kW standby | 1 | $7,000–$14,000 |
| **Trays & Mesh** | 60 trays + spares | 1 | $4,000–$10,000 |
| **Electrical** | Shore Power | 1 | $5,000-$10,000 |
| **Electrical** | Panel, GFCI, alarms | 1 | $1,500–$5,000 |

# Appendix D - Transport Canada



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Transport Canada Transports Canada

## *CANADIAN NAVIGABLE WATERS ACT* — DESIGNATED CLASS OF MINOR WORKS UNDER THE *MINOR WORKS ORDER*

## Outfalls and Water Intakes

**Outfalls and water intakes that meets the following criteria are designated as minor works:**

a) The outfall or water intake does not extend vertically above the bed of the navigable water more than:
   (i) in the case of a navigable water of less than 15 m in depth[i], 5% of the depth of the water , or
   (ii) in any other case, 1 m;
b) The outfall or water intake does not alter either the level or the flow of the navigable water to the point of interfering with navigation;
c) The outfall or water intake is more than 30 m from a navigation channel; and
d) The outfall or water intake is not associated with an existing or proposed dam, weir or an existing or proposed reservoir of water created by the construction of a dam or weir.

### Reposition or remove

If an outfall or water intake designated as a minor work under this class no longer meets the minimum depth criteria identified above, the owner of the outfall or water intake must, as soon as possible, reposition the outfall or water intake to meet the minimum depth criteria or remove the outfall or water intake

## General Requirements

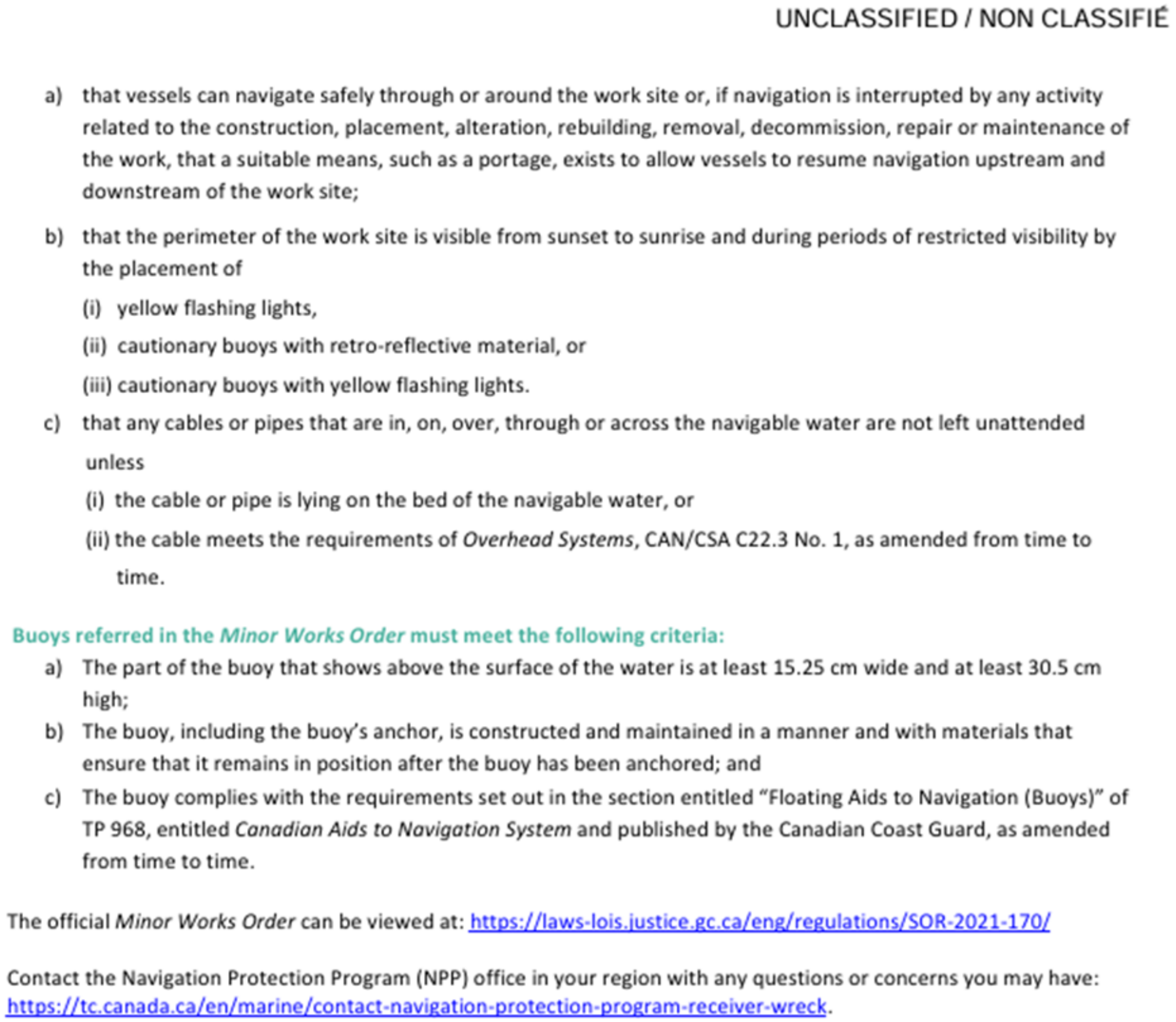
### Prior notifications

Before beginning the construction, placement, alteration, rebuilding, removal or decommissioning of outfalls or water intakes in, on, over, under, through or across a charted navigable water[ii], the owner of the minor work must deposit information on Transport Canada's registry describing the activity and the minor work's location, publish a notice on Transport Canada site entitled "Publish a notification of work " on the external submission site for the Navigation Protection Program, as amended from time to time, unless the minor work has gone through a federal or provincial review process.

Furthermore, the owner of the work must, in writing, notify at least 48 hours before a Canadian Coast Guard Marine Communications and Traffic Services Centre of the day on which construction, placement, alteration, rebuilding, removal or decommission of the work is expected to begin. The owner must also notify the Canadian Hydrographic Service and the Canadian Coast Guard Marine Communications and Traffic Services Centre upon completion.

**During the construction, placement, alteration, rebuilding, removal decommissioning, repair or maintenance of a minor work, the owner of the work must ensure:**

Canadä



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a) that vessels can navigate safely through or around the work site or, if navigation is interrupted by any activity related to the construction, placement, alteration, rebuilding, removal, decommission, repair or maintenance of the work, that a suitable means, such as a portage, exists to allow vessels to resume navigation upstream and downstream of the work site;

b) that the perimeter of the work site is visible from sunset to sunrise and during periods of restricted visibility by the placement of
   (i) yellow flashing lights,
   (ii) cautionary buoys with retro-reflective material, or
   (iii) cautionary buoys with yellow flashing lights.

c) that any cables or pipes that are in, on, over, through or across the navigable water are not left unattended unless
   (i) the cable or pipe is lying on the bed of the navigable water, or
   (ii) the cable meets the requirements of *Overhead Systems*, CAN/CSA C22.3 No. 1, as amended from time to time.

**Buoys referred in the *Minor Works Order* must meet the following criteria:**

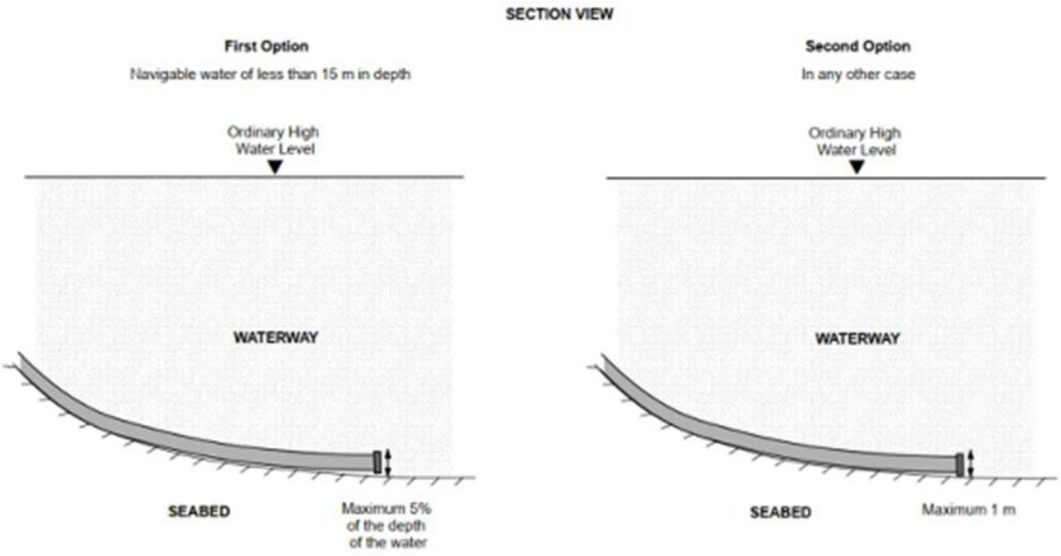
a) The part of the buoy that shows above the surface of the water is at least 15.25 cm wide and at least 30.5 cm high;

b) The buoy, including the buoy's anchor, is constructed and maintained in a manner and with materials that ensure that it remains in position after the buoy has been anchored; and

c) The buoy complies with the requirements set out in the section entitled "Floating Aids to Navigation (Buoys)" of TP 968, entitled *Canadian Aids to Navigation System* and published by the Canadian Coast Guard, as amended from time to time.

The official *Minor Works Order* can be viewed at: https://laws-lois.justice.gc.ca/eng/regulations/SOR-2021-170/

Contact the Navigation Protection Program (NPP) office in your region with any questions or concerns you may have: https://tc.canada.ca/en/marine/contact-navigation-protection-program-receiver-wreck.



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[i] Measurements — Depth or height

Unless otherwise indicated, any depth or height referred to in this Order is measured from the ordinary high water level at the site where the minor work is situated.

[ii] Charted navigable water means navigable waters for which nautical charts are produced by the Canadian Hydrographic Service or the National Oceanic and Atmospheric Administration of the United States.

# Appendix E - DIY Construction Guide

This Appendix provides detailed, practical guidance for owner-built oyster nursery systems. It is written to support cost-effective construction by operators and community groups, while maintaining durability, safety, and regulatory awareness. These guidelines describe best-practice construction approaches rather than engineered drawings; site-specific conditions may require professional input.

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## E1 General DIY Design and Construction Principles

Successful do-it-yourself (DIY) nursery construction relies on disciplined simplicity and conservative design margins.

Key principles include:

- Design for flow, not complexity: nursery performance is driven by water movement, oxygen delivery, and waste removal rather than mechanical sophistication.
- Oversize hydraulic components: larger pipes, headers, and plenums tolerate fouling, reduce friction losses, and protect biological performance.
- Build modularly: expansion should occur by replicating proven modules rather than redesigning the system.
- Prioritize access and serviceability: every pump, valve, tray, and screen must be reachable for daily inspection and rapid maintenance.
- Assume failure will occur: power loss, fouling, and storms are inevitable; systems must recover quickly without catastrophic loss.

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## E2 Land-Based Flow-Through Nursery Construction (Step-by-Step)

### E2.1 Building and Site Preparation

- Select a location with reliable access to clean seawater and sufficient elevation for gravity discharge.
- Use an insulated structure or retrofit space that allows year-round access and worker safety.
- Install a sealed concrete floor sloped 1–2% toward trench drains.
- Provide adequate lighting, ventilation, and humidity control to protect both workers and electrical systems.

### E2.2 Marine Intake and Pump Station

- Install an HDPE or PVC intake pipe with a removable coarse debris screen.

- Anchor intake lines to prevent movement, abrasion, and ice damage.
- Construct a wet well or pump pit sized for duty and standby pumps.
- Install two pumps (duty + standby) with isolation valves and check valves to allow rapid changeover.

### E2.3 Plumbing and Flow Distribution

- Install an oversized main header along the nursery floor or wall.
- Run individual branch lines to each silo, each fitted with a true-union ball valve.
- Use unions and flexible couplings to allow the removal of components without cutting pipe.
- Provide a clean-out or flush port at the end of the header.

### E2.4 Silo and Tray Installation

- Secure vertical silos to the floor or frames to prevent movement.
- Install bottom plenums and distribution plates to spread flow evenly across trays.
- Stack trays with sufficient spacing to allow free upwelling and easy removal.
- Fit overflow lips to direct discharge cleanly into trench drains.

### E2.5 Electrical and Backup Power

- Install marine-rated electrical panels, conduits, and ground fault circuit interrupter (GFCI) protection.
- Provide alarms for power failure and high water levels.
- Install a generator sized to support full system load, with clear procedures for startup and refuelling.

## E3. Floating FLUPSY Construction (Step-by-Step)

### E3.1 Floating Platform and Deck Layout

- Use commercial HDPE floating docks where possible for durability and stability.
- Ensure sufficient deck area for silos, manifolds, and safe working access.
- Install non-slip surfaces, guardrails, and tie-off points.

### E3.2 Mooring System

- Design moorings based on site exposure, fetch, and ice conditions.
- Use multiple anchors and adequate chain length to limit movement.
- Protect all lines from chafe and abrasion.

### E3.3 Pump and Intake Installation

- Mount pumps below deck in protected positions.
- Use reinforced intake hose with coarse debris screens.
- Secure pump cables and hoses to prevent strain and wear.

### E3.4 Manifold and Silo Assembly

- Install a central header manifold with individual branch valves.
- Secure silos firmly to the deck or rack system.
- Verify visible, uniform upwelling before stocking seed.

### E4. Commissioning and Initial Operation

- Run the system at full flow for 24–48 hours before adding seed.
- Check for leaks, vibration, uneven flow, or electrical faults.
- Adjust valves to balance upwelling across all silos.
- Introduce seed at conservative densities and monitor closely during the first week.

## E5. Safety, Compliance, and When to Seek Professional Input

### E5.1 Safety Requirements

- Use GFCI protection and proper grounding for all electrical systems.
- Maintain clear walkways, guardrails, and lifesaving equipment on floating platforms.
- Train staff in lockout, pump isolation, and emergency response procedures.

### E5.2 Regulatory Awareness

- DIY construction does not eliminate regulatory requirements. Operators should consult relevant authorities regarding:
- Marine intakes and discharges
- Floating structures and moorings
- Electrical installations

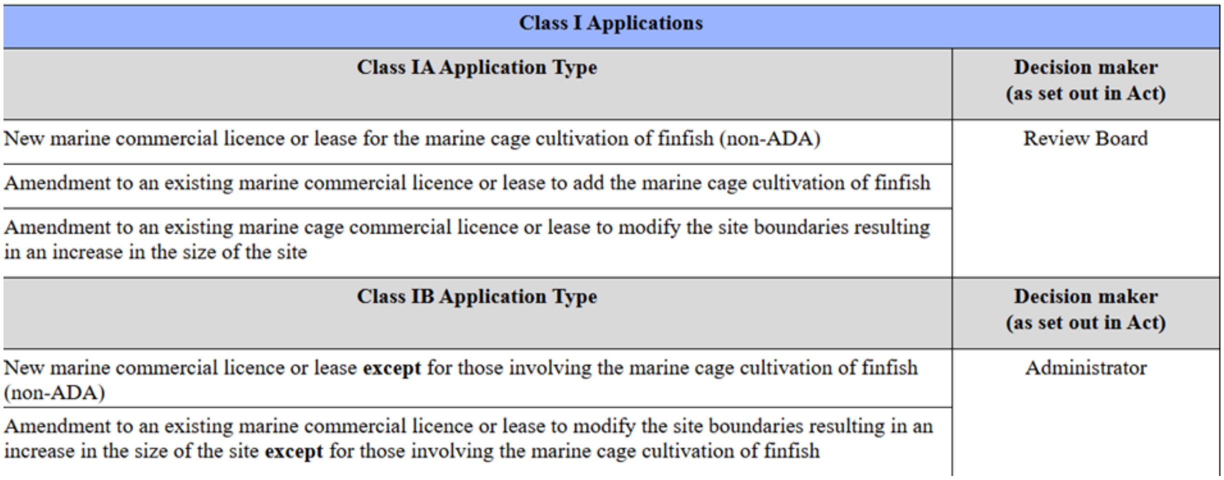
### E5.3 When to Bring in Professionals

- Professional input is strongly recommended for:
- Mooring design in exposed or ice-prone sites
- Electrical system design and installation
- Structural engineering for buildings or large floating platforms

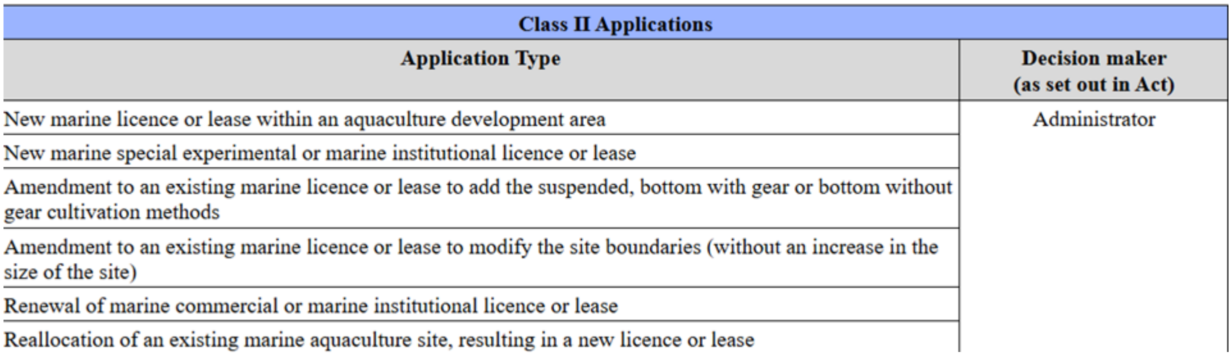
DIY construction is most effective when operators focus on plumbing, silo fabrication, tray systems, and layout, while leveraging professional expertise for higher-risk elements.

## Appendix F - NSDFA Regulations

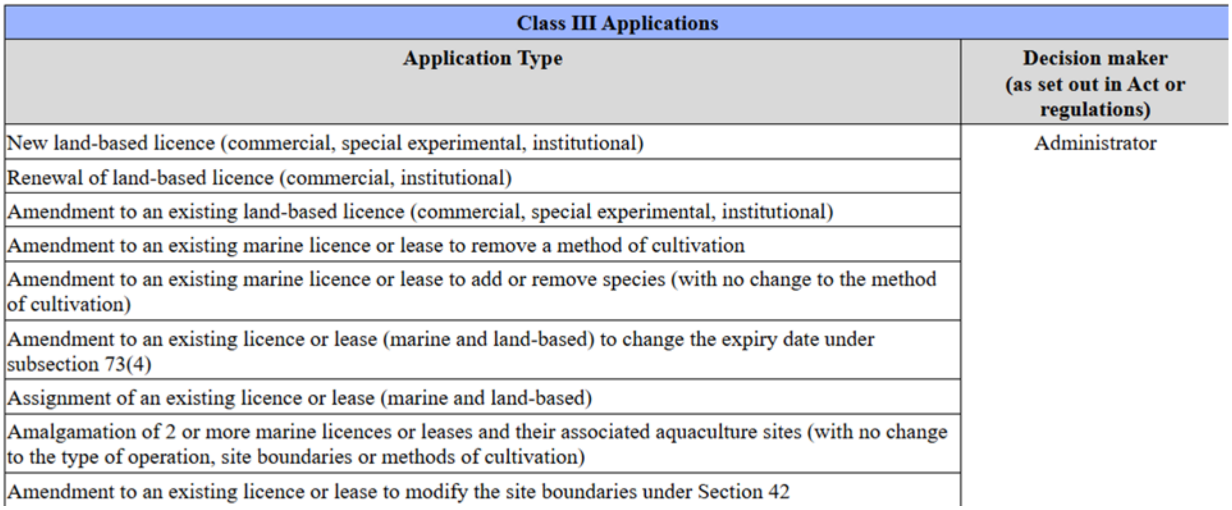
## F1. Classification of Applications



| Class I Applications | |
|---|---|
| **Class IA Application Type** | **Decision maker (as set out in Act)** |
| New marine commercial licence or lease for the marine cage cultivation of finfish (non-ADA) | Review Board |
| Amendment to an existing marine commercial licence or lease to add the marine cage cultivation of finfish | |
| Amendment to an existing marine cage commercial licence or lease to modify the site boundaries resulting in an increase in the size of the site | |
| **Class IB Application Type** | **Decision maker (as set out in Act)** |
| New marine commercial licence or lease **except** for those involving the marine cage cultivation of finfish (non-ADA) | Administrator |
| Amendment to an existing marine commercial licence or lease to modify the site boundaries resulting in an increase in the size of the site **except** for those involving the marine cage cultivation of finfish | |



| Class II Applications | |
|---|---|
| **Application Type** | **Decision maker (as set out in Act)** |
| New marine licence or lease within an aquaculture development area | Administrator |
| New marine special experimental or marine institutional licence or lease | |
| Amendment to an existing marine licence or lease to add the suspended, bottom with gear or bottom without gear cultivation methods | |
| Amendment to an existing marine licence or lease to modify the site boundaries (without an increase in the size of the site) | |
| Renewal of marine commercial or marine institutional licence or lease | |
| Reallocation of an existing marine aquaculture site, resulting in a new licence or lease | |



| Class III Applications | |
|---|---|
| **Application Type** | **Decision maker (as set out in Act or regulations)** |
| New land-based licence (commercial, special experimental, institutional) | Administrator |
| Renewal of land-based licence (commercial, institutional) | |
| Amendment to an existing land-based licence (commercial, special experimental, institutional) | |
| Amendment to an existing marine licence or lease to remove a method of cultivation | |
| Amendment to an existing marine licence or lease to add or remove species (with no change to the method of cultivation) | |
| Amendment to an existing licence or lease (marine and land-based) to change the expiry date under subsection 73(4) | |
| Assignment of an existing licence or lease (marine and land-based) | |
| Amalgamation of 2 or more marine licences or leases and their associated aquaculture sites (with no change to the type of operation, site boundaries or methods of cultivation) | |
| Amendment to an existing licence or lease to modify the site boundaries under Section 42 | |

(Source: NSDFA application decisions)