

Scaling Restoration Through Aquaculture:

Partnering With Oyster Growers to Rebuild Reefs

The Nature
Conservancy



Pew

Learnings From the Supporting Oyster
Aquaculture and Restoration (SOAR) Program



About This Handbook

The Supporting Oyster Aquaculture and Restoration (SOAR) program, co-developed and implemented by The Nature Conservancy (TNC) and The Pew Charitable Trusts (Pew), provides the foundation for this handbook. The guidance that follows reflects lessons learned from SOAR's implementation across multiple states and is intended to support similar efforts in diverse contexts.

Credits and Contributors

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PROGRAM DEVELOPMENT CHECKLIST

I. Understand the Connections Between Restoration and Aquaculture (Chapter 1)	☐ Identify the primary limitation to reef recovery (e.g., insufficient breeding stock, low oyster abundance) ☐ Assess whether increasing oyster abundance or reproductive capacity is an appropriate strategy to address that limitation ☐ Confirm that aquacultured oysters are ecologically appropriate and permissible for restoration use in the system ☐ Evaluate whether integrating aquaculture can advance restoration goals while providing complementary benefits (e.g., increased capacity, grower participation) ☐ Confirm alignment with existing restoration priorities, management plans, or recovery strategies, and make a documented decision to proceed or not proceed
II. Determine Applicability and Strategic Fit of a SOAR-Style Program (Chapter 2)	☐ Identify specific benefits of using aquaculture products (adult oysters, spat on shell, blank shell) to advance restoration goals ☐ Confirm that oysters used for restoration are native and appropriately sourced (species, genetics, geography) ☐ Evaluate whether incorporating adult or reproductively mature oysters will meaningfully increase breeding biomass and larval supply ☐ Identify opportunities to support grower economic resilience while advancing restoration outcomes
III. Structure the Program (Chapter 3)	Understand the Landscape: ☐ Define the geographic scope of the program and confirm restoration site availability or permitting requirements ☐ Assess ecological suitability of proposed sites (salinity, disease, predation, hydrodynamics, substrate) ☐ Engage Tribes, communities, regulators, and rightsholders early in program development ☐ Identify and engage a diverse and accessible grower base, including new and small-scale operations ☐ Develop and document a biosecurity and human health plan covering disease, pests, transport, and worker safety Design the Program: ☐ Establish clear, purpose-driven goals (ecological, economic, or hybrid) with measurable metrics ☐ Assess program capacity (staffing, expertise, partners, infrastructure) ☐ Secure full life-cycle funding, including purchases, deployment, monitoring, and communications ☐ Build partnerships with clearly defined roles, responsibilities, and decision authority ☐ Develop a transparent and equitable pricing framework for oysters and grower services, aligned with industry norms ☐ Define a communications strategy for internal coordination and external reporting

IV. Implement the Program (Chapter 3)	☐ Conduct grower outreach, screening, and selection using transparent eligibility criteria ☐ Execute contracts and tracking systems that support efficient purchasing and payment ☐ Coordinate logistics for harvest, transport, and deployment to minimize stress, mortality, and biosecurity risk ☐ Implement quality assurance and quality control (QA/QC) procedures at delivery and deployment locations ☐ Deploy oysters and materials according to site design and timing aligned with spawning and recruitment ☐ Communicate clearly with growers, partners, and relevant agencies throughout implementation
V. Monitor, Evaluate, and Adapt (Chapter 3)	☐ Establish baseline ecological and socioeconomic conditions prior to deployment ☐ Implement monitoring that distinguishes program effects from background variability ☐ Track core ecological metrics (survival, recruitment, density, reef structure) ☐ Evaluate socioeconomic outcomes for growers and communities ☐ Use results to adapt site selection, deployment methods, pricing, or biosecurity protocols ☐ Maintain shared data systems for transparency and collaboration ☐ Apply findings to future program rounds and regional scaling efforts



TNC's Brianna Group (left) and Steve Weglarz of Cedar Point Oyster Company add oysters to a restoration reef near Nannie Island as part of the SOAR program. Great Bay in Durham, New Hampshire. © Jerry and Marcy Monkman/EcoPhotography

EXECUTIVE SUMMARY

In many coastal regions around the world, oyster and other shellfish populations have declined to such low levels that natural recruitment is no longer sufficient to sustain them (Beck et al., 2011; Moore et al., 2018; zu Ermgassen et al., 2013). Where once self-replenishing reef systems thrived, overharvesting, habitat degradation, sedimentation, pollution, and disease have eroded breeding stocks to the point that larval supply, the foundation of reef recovery and persistence, has collapsed. In these recruitment-limited systems, restoration must begin by rebuilding breeding populations capable of producing and distributing larvae at ecologically meaningful scales.

Over the last 6 years, the Supporting Oyster Aquaculture and Restoration (SOAR) program has demonstrated a viable approach to oyster habitat restoration by utilizing the expertise, infrastructure, and products of the aquaculture industry to address two primary challenges: low larval recruitment and limited restoration capacity.

Developed and implemented by The Nature Conservancy (TNC) and The Pew Charitable Trusts (Pew) from 2020 to 2026, SOAR addressed both ecological and economic challenges during the COVID-19 pandemic, helping to stabilize oyster farming businesses and advance restoration goals in recruitment-limited estuaries.

By integrating industry expertise and materials into the restoration process, SOAR has provided benefits beyond those of many past and ongoing restoration efforts and has included direct support for coastal businesses and communities. It was initially implemented in seven U.S. states as both a response to the economic disruptions of COVID-19 and an innovative tool for transporting single adult oysters and/or shucked shells purchased from commercial growers to native oyster restoration sites. SOAR then expanded in 2023 with additional support from the National Fish and Wildlife Foundation and Builders Vision, including California as an eighth state.

In total, SOAR has deployed over 3,000 yd³ (2,294 m³) of shell, purchased more than seven million oysters from over 150 growers (including 1.4 million in farmer-grown spat on shell), and relocated them to 35 restoration sites. The program has supported at least 1,000 jobs and has set a precedent for coupling industry engagement with large-scale ecosystem recovery.

The purpose of this handbook is to describe how to restore the breeding capacity of native oysters by leveraging the expertise, infrastructure, and products of the aquaculture industry. The growing field of conservation-facing aquaculture practices—including conservation aquaculture, ecologically beneficial aquaculture, and regenerative and

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Zack Greenberg (Pew) and Christine Suter (Friends of the Bay) count oysters for a SOAR deployment in Oyster Bay, NY. © Rebekah Borgert/TNC; An oyster grower drives their vessel to a SOAR restoration site in Fairhaven, MA. © Hayley McManus



restorative aquaculture—has demonstrated that collaboration among growers, scientists, and managers can accelerate reef recovery while enhancing industry resilience (Chan et al., 2022; Overton et al., 2024; Ridlon et al., 2021; TNC, 2024).

Programs that engage the shellfish aquaculture industry to purchase and transport oysters for restoration can deliver immediate ecological benefits but also require careful planning, biosecurity oversight, and coordination with agencies and growers. This handbook provides a practical framework, grounded in lessons from SOAR, to support the design and implementation of similar programs. It outlines best practices for practitioners seeking to partner with the shellfish aquaculture industry by procuring aquaculture-reared shellfish for restoration across a range of geographies and management contexts.

While designed to address most considerations, this handbook does not provide guidance on evaluating the suitability or feasibility of reef restoration itself; for that, refer to *Restoration Guidelines for Shellfish Reefs* (Fitzsimons et al., 2019). Additional information may supplement this document as the SOAR program completes ongoing data collection and analysis.

This document is intended to serve a broad audience, including state resource managers, nongovernmental organizations, shellfish grower associations, federal resource and conservation agencies, academic institutions, philanthropic foundations, financial supporters, and policymakers.

CHAPTER 1:

INTRODUCTION

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The Supporting Oyster Aquaculture and Restoration (SOAR) program helped redefine restoration not as a stand-alone activity but as a collaborative enterprise that strengthens coastal communities and their working waterfronts. Evaluations of the program’s ecological and socioeconomic performance show clear benefits and provide evidence that aligning restoration with aquaculture can create a more sustainable and resilient future.

Experienced shellfish resource managers or restoration practitioners may be very familiar with the significance and ecosystem value of shellfish and specifically oysters. This chapter provides some background on the value and function of oysters. Note, although the term *reef* is used throughout, *oyster bed* may be more appropriate when referring to Olympia oysters (*Ostrea lurida*). Similarly, although SOAR focused on oyster restoration, this framework could be applied to other bivalve species, such as clams and mussels.

Oysters: Nature’s Engineers

Oysters are keystone species in estuarine and coastal ecosystems. Their unique biology enables them to function as natural water filters, habitat architects, and potent agents of nutrient cycling and sediment stabilization. By filtering water, oysters can improve water clarity, facilitate seagrass growth, and regulate nutrient dynamics (Kellogg et al., 2013; Newell, 2004). Their three-dimensional reef structures provide habitat that supports diverse fish and invertebrate communities, enhancing local biodiversity and secondary production (Coen et al., 2007; zu Ermgassen et al., 2016). Collectively, these functions make oysters vital to coastal resilience by providing nature-based solutions to challenges, including eutrophication, shoreline erosion, and climate change (Beck et al., 2011; Grabowski et al., 2012; Sun et al., 2025).

Biology and Function

Two prominent native North American oyster species, the Eastern oyster (*Crassostrea virginica*) and the Olympia oyster (*Ostrea lurida*), exhibit remarkable physiological adaptability, tolerating wide ranges of salinity and temperature (Galtsoff, 1964; Johnson et al., 2021; Kennedy et al., 1996; Pritchard et al., 2015; Johnson et al., 2021). Eastern oysters are broadcast spawners releasing eggs and sperm into the water column where fertilization occurs externally. Species in the *Ostrea* genus fertilize internally and release larvae partway through development (Galtsoff, 1964). The resulting larvae are planktonic for several weeks, during which they develop a shell and foot used to locate and attach to hard substrates, typically the shells of other oysters or similarly firm material (Kennedy et al., 1996).

Following settlement, larvae undergo metamorphosis into sessile juveniles known as *spat*, which can grow into adults and form dense, three-dimensional reef structures. These reefs provide complex habitats for a wide range of fish and invertebrates, enhancing biodiversity and ecosystem productivity (Coen et al., 2007; zu Ermgassen et al., 2016). Eastern and Olympia oysters are protandric hermaphrodites; individuals can change sex, often starting life as males and transitioning to females as they grow larger and older (Kennedy et al., 1996; Pritchard et al., 2015).

Under natural conditions, oysters may live up to 20 years, although disease, degraded water quality, sedimentation, predation, and harvest often reduce average lifespans (NOAA Fisheries, 2026). In aquaculture settings, oysters typically reach market size within 12 months to 4 years, depending on region, water temperature, and growing methods (Kiffney et al., 2026; Yang et al., 2018).

Ecosystem Services

Oysters provide a wide range of *ecosystem services*: the benefits of their ecological functions that support both environmental and human well-being. Researchers (Coen et al., 2007; Reeder-Myers et al., 2022) have categorized ecosystem services as provisioning (e.g., food and raw materials), regulating (e.g., water filtration, nutrient removal, shoreline stabilization, and carbon sequestration), Indigenous and cultural values (e.g., spiritual connections, first food practices, recreation, and aesthetic values), and supporting services (e.g., nutrient cycling, habitat creation, and biodiversity enhancement).

These services are critical to the health, productivity, and resilience of coastal ecosystems, yet they are often undervalued or degraded by land-use change, overharvesting, pollution, and climate-driven stressors (Beck et al., 2011; Grabowski et al., 2012; Okon et al., 2023). When cultivated sustainably, oyster aquaculture operations can provide ecological benefits like those of natural reefs, such as enhancing nutrient cycling, stabilizing sediments, and improving local water quality, while also supporting livelihoods and local food systems (Alleway et al., 2019; Chan et al., 2022; Grabowski et al., 2012; van der Schatte Olivier et al., 2020). Healthy oyster reefs improve water clarity by filtering phytoplankton and sediments, promote denitrification and nutrient retention, and provide complex three-dimensional habitat that supports commercially, recreationally, and ecologically important fish and invertebrates (Kellogg et al., 2013; Newell, 2004; zu Ermgassen et al., 2016). Table 1 shows the many ecosystem services derived from shellfish reef ecosystems and shellfish aquaculture.

Table 1: Ecosystem services derived from shellfish reef ecosystems and shellfish aquaculture, the beneficiaries of each service, and how this service is provided by shellfish reefs or farms. Adapted from Fitzsimons et al. (2019).

Ecosystem service	Beneficiaries	Mechanism – reef	Mechanism - farm
Finfish and crustacean enhancement	Commercial and recreational fishers, Indigenous communities, coastal culture	Provides refuge and high prey abundance (e.g., biofouling and associated organisms) in the three dimensional reef structure (Peterson et al., 2003)	Provides refuge and high prey abundance in the gear structure. This would vary by farming intensities, gear types, and location (Theuerkauf et al. 2021)
Reduced shoreline erosion	Coastal landowners and municipalities	Mitigates erosion, Provides wave attenuation and sediment trapping and stabilization (La Peyre et al. 2015)	Dampens waves via the oyster aquaculture gear (Alleway et al., 2019).
Increased water clarity	Seagrass, recreational users	Improves clarity due to oysters grazing on phytoplankton (Ray et al., 2015).	Same as for reef mechanisms.

Ecosystem service	Beneficiaries	Mechanism – reef	Mechanism - farm
Nitrogen removal	All users of eutrophic water bodies	Enhances microbial denitrification due to oysters filtering excess nutrients from the water column and transferring them to reef/sediment (Humphries et al., 2016; Kellogg et al., 2013; Ray et al., 2021).	Provides microbial denitrification driven by oysters filtering excess nutrients from the water column. The value of this nutrient removal ecosystem service is estimated at \$1,321–\$7,739 per acre each year (Barrett et al., 2022).
Oyster fishery enhancement	Recreational and commercial fishers	Produces a spillover of larvae from restored oyster reefs to fished reefs, enhancing wild oyster fisheries (Theuerkauf et al., 2021).	Produces a spillover of larvae from oysters on farms to fished reefs, enhancing wild oyster fisheries (Bishop et al., 2023).
Cultural value	Coastal communities	Sustains heritage harvesting practices and reinforces place-based identities around historic reefs and waterfront communities—enabling community rituals, recreation, and shared memory tied to the shellfish ecosystem (Michaelis, 2020).	Sustains livelihoods on the water, preserving family or community identity tied to shell-fishing and creating new social and experiential opportunities around the production of local food (Michaelis, 2020).
Biodiversity enhancement and ecosystem stability	Coastal food webs	Increases structure and food availability in the form of biodeposits from filtration. Increases low-trophic diversity and abundance (Kellogg et al., 2013).	Increases mobile fauna abundance and richness from the aquaculture structures, enhancing biodiversity and supporting ecosystem stability (Theuerkauf et al., 2021).
Economic value	Coastal economies	Supports jobs and contributes to local and regional economies via oyster restoration. Beyond direct economic activity, restored reefs strengthen commercial fisheries, improve water quality, and deliver long-term ecosystem services that, in turn, provide economic value (Hall & DeAngelis, 2024; Knoche et al., 2020).	Supports jobs in aquaculture and related supply chains and businesses. Oyster farms remove an average of \$10,147 of nitrogen per hectare per year, producing up to \$2,848 of enhanced recreational benefits and up to \$2,504 of enhanced commercial fishery benefits per hectare per year (Barrett et al., 2022).
Note: Not all shellfish reefs, beds, or farms provide all services. Some services provided are specific to location, aquaculture gear type, or species.			

Shellfish Restoration

Shellfish restoration involves the reestablishment of habitat formed by native bivalves such as oysters, mussels, and clams within their natural range. The goal is to reverse historical losses, restore the ecosystem services these habitats provide, and strengthen the resilience of coastal and estuarine systems (Beck et al., 2011; zu Ermgassen et al., 2013). These services include water filtration, shoreline stabilization, nutrient cycling, carbon sequestration, and habitat provision for fish and invertebrates of commercial, recreational and ecological importance.

Because these benefits depend on the persistence of healthy, three-dimensional reef structures, shellfish can only be expected to thrive and build habitat in environmentally suitable areas. Common restoration methods include placing single diploid oysters or *spat on shell* (hatchery-produced larvae set on recycled oyster shell) onto a reef base composed of fossil shell, rock, recycled shell, or artificial substrates such as salvaged concrete, reef balls, or oyster castles. (A *single oyster* refers to a loose oyster maintained and sold individually, as opposed to a *double oyster*, which is an unintended set of two or more oysters.) Reestablishing or enhancing the base of a reef provides the foundation for future generations of oysters to accumulate and form a new or restored reef. Assessing site suitability, including salinity, temperature, substrate stability, and water quality, is therefore a critical first step in any restoration effort (Fitzsimons et al., 2019).

The reef height of a reef is a primary driver of persistence and function. Restored reefs below a critical threshold are often short-lived, while those exceeding it can achieve self-sustaining population dynamics (Colden et al., 2017). Reefs typically thrive only when elevated above the sediment surface, allowing oysters to avoid smothering and maintain adequate access to food and oxygenated water. The required height for Eastern oyster reefs varies with site-specific hydrodynamic and sedimentation conditions but is typically 30 cm to 1 m (Colden et al., 2017; Schulte et al., 2009). The Olympia Oyster Restoration Plan, developed by the Washington Department of Fish and Wildlife (WDFW) in 2012, states that native oyster beds may have been as much as 1 ft (0.3 m) in height (Blake & Bradbury, 2012), though low-relief beds with multiple age classes are more typical today.

Equally important is understanding *recruitment potential*, or the expected settlement of larvae at a given site. In substrate-limited systems, where larval supply is sufficient but a lack of clean, hard material limits settlement, restoration primarily involves adding substrate timed to coincide with peak larval settlement. In contrast, larvae-limited systems, where too few breeding adults exist to produce sufficient larvae to sustain a population, require restoration efforts that first rebuild breeding populations to reestablish a sustainable larval source.

Benefits of Using Spat-On-Shell Oysters in Restoration

Spat on shell has long been a cornerstone of oyster restoration. Many restoration programs, including those in the Chesapeake Bay and Puget Sound, rely on planting spat on shell at restoration sites, and it remains one of the most widely used and scalable strategies for building oyster structure, enhancing recruitment, and accelerating oyster population growth.

This approach has also been integrated with the aquaculture industry in various ways. For example, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) developed a restoration program involving oyster farmers in Maryland, Rhode Island, Virginia, and elsewhere. Specific to Rhode Island, growers tended spat on shell for a season or more before deployment, dramatically reducing initial spat mortality (NRCS, n.d.). More generally, having growers nurture young oysters as either attached spat or single seed for several months prior to planting allows juveniles to surpass their most vulnerable life stage, which may result in higher survival once placed on the restoration site. SOAR piloted this approach in several states, and an analysis of the results is ongoing.

Hatchery Contributions—Direct and Indirect

Hatcheries support restoration both directly and indirectly. Directly, hatcheries can produce large quantities of eyed oyster larvae that are then set on shell to create spat-on-shell or released for *field setting* at restoration sites. These methods used globally, especially for *Crassostrea* species and increasingly for *Ostrea*, are relatively low-cost and can be scaled in compact facilities. Once set, spat-on-shell can be efficiently transported to reefs for planting. One practical limitation, however, is that some hatcheries face increasing demand from both commercial aquaculture farms and restoration projects, which can constrain the availability of larvae or seed for restoration.

Indirectly, hatcheries support restoration by supplying seed to the aquaculture industry for grow-out. If hatchery seed is *diploid* (fertile) rather than *triploid* (sterile), those farm-raised oysters will spawn and contribute larvae to surrounding waters during their time on the farm. In this way, standard aquaculture operations can augment the regional larval pool as an added benefit of routine farming, effectively acting as satellite breeding populations. SOAR's collaboration with California and Washington growers purposely supported the cultivation of native diploid Olympia oysters over several years to ensure those oysters released at least one or two cohorts of larvae into the wild before harvest.

Genetics is an important consideration in hatchery-based restoration efforts. Many hatchery breeding lines have been selected for traits favorable to aquaculture production, such as fast growth and disease resistance, which may not always align with restoration needs. Reduced genetic diversity or domesticated traits could affect the resilience of restored reefs (Hornick & Plough, 2022). In response, some regions, including Washington State, have established special permitting and broodstock protocols for hatcheries producing oysters for conservation, helping ensure that restoration seed is genetically diverse and suited to local conditions.

Grow-Out Partnerships

Beyond hatcheries, grow-out operations can contribute directly to restoration through innovative partnerships. Through the SOAR program, for example, oyster growers in Massachusetts, New Hampshire, and New York were contracted to grow spat on shell to a robust size specifically for restoration projects. Rather than deploying spat as tiny, fragile post-larval oysters, growers raised them to more than 1 in. (2.5 cm) in shell height before transplanting them to a restoration site. At that size, juvenile oysters have outgrown their most vulnerable stage and are far less susceptible to early predation and mortality.

Depending on local industry infrastructure, some growers obtained larvae from hatcheries and set their own spat, while others received preset spat on shell from partner hatcheries or universities and then tended them on their farms. Although these farm-raised juveniles were not yet large enough to have the high per capita fecundity of adult broodstock, they represented a substantial quantity of young oysters, often about five spat per recycled shell, that had already survived their earliest life-stage hazards.

This approach effectively front-loads restoration with a cohort of juveniles that has a much greater chance of reaching adulthood on the reef. It has proven particularly valuable in systems where intense predation or other factors typically decimate wild oyster spat shortly after settlement. By partnering with aquaculture operations for this intermediate nursery stage, restoration projects can achieve greater initial survival and faster reef development than through natural recruitment or hatchery planting alone.

This stage is also where the oyster aquaculture industry can play a valuable role in both the production of reproductive oysters and the procurement of shell substrate. By producing and supplying reproductively capable oysters for outplanting, growers can accelerate the development of breeding populations and the recovery of recruitment-limited systems. In the United States, such conditions are most common in the Northeast and along the West Coast, though portions of the Southeast and Gulf regions may also benefit from efforts to enhance broodstock density and larval supply (Schulte et al., 2009).

Restoration Challenges

Despite their immense ecological and economic value, oyster populations have experienced dramatic global declines, estimated at around 85% worldwide and over 90% in many coastal waters of the United States during the past century (Beck et al., 2011; zu Ermgassen et al., 2013). Oysters once formed vast reef complexes that filtered estuaries and stabilized shorelines, but populations have been severely reduced by overharvesting, habitat degradation, sedimentation, pollution, and disease (Beck et al., 2011).

Two protozoan pathogens, Dermo (*Perkinsus marinus*) and MSX (multinucleated sphere unknown; *Haplosporidium nelsoni*), have been especially influential in shaping oyster population dynamics and restoration outcomes on the East and Gulf coasts. Dermo, first described in the Gulf, proliferates in warm, saline waters and causes progressive tissue damage that reduces growth and increases mortality, particularly in older oysters (Andrews & Hewatt, 1957; Ford & Tripp, 1996). MSX, introduced to the United States in the late 1950s, causes widespread mortality, killing oysters from spat to adult life stages (Virginia Institute of Marine Science, n.d.). Together, these diseases have constrained natural recovery and complicated restoration efforts, particularly in the mid-Atlantic and Gulf regions.

Emerging environmental stressors now exacerbate these longstanding pressures. Ocean acidification reduces carbonate availability needed for shell formation, impairing larval settlement and early development (Waldbusser et al., 2015). Warming waters can accelerate disease proliferation and alter reproductive cycles, while increased storm intensity and runoff can negatively impact oyster life-cycle processes (Bowling et al., 2026; Pruett et al., 2022). These interacting stressors underscore the need for adaptive restoration approaches that integrate disease-resistant broodstock, dynamic siting, and long-term monitoring to help ensure restored oyster populations persist under changing conditions.

Aquaculture: Farming for Food and Function

Aquaculture, the controlled farming of aquatic organisms, has become a key component of global seafood production. Shellfish aquaculture can be among the most environmentally sustainable forms of aquaculture because it relies on natural plankton for feed, eliminating the need for external inputs (Gephart et al., 2021). This makes appropriately sited and managed oyster aquaculture both economically efficient and ecologically restorative, contributing to improved water quality, enhanced larval supply, and better habitat structure in coastal ecosystems.

While there are limitations to aquaculture data in the United States (Froehlich et al., 2022), it is understood that aquacultured oysters are the fastest growing part of the aquaculture sector (Petrolia et al., 2026) and play an increasingly important role in terms of economic value and environmental benefits. In 2023, the estimated value of aquacultured oysters in the U.S. was \$327 million (NOAA Fisheries et al., 2025). Oyster farming plays a foundational role in the blue economy, supporting jobs on the water and across the supply chain and providing a sustainable, domestically sourced food product.

There is a growing recognition of the value and services that healthy shellfish populations and aquaculture provide for people and the environment. This has led to increased social acceptance of public investment toward the recovery of native shellfish populations. Safeguarding these ecosystem services through conservation, restoration, Indigenous management and cultural practices, and responsible aquaculture is essential to sustaining water quality, biodiversity, and the resilience of coastal communities.

Shared Goals: Restoration and Aquaculture

Historically, restoration and aquaculture were treated as distinct disciplines: one focused on repairing ecosystems, the other on producing food. Today, they are increasingly recognized as complementary when pursued at the right scale and in the right places. Both can improve water quality, enhance biodiversity, and in some cases, provide coastal protection. Together, they can help sustain working waterfronts, historic, community-based areas that support coastal economies and the aquaculture industry.



SOAR collaborated with the Basin Oyster Project and Maine Oyster Company (MOC) in Maine, here an MOC vessel heads out to check their gear. © Clark Tate

Today, many oyster farmers collaborate with scientists, managers, and restoration practitioners, positioning aquaculture as a partner in conservation. In Chesapeake Bay, the benefits that oyster farms provide (water filtration, nitrogen and sediment removal, and improved water quality) are recognized in policy frameworks such as the 2016 expert panel report on oyster best management practices (BMPs). The 2016 BMPs established protocols to quantify nutrient removal and award credits for ecosystem services (Cornwell et al., 2016). Today, some growers on the East, Gulf, and West coasts are actively developing operational and long-term business plans for oyster cultivation specifically for restoration and, in some cases, co-developing those practices with Indigenous peoples. By blending ecological and economic goals, restoration and aquaculture can regenerate marine environments while strengthening coastal communities and livelihoods.

Water Quality

Water quality is a fundamental shared goal of both shellfish restoration and commercial aquaculture for human consumption. Clean water is not only essential for healthy estuarine ecosystems but also a public health priority, particularly in coastal communities where water quality affects fisheries, recreation, and human well-being. For shellfish aquaculture, clean water is fundamental to business viability: oysters must be harvested from approved waters that meet public health standards, and the long-term success of any aquaculture operation depends on maintaining those conditions. In this way, restoration and aquaculture are aligned not only by ecological objectives, but also by a shared reliance on clean, productive waters.



Restorative Aquaculture

Restorative aquaculture refers to subsistence or commercial aquaculture practices that provide ecological benefits, with the potential to deliver net-positive outcomes while maintaining economic viability (Alleway et al., 2023; The Nature Conservancy [TNC], 2021). The concept of restorative aquaculture recognizes that subsistence and/or commercial shellfish and seaweed production can, when farmed well, align and contribute to broader environmental and social goals such as habitat creation, water purification, shoreline protection, and climate change mitigation (Alleway et al., 2023; Theuerkauf et al., 2021). This approach bridges the gap between production and conservation by demonstrating that aquaculture, when thoughtfully designed and managed, can serve as a powerful tool for ecosystem recovery.

Oyster farmers are uniquely positioned to support this growing field. They possess the expertise, equipment, and supporting infrastructure, such as hatcheries or nurseries, required for production and deployment from family farms to large-scale operations. By partnering with restoration programs, growers can diversify income streams while advancing environmental outcomes.

Restorative aquaculture may also contribute to climate resilience by promoting or supporting carbon sequestration, nitrogen removal, and the buffering of local acidification (in the case of seaweed) (Alleway et al., 2019; Filgueira et al., 2015). Beyond these environmental gains, this holistic approach can strengthen coastal economies, sustain working waterfronts, and foster collaboration among growers, scientists, managers, and coastal communities.

Market Opportunities

Like any farmed product, oyster farming yields some oysters that are unsuitable for market sale, often due to shell deformities or other aesthetic imperfections. While unsellable for the half-shell trade, these oysters may be well suited for restoration. Redirecting such product streams offers farmers an opportunity to generate supplementary income while contributing to restoration efforts. Expanding these restoration opportunities and associated supply chains can help close the loop between seafood production and ecosystem recovery.

Leveraging Aquaculture in Ecosystem Recovery

Projects that intentionally integrate aquaculture and restoration have shown that these approaches can complement one another, enhancing both oyster production on farms and success rates at restoration sites (Alleway et al., 2019). This growing body of evidence demonstrates that, when managed collaboratively, the result can be greater than the sum of its parts.

With this understanding, policy frameworks and management strategies can encourage models that strengthen both economic resilience and ecological recovery. Recognizing and enabling these benefits lays the foundation for a sustainable, circular coastal economy in which aquaculture supports restoration, and restoration, in turn, enhances aquaculture viability.

To provide context for this integrated approach, Chapter 2 outlines key ecological interactions, management considerations, and policy conditions for effectively combining commercial oyster aquaculture with restoration initiatives.

An oyster bed in Washington state, SOAR worked with PSRF and industry to support restoration efforts at Dyes Inlet. © Molly Bogeberg/TNC

CHAPTER 2:

MAKING THE CASE FOR CONNECTING OYSTER AQUACULTURE AND RESTORATION

Past Programs Connecting Oyster Aquaculture and Restoration

Programs that connect oyster aquaculture and restoration have emerged in response to recurring challenges faced by shellfish growers, particularly during times of market disruption or surplus production, and the need to create alternative pathways for oysters to support reef recovery. These efforts have shown that purchasing farmed oysters for restoration can sustain livelihoods while advancing ecological outcomes.

An important early example came from TNC's New Hampshire Chapter, which in 2019 launched a program in Great Bay, New Hampshire, using USDA NRCS funding to purchase “uglies” (oversized, misshapen, or double oysters that were often unsellable in the half-shell market) from local growers. Rather than being discarded, these oysters were repurposed to enhance existing restoration reefs. The effort strengthened partnerships between growers and conservation practitioners while demonstrating the ecological and economic benefits of redirecting unsellable oysters toward habitat restoration.

This work was built on earlier efforts to link oyster aquaculture and restoration, including programs initiated in Rhode Island in 2007, when USDA NRCS partnered with the Rhode Island Department of Environmental Management and TNC. That program helped pioneer the purchase of hatchery-produced spat-on-shell oysters for deployment on restoration reefs. With the onset of COVID-19, NRCS programs in several states also began purchasing market-sized adult oysters, or singles, to relocate them from farms to restoration sites throughout the region.

Scaling Through the SOAR Program

At the onset of the COVID-19 pandemic in 2020, the collapse of demand for oysters on the half shell from restaurants left oyster farmers across the United States with significant unsold inventory. Building on the lessons and partnerships developed through earlier efforts such as the Great Bay program, TNC, Pew, and multiple Sea Grant programs collaborated to create the Supporting Oyster Aquaculture and Restoration (SOAR) initiative. Backed initially by private funding, SOAR launched in Massachusetts, Maine, Maryland, New Hampshire, New Jersey, New York, and Washington.

In 2023, the program gained support from the National Fish and Wildlife Foundation and expanded into California, its eighth state. Across all participating states, SOAR has deployed over 3,000 yd³ (2,294 m³) of shell, purchased more than five million oysters from over 150 growers, relocated them to 35 restoration sites, and supported at least 450 jobs.

The SOAR program helped redefine restoration not as a stand-alone activity but as a collaborative enterprise that can strengthen working waterfronts and coastal communities. Evaluations of the program's ecological and socioeconomic performance show clear benefits and provide evidence that aligning restoration with aquaculture can help create a more sustainable and resilient coastal future.

While this chapter focuses on the use of cultured single adult oysters and spat on shell for restoration, these are only some of the many ways the aquaculture industry can support and enhance restoration outcomes. Restoration costs can be reduced and program scale expanded by leveraging the full breadth of the commercial shellfish sector. When viewed holistically, the entire oyster supply chain, from hatchery production and grow-out operations to transportation and shell recycling, can contribute meaningfully to reef recovery. The sections that follow synthesize key scientific evidence supporting the value of connecting oyster aquaculture and restoration efforts.

Benefits of Using Adult Oysters in Restoration Projects

Incorporating adult oysters, or reproductively mature individuals, into restoration projects increases a reef's breeding biomass and enhances its capacity for self-sustaining reproduction, along with other ecosystem services as described in Chapter 1. The key measure of oyster reproductive potential is egg production, which scales exponentially with oyster size.

Restoration projects that use juvenile spat on shell, as opposed to larger single oysters, will be predominantly male-dominated and lack larger reproductive females in the first year or two. Integrating larger, mature oysters (e.g., via a SOAR-like purchase program) helps establish diverse age and size classes, jump-starting reef productivity and enhancing recruitment potential (for more information, see Mroch et al., 2012). Although site conditions influence the exact size–fecundity curve, the overall exponential pattern holds across locations. It is worth noting that even oysters in aquaculture can bolster wild reproduction if diploid oysters are used and allowed to spawn during grow-out on the farm. For example, when SOAR partnered with growers in California and Washington to cultivate diploid Olympia oysters, those farmed oysters contributed larvae to the surrounding ecosystem. Preliminary recruitment data (Griffin & Hancock, 2026) collected near the farms suggest that recruitment increased when oysters were held on-site for multiple spawning seasons. These findings remain preliminary, as accounting for natural interannual variability in recruitment would require a larger number of sites and a longer monitoring period than was feasible. Nonetheless, this indirect broodstock contribution highlights the potential synergy between aquaculture and restoration.

If oyster life expectancy is shortened, the duration of their reproductive advantage is likewise shortened. Multiple factors influence oyster life expectancy, but in restoration, the primary concerns are predation and disease, as noted in Chapter 1. Breeding programs and natural selection have increased disease tolerance so that these pathogens no longer prevent oysters from reaching market size (Ford & Tripp, 1996). However, shorter lifespans still limit the number of spawning seasons that large oysters can participate in before succumbing to disease.

Two biological parameters are key to assessing the benefits of adding adult oysters: breeder survival (longevity) and the addition of new individuals to the population (recruitment). As part of SOAR's biological monitoring program, these dynamics were evaluated by:

- estimating survival using population counts, proportional survival (the proportion of the population identified as recently dead—i.e., with valves still attached), and survival trays; and
- correlating increased breeding biomass with subsequent recruitment observed at restoration sites.

Together with density and size-frequency data, these measures link oyster survival and reproduction to the broader ecosystem services (from water filtration to habitat provisioning) that restored reefs provide.

Survival

Population-based survival estimates are only useful in limited circumstances. Once introduced, aquaculture oysters become indistinguishable from wild or previously seeded oysters. Therefore, comparing the total oyster population to the number originally added will exaggerate the calculated survival rate. Instead, *proportional survival* is measured as the ratio of live oysters to total oysters (live and dead *boxes*—an empty pair of oyster shells still attached at the hinge) in sample quadrats. The annual *death assemblage* (boxes with both valves still attached) indicates recent mortality. Shell breakage in these samples can also reveal mortality from large crushing predators (notably cownose rays, *Rhinoptera bonasus*).

Survival tray studies offer another approach: placing a known number of live adult oysters in open-topped cages on the reef and monitoring them over time. To yield meaningful results, the trays must remain open to natural predators (otherwise, they would overestimate survival) and be securely anchored to withstand storms without losing oysters.

Using these methods, restoration practitioners can determine how long the added adults survive and thus how long they contribute to the breeding population. Measuring survival (and concurrent recruitment, as described in the next section) indicates whether continued additions of breeding oysters are necessary or if the reef can sustain itself.

Please note that additional SOAR program data collected in 2024 and 2025 are still under review. This document shares the early lessons from 2020 to 2024. The next version of this document will incorporate additional lessons learned once full analysis is complete.

Recruitment

A restored reef can persist only if larval recruitment continues to replenish the population faster than its losses. Recruitment of juvenile oysters fluctuates yearly with environmental conditions, yet it is fundamental to the long-term persistence of oyster populations. Few regions have multi-decade records of natural oyster recruitment; New Hampshire is a notable exception. At New Hampshire's Nannie Island site, recruitment density declined from 2008 to 2014, mirroring a drop in the local breeding population (Figure 1). Post-2014 recruitment remained too low to reestablish a self-sustaining breeding population. Notably, a significant recruitment spike in 2021–2022 coincided with the addition of approximately 319,000 adult oysters to the site in November 2020 via the SOAR program. This pattern suggests that the introduced mature oysters enhanced local larval production and settlement. In 2023, the SOAR program shifted its focus from Nannie Island to the mouth of the Squamscott River. University of New Hampshire (UNH) partners and New Hampshire Fish and Game continue to monitor population trends and recruitment dynamics, adding to data collected since 2020. It is important to note that this is a correlation; the increased recruitment cannot be definitively attributed to the added breeding adults based on one site's data. However, the trend becomes more compelling as more restoration sites demonstrate the same pattern, strengthening the case that adding farmed adults boosts larval supply to local ecosystems.

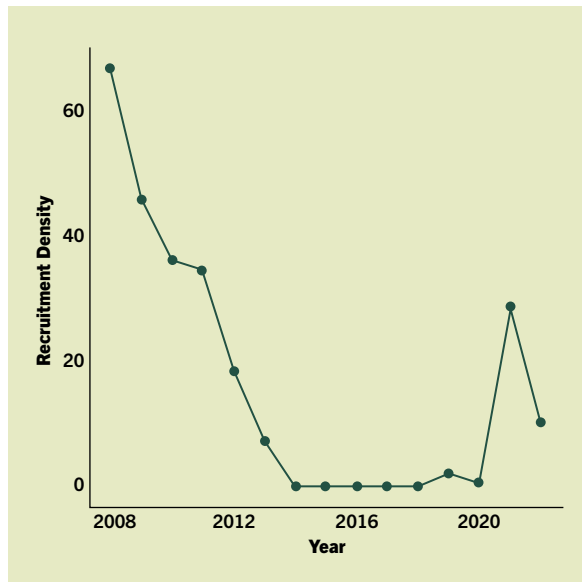


Figure 1. Time series of mean oyster recruitment density (recruits/m²) per year from 2008 at the Nannie Island wild reef site, directly adjacent to the restoration site in New Hampshire. Data from NH Fish and Game (2023).

Socioeconomic Benefits of Partnering With the Aquaculture Industry in Restoration

The SOAR program was first created to advance oyster restoration efforts while providing critical economic relief to oyster growers during the COVID-19 pandemic. To evaluate these outcomes, TNC engaged researchers at Northeastern University to assess SOAR's economic and social impacts across participating states (Grabowski et al., 2022). The findings from SOAR's first round of oyster purchasing in 2020–2021 demonstrate that aligning aquaculture with restoration yields significant socioeconomic benefits for coastal communities and the shellfish industry. Additional surveys were performed after later rounds of purchasing in 2023–2025, which will be analyzed and incorporated into future versions of this document. While these benefits are known, SOAR is unique as a documented, successful example of the interaction between ecological restoration and managed oyster resources. SOAR may serve as a proof of concept and provide a framework for accelerating restoration in partnership with industry.

Economic Relief and Avoidance of Losses

By purchasing surplus market-sized oysters from farms for use in restoration, SOAR injected much-needed financial support to growers and averted the waste of unsold product. About 60% of growers surveyed reported they would have kept unsold oysters on the farm until markets recovered, 30% would have sold at drastically reduced prices, and 22% would have had to dispose of unsold stock had the program not intervened (Grabowski et al., 2022). Thus, SOAR's purchase program for restoration prevented significant economic losses and operational costs that growers would have incurred in maintaining or culling unsold oysters.

Market Stability During Peak Impacts

At the height of the pandemic in 2020, 94.4% of oyster farmers experienced a collapse in demand as restaurants closed and seafood markets contracted. SOAR's support was especially timely during this period. In 2021, the percentage of growers still seeing reduced demand improved to 86.2% (Grabowski et al., 2022), indicating a partial market recovery, but most growers were still far from pre-pandemic sales. The program's rapid response in 2020–2021 effectively buffered the industry from deeper financial shocks, helping sustain many small businesses through an unprecedented downturn and preserving the broader market network for

when demand returned. By maintaining a baseline of sales (albeit for restoration rather than consumption), SOAR helped stabilize oyster prices and revenue, preventing a steeper crash that could have permanently shuttered farms.

Changes in Oyster Landings and Prices

Quantifying SOAR's direct impact on market trends is challenging due to natural variability, the small scale of operations, and regional differences. However, comparisons between participating and nonparticipating states suggest that states involved in the SOAR program fared better economically. Overall, states involved in SOAR saw smaller declines in oyster landing values and greater price stability than those that did not participate. For example, in states participating in SOAR, oyster farm-gate prices rose by an average of 14.6% from 2019 to 2020, whereas in nonparticipating states, they rose only 10.2%. In New England, landing (sales) values fell 29.4% in states with the program, compared to a 47.5% decline in a neighboring state without SOAR (Grabowski et al., 2022). These figures indicate that the SOAR program mitigated the economic hit; participating growers saw prices and revenues hold steadier than might have been expected.

Farm Size and SOAR Program Benefits

Most SOAR participants were small-scale businesses: 76% of growers farmed under 10 ac (4 ha), and the majority had fewer than five employees. This meant the program's impact was especially meaningful for family-run and boutique oyster farms with limited financial reserves. That said, both small and larger producers alike reported that SOAR stabilized their operations and provided vital continuity during the downturn (Grabowski et al., 2022). The infusion of funds from selling otherwise unsellable oysters allowed growers to keep their crews employed and maintain their culture gear and seedstock for the next season, essentially bridging the gap until the market could recover.

Oyster Grower Sentiment and Future Involvement in SOAR

Beyond tangible economic metrics, the program generated important social and psychological benefits. Across four surveys conducted between 2020 and 2025, growers overwhelmingly described the program as beneficial, with over 90% saying the initiative had been positive for them. SOAR reinforced a sense of community resilience and optimism within the aquaculture industry during a very challenging time. In 2020, 98.4% of growers expressed interest in participating in any future iterations of the program, and in 2021, 91.7% remained interested. Such high willingness to continue indicates that growers saw not only short-term relief but also potential long-term value in tying their industry to restoration efforts. The few barriers to future participation noted were the need for higher buy-out prices for their oysters and, for some, simply not having excess oysters to sell by 2021 (Grabowski et al., 2022).

Support for Long-Term Solutions

Notably, growers have signaled strong interest in developing sustainable, long-term market mechanisms that integrate aquaculture with restoration beyond the emergency context of the pandemic. In the 2022 SOAR survey, 83.2% of growers said they were interested in developing long-term commercial outlets to sell oysters specifically for restoration (i.e., diversifying their customer base beyond food markets). Additionally, 60% supported the idea of ecosystem service payment programs that would reward growers for the environmental benefits their farming activities provide (such as water filtration or habitat structure), effectively monetizing the positive externalities of shellfish aquaculture (Grabowski et al., 2022). These findings highlight a clear desire to integrate aquaculture more fully into long-term restoration and conservation frameworks, moving past one-off crisis response toward enduring partnerships.



Engaging Industry Resources in Restoration

To translate industry interest into practice, restoration practitioners can leverage various components of the oyster aquaculture supply chain. A holistic seed-to-plate-to-shell approach acknowledges that every stage of oyster production and use offers opportunities to support reef recovery. For instance, the aquaculture industry possesses the vessels, gear, labor, and local expertise needed to transport and deploy restoration materials efficiently. Growers' experience with tides, channels, and site conditions often makes them uniquely effective partners in the logistics of oyster restoration. Indeed, several states contracted with oyster farmers not just to supply oysters but also to deliver and plant those oysters (or shell) onto restoration sites. In doing so, growers earned additional income for their services while projects benefited from professional handling and timely deployment, improving the overall success and cost-effectiveness of restoration efforts.

Another critical resource is shell. Oyster shell is one of the most valuable commodities for rebuilding reefs—it is needed both as a surface for spat-on-shell production and as a structural substrate on restoration sites. The seafood and aquaculture industry plays multiple roles in shell supply and recycling. Growers, distributors, and restaurants contribute by saving and curing oyster shells that would otherwise be discarded. Community and municipal shell recycling programs prevent shell waste from entering landfills and instead redirect it to restoration projects (Hall & DeAngelis, 2024). Nonprofit and commercial collection networks often coordinate pickups, sometimes piggybacking on existing seafood distribution routes to maximize efficiency.

For example, the Town of Oyster Bay in New York collects and cures oyster shells from local restaurants and community events, then uses those shells in nearby reef restoration efforts under the town's management plan. In Georgia, a nonprofit initiative called Shell to Shore partners with seafood distributors to retrieve used oyster shells during their routine delivery runs, minimizing additional transportation costs while steadily funneling shell to restoration sites. Even the growers themselves can contribute shell material: many oyster farms accumulate cull piles of shucked shell on their property, and in Washington state, some restoration practitioners have purchased shell directly from growers to use as a reef base, providing growers a supplemental revenue stream for what is essentially a by-product of farming. Recycling and reuse of shell completes a circular loop in the restoration economy: shells that originate from aquaculture and the seafood industry are returned to coastal waters, where they become the foundation for new oyster reefs.

Eric Sparkman, a Shellfish Biologist for the Squaxin Island Tribe, conducts monitoring at an Olympia oyster restoration site. © Molly Bogeberg/TNC

CHAPTER 3:

BEST PRACTICES AND PROGRAM ELEMENTS

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Implementing a program that purchases oyster aquaculture products from growers or hatcheries for use in restoration projects requires careful planning, coordination, and collaboration. Drawing on lessons learned from the SOAR program, this chapter provides a structured framework and set of tested practices for designing, launching, and sustaining an effective and impactful program. Case studies presented throughout this chapter provide real-world examples of the program elements, and additional case studies are available in the appendix.

The guidance presented here is organized into four key sections, each addressing a critical stage in program development:

1. Understand the Landscape

This section outlines how to assess the environmental, regulatory, social, and economic contexts that shape a program. Understanding these boundaries and external influences helps define a clear scope and anticipate factors affecting success.

2. Design the Program

Developing a shared vision and setting realistic, community-led, and community-supported goals are key. Establishing a solid foundation at this stage ensures programs align with local priorities and can secure partnerships that foster trust, collaboration, and shared ownership of restoration outcomes.

3. Implement the Program

This section details the practical elements of program implementation—from procurement and logistics to communication and evaluation. Careful attention to these operational components will help ensure an efficient and effective rollout.

4. Monitor and Adapt

Finally, this section discusses how to measure program performance, track outcomes, and adjust approaches based on lessons learned. Adaptive management is key to long-term program success.

While Chapter 3 is presented as a generally chronological path from understanding the landscape to monitoring outcomes, programs may vary based on regional conditions, resources, and priorities. Practitioners are encouraged to adapt the sequence and emphasis of these steps to best fit their unique circumstances and goals.

At the outset of any program, setting clear goals is essential. The original SOAR program was created to balance economic and ecological needs, supporting oyster growers during a period of economic hardship (the COVID-19 pandemic) while also benefiting natural systems by advancing oyster restoration efforts. New programs that purchase and relocate farmed oysters to restoration sites may be designed to meet solely economic objectives, solely ecological objectives, or a hybrid of both, provided the enabling conditions exist.

Program goals should be developed collaboratively with industry as well as state resource management agencies to ensure feasibility and buy-in. Partner input will help determine the appropriate scale of the program: how many growers are likely to participate, how many restoration sites may benefit, and how many oysters can realistically be purchased. Program goals will also shape logistical considerations such as transportation methods, oyster size classes to be purchased, and eligibility criteria for participants.

1. Understand the Landscape

Designing a program that links oyster aquaculture to restoration begins with a thorough understanding of the landscape, including physical, ecological, regulatory, social, and economic considerations. This section provides guidance on assessing these interrelated factors to build a strong foundation for a program.



CASE STUDY

Maryland

Given Maryland's complex political and regulatory landscape, active industry engagement has been critical. TNC, Pew and other partners have worked closely with the state's aquaculture community to align conservation goals with business realities. These relationships foster transparency, innovation, and collective problem-solving among a tight-knit network of watermen, farmers, and restoration practitioners. By integrating grower perspectives into program design and implementation, Maryland's SOAR efforts have gained credibility and momentum. The result is a more resilient partnership model, one that balances restoration objectives with the sustainability of working waterfronts, ensuring long-term benefits for oyster populations and the people who depend on them.

Photo: © Humna Sharif



Define the Project Scope and Assess Restoration Site Readiness

Begin by clearly identifying the geographic boundaries of the ecosystem in which a program will operate. Some programs may choose to focus on a single tributary or estuary, while others may span multiple political jurisdictions or even involve the transfer of oysters across state lines. Understanding the spatial and environmental context of a program's focal area will help clarify where oysters can be sourced; where they can be deployed (e.g., avoiding any impaired areas closed to aquaculture, restoration, or harvest); what relevant regulatory or permitting considerations must be addressed, including biosecurity; and what factors may influence success, such as water quality, hydrodynamics, or the presence of existing reef habitat.

While looking at the project scope, we recommend an early assessment of whether restoration sites in the area exist for the transfer of oysters from aquaculture operations, or if they will need to be created. Also, clarify the intended scale of restoration, from small pilot projects to large ecosystem-scale efforts. For situations where existing restoration sites can be used, programs can often begin implementation within the first year if the sites are already permitted, monitored, and well-documented.

If restoration sites need to be created, there may be a significant increase in the time required to get the program running. Establishing these new areas requires additional time to secure permitting approvals, design monitoring protocols, and gain stakeholder buy-in. State natural resource agencies, local Tribes, and in some cases, federal agencies must often be consulted to delineate approved spatial boundaries for restoration sites. Permits to transport oysters and testing protocols may also be required to mitigate the risk of disease transfer or to address shellfish sanitation requirements.

Integrate Scientific Expertise and Monitoring

Scientific expertise complemented by local knowledge is essential for a successful project. Scientists can help determine the right approach to restoration based on site conditions and can support decisions about project scale and design to maximize ecological outcomes. For example, restoration sites may be constructed as reefs or beds. Based on local availability and industry capacity, projects may need to consider using single oysters, spat-on-shell oysters, or both. In all cases, leveraging scientific expertise and documenting baseline conditions is imperative to understanding the impact of the program.

Developing a monitoring plan to meet regulatory requirements and support adaptive management ensures that baseline conditions are captured and project impacts are measured. Improvements can then be made over time based on lessons learned. It is critical to budget sufficient funds to carry out monitoring activities. For guidance, see the *Restoration Guidelines for Shellfish Reefs* (Fitzsimons et al., 2019) and the *Oyster Habitat Restoration Monitoring and Assessment Handbook* (Baggett et al., 2014).

Understand the Regulatory and Policy Environment

Operating within the laws, policies, and regulatory frameworks of a given geography is fundamental to building a legitimate and collaborative program. Before launching a SOAR-like initiative, project leaders should review all applicable local, state, federal, and Tribal regulations and should consult with local Tribes on oyster aquaculture, restoration, and shellfish transfer. In some jurisdictions, purchasing oysters in bulk from growers requires a letter of authorization and/or special permits from relevant state agencies.

It is also essential to clarify how oysters purchased under a program will be classified and regulated. In certain states, they are treated as consumable seafood products like those destined for restaurants, meaning state health departments must review and approve program protocols. In other states, oysters destined for restoration may be treated as substrate materials used for reef construction. Diploid and triploid oysters may be regulated differently depending on the location of the restoration site. The regulatory interpretation will determine which agencies oversee permitting and compliance.

Biosecurity, the set of procedures designed to prevent the spread of disease and protect both oyster and human health, must be addressed from the outset. Most states have established biosecurity requirements for oyster harvesting, handling, and transportation. These typically include time and temperature controls for harvest and storage, seasonal restrictions on harvest and transport, and requirements for maintaining cold chain conditions during shipment.

Finally, understanding the broader permitting landscape is critical to avoid costly delays. Work closely with relevant state and federal partners early in program design to determine which permits will be required, particularly when oysters may be transferred between different waterbodies or jurisdictions. In many cases, obtaining these permits can take several months to years, so engaging regulatory agencies and integrating permitting timelines into the early stages of program planning is strongly recommended.



CASE STUDY

Maryland

In 2020–2021, SOAR targeted sites like Eastern Bay, St. Mary’s River, and the Nanticoke, where oysters would support state goals and growers were nearby. By 2024–2025, site selection also aimed to balance proximity to growers with state restoration priorities and monitoring logistics. A key challenge was disease prevalence, as data from the Maryland Department of Natural Resources (MD DNR) fall survey showed varying levels across the state, raising concerns about moving oysters from different disease levels to restoration sites. In response, and with guidance from MD DNR, SOAR limited participation to ensure strict biosecurity, preventing the transfer of oysters with higher disease intensity into healthier waters. This approach prioritized ecological integrity over program scale, reinforcing biosecurity as a nonnegotiable principle. Although participation was lower, Maryland’s SOAR program safeguarded restoration goals by maintaining strong biosecurity standards. This ensured that oyster restoration supported state priorities without compromising ecosystem health.

Photo: © Humna Sharif/TNC



Analyze System Dynamics and Ecological Suitability

A clear understanding of natural recruitment dynamics and the availability of diploid oysters for purchase within a program’s target ecosystem are important factors in determining whether a program for oyster purchase and restoration will meaningfully advance restoration goals. These programs have the greatest potential for restoration impact when adult oysters, along with their associated reproductive capacity, are relocated into restoration areas where larval supply is limited, and substrate is available to support reproduction and recruitment in the first season. Adding substrate and broodstock immediately before the natural spawning season will maximize recruitment in the first season.

If the target waterbody already supports a self-sustaining oyster population with robust broodstock and strong hydrodynamic circulation that effectively disperses larvae, it may not be an ideal candidate for a SOAR-like program using diploid oysters because sufficient reproductive capacity already exists. In such systems, restoration objectives may be achieved more effectively through other aquaculture or management strategies, for example, by adding substrate (see Chapter 2). Site design considerations should always align closely with the reproductive potential and ecological context of the system, including the physical characteristics and history of the area targeted for restoration.

It is equally important to assess the presence and potential impact of predators. Species such as the European green crab (*Carcinus maenas*) and invasive oyster drills (e.g., *Ocenebrellus inornatus*) on the U.S. Pacific coast and the cownose ray in the mid-Atlantic have been shown to cause significant losses at restoration sites, particularly where oysters are deployed as singles. In systems where these or similar predators are prevalent, adding adult oysters may not be the most effective restoration strategy, and alternative designs or protective measures for limiting predation should be considered, including using oysters of a larger size or in a different configuration.



CASE STUDY

New Jersey

SOAR's 2020 restoration work at Tuckerton Reef in New Jersey was severely impacted by cownose ray predation, which wiped out many of the single adult oysters planted there. This highlighted the vulnerability of single oysters to ray pressure and the need for careful site selection. In 2023, SOAR factored predation risk into site selection and restoration methods. Programs like the Ocean County Soil Conservation District's aquaculture project – called Conservation Opportunities Advancing Sustainable Technologies for Aquaculture Leases (COASTAL) – emerged as a solution, allowing for a more complex structure and reducing losses to predators. In 2023–2025, SOAR struggled to find suitable projects in New Jersey due to predation risk. Sites like Great Bay were too exposed to rays, while others, such as Great Egg Harbor River, faced logistical and cost barriers, underscoring how predation and practical constraints remain major challenges for oyster restoration.

Photo: © Susan Allen



Characterize the Oyster Resource

Understanding both the natural and cultured populations of oysters within a program's target system is foundational to designing a successful program. A sufficient oyster supply from growers and availability of infrastructure to facilitate transport are essential to ensure transfers from aquaculture operations to restoration sites can occur at ecologically meaningful scales. In short, the greater the availability of oysters, the higher the likelihood of demonstrating measurable ecological improvement. Coordinate with local natural resource agencies, suppliers and growers to verify the availability and accessibility of oyster resources for the project.

Using only native species is critical. The introduction of non-native species can have severe ecological consequences, including competition with native populations and habitat alteration. For instance, the Pacific oyster (*Crassostrea gigas*), introduced to support a declining oyster industry, has outcompeted the native Olympia oyster in some regions, such as Puget Sound.

Collaborating with academic and agency partners adds great value by documenting key biological characteristics of the oysters to be used in a restoration program, including expected survival, growth, fecundity, and disease prevalence. These baseline metrics inform restoration design and determine the quantity and suitability of oysters needed to establish a viable restoration project.

- **Survival rates** indicate the expected lifespan of oysters and anticipated maintenance needs; longer-lived oysters sustain benefits and reduce replenishment costs. Short-lived oysters will require continued expense and investment to maintain viable oyster populations.
- **Growth curves** reflect how quickly oysters reach maturity, become reproductively viable, and begin producing larvae, influencing the pace of restoration outcomes. Faster-growing oysters will reach maturity sooner and will produce larvae earlier, accelerating the distribution of larvae.

- **Disease prevalence** data are essential to guide stock selection and site suitability assessments. Work with the appropriate state agencies and academic partners to document disease levels in local oyster populations before designing the project.

Because not all oyster lines perform equally at a restoration site, use locally sourced or genetically adapted broodstock when possible. It is also good practice to track genetic lines and their survival or to purchase oysters with diverse genetics to reduce risk.

Engage Communities

Meaningful engagement with communities, especially Indigenous communities and rightsholders, is essential to designing a program that aims to restore native oysters. As original stewards of the lands and waters, Indigenous peoples hold traditional ecological knowledge of oyster populations and management, past and present, and they are often leaders in local restoration efforts. Many Washington Tribes have co-management authorities of shellfish and must be included in early conversations when developing a program and considering locations for restoration activities. Strong community support is vital for smooth program implementation. When the community understands and values the program's goals, projects are far less likely to encounter controversy or unexpected challenges from the public, government officials, or other interested groups.

Restoration programs often involve a wide range of individuals and organizations with diverse cultural, socioeconomic, and political perspectives. Some groups, such as adjacent landowners or waterway users who prioritize recreation, scenic views, or commercial activities, may be less supportive of aquaculture or restoration efforts. Visioning early and creating space to exchange ideas among community members and other project participants (industry members, scientists, resource managers, etc.) is strongly recommended to build a shared understanding of the project's value and address concerns before they escalate.

Generally, engagement should begin early and occur throughout the program. Attending stakeholder meetings in the community where a program intends to operate can provide a better understanding of the landscape at large, help build connections, and establish trust. During the design of a SOAR-like program (see Section 2 in this chapter), we recommend several effective strategies, such as hosting virtual or in-person community meetings and offering informational webinars on relevant topics like "The Importance of Oysters in Aquaculture and Restoration," to provide opportunities for participating in the design, implementation, monitoring, and communication phases of the project.

Understand the Aquaculture Industry and Build Equity

Engaging oyster growers is essential. Cultivating their interest and support ensures that enough oysters can be sourced, transported, and deployed to meet program goals.

The SOAR program purposefully worked to include all growers able and interested in participating, beginning with a clear understanding of who they are. Identifying potential growers, including new industry entrants, is a foundational step. Outreach through permitting-agency listservs, industry associations, farm extensions, funding networks, and direct communication with emerging growers helps ensure no eligible producer is overlooked. Meeting growers where they are is critical, as operations vary widely in scale and experience, from small hobbyist farms to multigenerational commercial businesses.

A successful SOAR-like program may also require dependable industry infrastructure like hatcheries producing diploid larvae, sufficient seed availability to avoid production bottlenecks, and reliable transport and deployment capacity to move oysters to restoration sites. Low hatchery production of seed oysters may

present a challenge in those areas where seed is needed to jump-start reproduction in a system. Over time, a restoration market will generate additional demand that can support scaling seed production and related infrastructure. Similarly, some infrastructure or resources may have limitations to their use, such as curing requirements for spat on shell or limitations on where and how collected shell is used. For example, some communities in New York request that shell collected in their community only be used to support restoration projects in their community.



CASE STUDY

New Hampshire

In 2023 and 2024, TNC partnered with UNH Jackson Estuarine Laboratory and nine New Hampshire oyster farms to grow spat on shell for restoration. Larvae were set at UNH and distributed to farms, which were compensated for pickup, on-farm distribution, weekly maintenance, and deployment. Although settlement rates were low in both years (14% and 17.7%), farm-based grow-out produced strong survival (72% and 50.2%) (Griffin & Hancock, 2026). The program's pricing structure drew from a 2019 pilot and NRCS Environmental Quality Incentives Program models, and farms were offered either TNC-provided gear or stipends to use their own equipment. Farmer feedback showed that gear needs varied widely, underscoring the importance of early consultation with growers. Because New Hampshire lacks public remote setting infrastructure, TNC relied on UNH for spat production, but repeated low set years highlighted the risks of hatchery based setting and the need for backup strategies. Combining purchases of spat on shell with large single oysters expanded farm participation and introduced multiple age classes to restoration sites, though project leads must weigh availability, risk, and cost effectiveness. Overall, the dual product approach shows promise for strengthening restoration outcomes while supporting local aquaculture operations.

Photo: © 2020 Jerry and Marcy Monkman/EcoPhotography



Prioritize Biosecurity and Human Health

Every transfer of live oysters introduces potential risks for the spread of disease and invasive species. Programs must develop and follow a comprehensive biosecurity plan. A biosecurity plan, for example, may include protocols for testing and transportation, special harvest and handling procedures, and guidelines for worker safety. **We strongly recommend consulting with the relevant state authorities to ensure compliance with the full suite of relevant regulations and to safeguard both ecological and public health.**

When moving aquaculture products (e.g., oysters or shell) from one location to another, it is critical to understand local rules and regulations for transfers and take precautions to prevent negative impacts on the oyster resource, the oyster aquaculture industry, local habitats, and restoration sites. Potential negative impacts from transferring aquaculture products include: (1) oyster mortality, (2) disease spread (MSX, Dermo, OsHV-1, and other pathogenic diseases), (3) incidental transfer of non-native organisms and pests (oyster drill eggs, juvenile fish species, etc.), and (4) reduction of oyster genetic diversity.

Mitigating oyster mortality: The farther an oyster is moved from where it is grown, the greater the likelihood of negative impacts on industry and restoration goals. Depending on program design—such as whether delivery is included in the per-oyster price—longer transport distances may incur additional costs and generally increase handling risk. When oysters are harvested, transferred, or deployed, they endure changes in temperature, salinity, and other environmental factors. These transitions can stress oysters, which, in turn, increases oyster susceptibility to mortality. For these reasons, minimizing the distance between transfer sites and the duration of disturbance should be prioritized.

Preventing the spread of disease: Understanding disease prevalence is critical to minimizing negative outcomes in oyster restoration. On the East and Gulf coasts, the primary diseases affecting oysters are Dermo (caused by *Perkinsus marinus*) and MSX (caused by *Haplosporidium nelsoni*), both of which destroy oyster tissue, primarily in adults older than 1 year. Detection of these pathogens within a geographic area should inform decision making as to whether oysters may be safely moved between or within systems. In most states, growers must follow tagging and harvest procedures for time/temperature control to protect against disease and other pathogens. These protocols may be required for oysters being moved for restoration purposes.

Avoiding species transfers: State regulations must be consulted to ensure that oyster transfers occur within acceptable geographic boundaries. In many cases, local marine resource managers designate restricted zones when invasive species or marine pests are detected. Oysters, along with other shellfish, may not be transferred outside of these zones to prevent incidental species transfers, or *hitchhikers*. For example, in Washington state, restricted zones exist to limit the spread of European green crabs and oyster drills.

Generally, systems that are hydrodynamically connected likely represent the lowest risk of negative impacts from the transport of oysters; restoration sites should receive oysters from the closest possible shellfish growers, ideally within the same embayment. This can help limit the accidental spread of other pests, such as the mud blister worm (*Polydora websteri*) and oyster redworm (*Mytilicola orientalis*)—parasitic organisms that render oysters inedible along the western U.S. coast. In agreements with participating growers, the SOAR program reserved the option to turn down any oysters if they did not appear to be free of fouling organisms or in good health.

When setting up a SOAR-like project, program staff should discuss with site managers and regulators if there are biosecurity considerations when determining eligibility to participate, interventions and protocols they would like the program to follow, and data needed to support those processes. In New York, for example, a 5-minute salt brine dip has been required prior to moving oysters between some locations.

Genetics: Where possible, the genetic composition of oyster populations should be assessed and incorporated into the selection of source stock. Some programs, such as those in Washington state, have developed genetic guidelines that encourage growers to use only Olympia oysters meeting restoration-grade genetic criteria. The likelihood of restoration success increases when adult oysters transported from aquaculture farms to restoration sites have genetic signatures closely matching those of native oysters in the system. For all SOAR-like projects, genetic factors should be considered when selecting oyster populations best suited to achieve restoration objectives. Broodstock from restoration sites may be viable resources, if not highly desired, for placement in other systems and in other prospective restoration sites.

Other considerations for success: Organizations implementing a SOAR-like program should check with local regulators about other rules that may apply, such as limits on transporting oysters during rain closures (i.e., temporary pauses on harvest after heavy rains that wash bacteria, viruses, and pollutants into water-

ways), outside of harvest times, during vibrio season (i.e., when *Vibrio* bacteria that pose a human health concern have elevated concentrations), or tagging and harvest procedures specific to oysters being used for restoration. Lastly, regarding human health, a plan for protecting and ensuring the safety of those involved in transporting oysters must be developed. It might include a review of safety guidelines when working near or on the water, or procedures for providing personal protective equipment. Relevant agencies can assist or guide the development of these procedures.

2. Design the Program

Once a clear understanding of the physical, ecological, regulatory, social, and economic context is established, program design can begin. This stage focuses on developing a cohesive vision for the program, its structure, objectives, and intended outcomes and on establishing the partnerships needed for success.

Set Clear and Purpose-Driven Objectives

Defining both ecological and restoration objectives is important. These may include improving water quality, enhancing biodiversity, or increasing fish habitat, all of which can benefit from adding more diploid or triploid oysters to a system. For example, the initial phase of SOAR purchased both triploid and diploid oysters, reflecting its primary focus on COVID-19 economic relief, whereas the second phase prioritized diploid oysters to support reproductive outcomes. Several tools and resources can support this process. For example, TNC's Oyster Calculator (TNC, n.d.) can help estimate the number of oysters required to achieve desired outcomes (e.g., filtration rates, fish production). This tool should be complemented by current scientific literature. For instance, work in Chesapeake Bay demonstrates that in some cases, oyster placement alone cannot meet the full filtration needs of the ecosystem (Cerco & Noel, 2007).

All objectives should be quantitative and measurable. Establishing a baseline before the program begins allows for comparison over time and helps demonstrate progress. Metrics may include acres restored, juvenile fish recruitment rates, or revenue growth among participating growers. Some program goals have metrics that can be measured relatively easily, including water quality, habitat condition, and biodiversity.

Assess Program Capacity

Once the program goals are established, it may be necessary to develop the capacity to meet them. Many oyster purchase programs have been operated by very small teams, but it is important not to underestimate staffing. When evaluating capacity, consider these questions: Are there enough staff to carry out the program? Is staff already in place, or will new hires be required? Do partners have complementary capacity to support program operations? If hiring, are part-time or full-time staff needed? Can staff be embedded within state agencies or with other partners? A realistic understanding of staffing requirements early in the planning process reduces bottlenecks, improves program efficiency and establishes a foundation for program permanency.

Identify Funding for the Program

Securing adequate funding is central to any program involving the purchase and deployment of oysters. Programs like SOAR have relied on a combination of grants, federal and state programs, private donations, and philanthropic support. Before launching a new program, confirm that funding will cover the entire project period, including post-deployment monitoring, which is critical to demonstrating impact and refining future program phases. Funding typically must cover staff salaries and compensation, outside consultants, scientific experts, oyster purchases, transportation and logistics, and monitoring activities.

Pricing structures will vary depending on whether oyster products are purchased as clean shell, spat on shell, or market and oversized oysters. Potential funding sources include competitive grants, state and federal

programs, private donations, foundations, and private financing models, such as emerging ecosystem markets (nutrient trading frameworks that are largely still in development).

Build Partnerships and Support

A successful program depends on a strong network of partners and relationships grounded in trust and clear communication. Throughout all phases of the program, from early planning through implementation and monitoring, regular and transparent communication among partners is essential. Early outreach and relationship-building with community leaders, oyster growers, recreational fishers, the National Oceanic and Atmospheric Administration (NOAA), NRCS, oyster growers' associations, Sea Grant programs, Tribes, academia, and state and local agencies establishes the foundation for long-term collaboration. Scheduling consistent check-ins, particularly during planting season, helps maintain alignment and ensure smooth operations.

No single organization or agency will likely possess the capacity to carry out all components of a program of this complexity. Partners contribute essential skills, expertise, and resources across every phase of the project. Input from multiple stakeholder groups during pre-implementation planning is often one of the most important determinants of program success. During implementation, partners with experience in oyster collection, storage, gear management, and equipment cleaning become as essential as the oyster resource itself.



CASE STUDY

Massachusetts

TNC and NRCS have partnered to expand oyster restoration in Massachusetts, overcoming limited site availability by securing a Conservation Innovation Grant. This led to the launch of a fully permitted project in Hamblin Pond, Cape Cod, in May 2025—a major milestone for SOAR. Building on that success, TNC and NRCS established a 5-year cooperative agreement to create a statewide restoration plan, aiming to permit at least five more sites. With new funding directed to the Massachusetts Division of Marine Fisheries, the state is strengthening staff capacity and institutionalizing shellfish restoration as a key strategy for water quality and coastal resilience.

Photo: © Haley McManus



Identifying appropriate partners is a critical early step. Effective partnerships typically include restoration practitioners, resource managers, and commercial aquaculture representatives, among others. Program leads should work with Tribes, state agency partners, and resource managers and should use existing networks and mailing lists to develop a comprehensive list of growers and other potential collaborators. Many organizations can help identify the appropriate contacts, including agricultural extension offices; Sea Grant programs like the State Marine Aquaculture Coordination Network; oyster growers' associations, particularly the East Coast Shellfish Growers Association, Gulf Shellfish Farmers Association, and Pacific Coast Shellfish Growers Association; and environmental and marine resource agencies.

In many states, a single resource management agency may be well-positioned to serve as the central point of contact charged with creating the list of partners and coordinating partner communications. In many states, their fish and game division or their fish and wildlife division may serve that role. Health departments or soil and water conservation districts may also provide a centralized outreach pathway that is important for maintaining consistency and clarity. At the federal level, USDA NRCS, NOAA, or the U.S. Fish and Wildlife Service could lead partnership efforts.

Once partners have been identified and roles clarified, developing formal agreements such as memoranda of understanding or letters of commitment helps establish clear responsibilities, timelines, and resource-sharing expectations. If initial outreach identifies too few partners, it may indicate the need to reassess program feasibility or adjust the program’s approach to engagement.



CASE STUDY

Washington

Washington’s native Olympia oyster once flourished in the Salish Sea, but populations have declined due to the impacts of shoreline development, pollution, and overharvest. The Olympia oyster is listed as a “Species of Greatest Conservation Need” in Washington’s State Wildlife Action Plan, a “Priority Species” under the WDFW Priority Habitat and Species Program, and a “State Candidate” species designated by WDFW. In 2012, WDFW developed the *Plan for Rebuilding Olympia Oyster (Ostrea lurida) Populations in Puget Sound with a Historical and Contemporary Overview* (Blake & Bradbury, 2012). Since 1999, Puget Sound Restoration Fund (PSRF) has led large-scale restoration, operating the only conservation hatchery producing restoration-grade Olympia oysters at NOAA’s Manchester Research Station (the Kenneth K. Chew Center for Shellfish Research and Restoration). When SOAR began in 2021, TNC partnered with NOAA, WDFW, state agencies, Tribes, PSRF, and the Pacific Coast Shellfish Growers Association to understand regulatory frameworks and identify restoration opportunities.

Key factors emerged: few farmers raise restoration-grade Olympia oysters; broodstock must originate within each sub-basin; and WDFW controls oyster transfers through biosecurity permits. SOAR efforts focused on supporting Tribally led restoration efforts, including those led by the Squaxin Island Tribe and the Swinomish Indian Tribal Community, by purchasing restoration-grade singles from an oyster farmer and from PSRF’s hatchery to be used for restoration. Additionally, Pacific oyster shell was purchased from farmers to support PSRF’s shell enhancement project at Dyes Inlet.

Photo: Jodie Toft, Executive Director of the Puget Sound Restoration Fund, prepares for shell deployment at Dyes Inlet. © Hannah Letinich



Develop a Pricing Framework

One of the most critical factors in any SOAR-like program is creating an appropriate, equitable pricing framework for aquaculture products. The SOAR program regularly evaluates its pricing through ongoing conversations with similar initiatives (e.g., NRCS), industry members, regulators, and distributors. Market conditions evolve, and pricing frameworks should remain flexible and responsive.

Developing a transparent, equitable pricing structure benefits both growers and restoration practitioners. Early dialogue with growers' associations, state agencies, and federal programs can help determine appropriate prices for oysters, shell, and spat-on-shell. Historical and current market data are valuable reference points.

Pricing may be based on:

- individual count (per oyster),
- volume (per standardized unit),
- oyster size (inches or millimeters),
- gear type (water-column or bottom-grown), and
- growing location (tributaries vs. open bays).

Setting a minimum size for adult oysters is recommended. It also might be worth exploring a tiered pricing model, where a program pays a different price depending on the size of oysters being delivered. This approach requires clear communication with participating growers about the quality assurance and quality control (QA/QC) protocols used to estimate size and amounts delivered.



CASE STUDY

New York

SOAR initially used a pay by volume system to simplify purchasing and encourage growers to provide larger oysters, but the approach produced inconsistent quality and unintentionally rewarded unsorted or heavily fouled product. In response, SOAR shifted to a pay by piece model that was more familiar to the growers, required diploid, market-sized oysters, and applied QA/QC thresholds for mortality and undersized oysters, creating a fairer and more consistent standard. Growers were informed of program requirements through coordinated outreach with the New York State Department of Environmental Conservation, and purchase caps ensured equitable distribution of funds. This revised pricing structure improved product quality, increased fairness among growers, and supported broader participation in the program.

Photo: © Zack Greenberg



When developing a pricing framework, here are some key considerations:

- **Price:** Consider pricing oysters at or below market value when purchasing large, nonmarket oysters. The reproductive value of restoration must be balanced with the limited commercial demand for oversized oysters. It is also important to be cognizant of wholesale pricing where applicable. If possible, a program that can set a standard pricing framework will be seen as more equitable.
- **What is included in pricing:** In some regions under the SOAR program, growers delivered oysters to the restoration site and received a set price per trip. Elsewhere, transportation costs were integrated into the per-oyster price. Following industry standards is highly encouraged.
- **Collaboration:** Pricing decisions are strongest when co-developed among restoration practitioners, state managers, growers, and growers' associations. Allowing for localized adjustments and the realities of transportation logistics and market conditions will lead to a satisfactory pricing framework.
- **Volume and purchase limits:** Capping purchases per grower promotes broader participation and equitable distribution of funding. Balancing inclusivity with logistical and budgetary constraints can be a challenge for any program. Smaller growers may have difficulty meeting purchase program minimums or meeting narrow purchase windows, especially for large volumes of oysters.
- **Clear communication:** Communication of transparent criteria regarding size, quality, and purchase limits helps prevent confusion between growers and the program.
- **Pricing adjustments due to market variation:** Market fluctuations and competing demand (e.g., direct-to-consumer) may require pricing adjustments. Demand from direct-to-restaurant or direct-to-consumer markets may fluctuate and compete with the market for oysters used in restoration. Regular communication with growers helps navigate these dynamics.
- **Logistical complexities:** Transporting oysters across regions can be costly and labor-intensive. Pricing should account for these realities, and programs may identify efficiencies such as consolidating deliveries among multiple growers to reduce transportation and deployment costs.

Prepare a Communications Strategy

Clear messaging of program goals and anticipated outcomes is essential. Where possible, engage marketing and media professionals to help refine messaging and develop a concise, effective communications strategy. Communication needs will evolve throughout the program. For example, during the development phase, the priority will center on building awareness and conducting outreach to oyster growers and other key partners. Later, recruiting growers as messengers can help expand support for the program and is also a great way to authentically inspire new programs and partnerships.

3. Implement The Program

Once the program vision and design have been established, the next step is to carry out the program. This phase includes recruiting growers; conducting screening and selection; purchasing and deploying oysters to restoration sites; and teeing up effective monitoring activities.

Conduct Grower Outreach, Screening, and Selection

Engaging multiple oyster growers increases the likelihood of securing enough oysters to achieve ecologically meaningful outcomes. In regions where the number of growers exceeds available funding, it is important to establish transparent eligibility criteria and selection guidelines. Growers with oysters already available for purchase and those located near permitted or shovel-ready restoration sites should be prioritized.

A communications plan should be prepared in advance for situations when the program is unable to support all willing and eligible growers. Early, clear, and consistent outreach fosters trust and helps growers plan accordingly.

Implement Oyster Purchasing

Once partners are engaged, restoration sites selected, baselines established, and a pricing framework finalized (see this chapter's Section 2 on program design), the program can move into purchasing and deploying oysters to restoration sites.

A streamlined contracting and tracking system is essential, especially when working with multiple growers. Develop standardized contract templates and data-tracking tools early and allow sufficient time for review and refinement. Online tools, such as user-friendly enrollment websites, digital application forms, and web-based monitoring surveys, can greatly improve program efficiency. Application deadlines should be clear but flexible enough to accommodate grower needs.

Logistical considerations for moving oysters should also be evaluated. For example, milk crates or totes may complicate handling when compared to loose oysters or shell that can be more easily shoveled or loaded mechanically. Another example: Account for the tidal range at drop-off locations and restoration sites because it may determine the time frame for growers to drop off their oysters to adequately tee up deployment at a tide-accessible restoration site later in the day. Agencies may have policies in place that dictate the methods or containers required for transport.

Programs can structure oyster purchases in several ways (Table 2). When establishing a pricing framework, consider not only the immediate purchase needs but also options that help growers plan for future production and strengthen long-term restoration markets.

Table 2. Potential purchase program structures.

	Description	Benefit to growers	Project risk
Direct purchase	One-time purchase of an agreed number of oysters at a set price.	Fast and familiar process aligned with restaurant market practices.	Availability may vary when oysters are needed.
Advance purchase	Agreement to buy oysters at a future date. May include partial upfront payment.	Financial planning support. Allows growers to reserve or cultivate appropriate oysters.	Crop loss due to mortality or extreme weather.
Contract production	Contracts with growers to produce a set quantity of oysters specifically for a project.	Determines what product is grown for the program, ensuring the type of oyster is consistent with restoration goals.	Similar risks as above; requires longer-term planning.

Additionally, while SOAR worked directly with growers, a purchase program could also be structured to work with distributors or wholesalers to reduce some of the complexities of program coordination while still adhering to all necessary state and federal compliance and tracking. Using a mix of these approaches may help balance grower needs, project timelines, and ecological goals while supporting a resilient restoration-oriented aquaculture market.

Execute Oyster Deployments

A deployment day is a coordinated, fast-moving operation that depends on strong advance planning and clearly defined roles. Prior to deployment, programs should work with industry partners and relevant agencies to identify and confirm appropriate drop-off sites. Growers arrive at scheduled times to deliver oysters, which program staff then unload, count, and measure to verify quantities and ensure compliance with biosecurity and quality standards. Wherever possible, build flexibility into the drop-off schedule to accommodate unpredictable factors (e.g., weather, traffic, mechanical issues) and to support consistent operations if deployments occur at regular intervals.

Ensure adequate staffing at each drop-off site to manage the anticipated volume of oysters; this checkpoint is also an efficient opportunity to collect any additional data required by your program. All paperwork and photographs are gathered and digitized, and once QA/QC checks are complete, oysters are loaded onto vessels and deployed to restoration sites the same day.

The day concludes with updates to summary tables to confirm total quantities and support accurate and timely processing of payments. Programs such as SOAR have found it effective to dedicate a small team to collect data at the drop-off site, while others focus on the physical loading, counting, and moving of oysters, which can be substantial. In some instances, growers were met on the water at the restoration site, where the team performed their assessments from vessels before deploying the oysters.

Tell Your Story

Through implementation (Phase 3b), regular, internal-facing communications with partners, including scheduled check-ins and progress updates, are essential for maintaining coordination and transparency. After deployment (Phase 3c), external-facing communications via annual updates through press releases, social media posts, and photo and video features help demonstrate the program's impact and sustain public and partner support. When feasible, leverage partner communications staff or engage professional photographers and videographers to ensure high-quality materials. Maintaining an up-to-date website and active social media presence further enhances visibility. Hosting site visits for partners, supporters, and media outlets provides compelling opportunities to highlight progress and celebrate successes. Plan and prepare for growers to self-promote the program through their own marketing and communications channels, too.

4. Monitor And Adapt

Effective monitoring allows programs to measure ecological and socioeconomic change over time, evaluate success, and make informed adjustments to future implementation. Establishing strong baselines, using standardized monitoring methods, and adapting based on results are central to long-term program impact. Monitoring must be able to detect the ecological and socioeconomic impacts resulting specifically from relocating oysters to restoration sites, distinguishing these outcomes from background system dynamics.

Build the Monitoring Team

Effective monitoring often requires a blend of expertise. Ecological monitoring may be conducted by state resource management agencies or trained field staff, including growers, where appropriate. Socioeconomic monitoring may benefit from the involvement of social scientists or economists who can design surveys, evaluate market conditions, and assess community and industry responses. Partnering with academic institutions, particularly those with established oyster research programs, can further strengthen monitoring efforts. Faculty, staff, and students bring methodological rigor, support robust experimental design, ensure consistency across sites, and enhance the program's scientific credibility. Additionally, monitoring frameworks that incorporate culturally important indicators, Indigenous science, or Traditional Ecological Knowledge should be developed.

Establish Baselines and Measure Change

Monitoring efforts should begin before deployment. Baseline data, such as oyster density, reef height, size structure, or historical recruitment, provide the foundation for measuring the change associated with your restoration program. For example, if a site begins with 50 oysters/m² and increases to 75 oysters/m² in 2 years, a 50% increase can be documented. Baselines should incorporate historical information when possible and should complement clearly defined ecological goals (e.g., filtration capacity, nitrogen removal, biodiversity).

Following deployment, monitoring should occur at regular intervals to track early responses and long-term trends in reef development and socioeconomic conditions.

Define the Core Monitoring Framework

Monitoring approaches can be organized into four categories (Fitzsimons et al. 2019, 2020), consistent with guidance from Baggett et al. (2014, 2015).

I. Implementation monitoring

Determines whether restoration actions were completed as planned. Examples include verifying that oysters were deployed at the correct locations, volumes, and sizes.

II. Performance monitoring

Assesses whether restoration actions produced the expected outcomes. Performance metrics can be:

i. Socioeconomic outcomes

- Engagement of regulators and stakeholders critical to program or project oversight
- Public support and industry participation
- Jobs created or supported
- Economic stability or growth among growers

Additional socioeconomic metrics can include the direct economic impact on participating oyster growers and satisfaction among growers and project partners with program implementation and logistics.

ii. Ecological outcomes

- Recruitment: Are sufficient juvenile oysters being produced to replace natural mortality?
- Breeding biomass: Have numbers of mature adult oysters increased, particularly in recruitment-limited systems?
- Survival: How long do the breeding oysters live and contribute reproductively?

Core biological and ecological metrics commonly assessed in restoration programs include oyster density, mortality, size structure, survival, recruitment, reef height, and total reef area. These indicators provide a standardized foundation for assessing changes in population dynamics and reef development.

III. Ecosystem services monitoring

Assesses broader impacts of restoration projects on ecosystem services delivered by oysters and reefs, such as:

- Biodiversity
- Fish biomass and habitat use
- Water clarity and filtration
- Nutrient removal

These indicators typically require more intensive monitoring and should be planned in collaboration with experienced practitioners.

IV. Adaptive management via long-term monitoring

Because oyster population dynamics and environmental conditions vary from year to year, a single monitoring event cannot capture a program's true ecological performance. Multiyear data collection is essential for distinguishing short-term variability from meaningful ecological change. For example, SOAR used a monitoring frequency of 12 months to facilitate adaptive management and align with funding requirements. Some metrics should be analyzed yearly (e.g., recruitment and survival), while others should have different time frames (e.g., measuring reef height and changes in reef area every 3 years). For additional information, we recommend Baggett et al. (2014).

Monitoring results across socioeconomic and ecological dimensions informs program refinement, improvements to restoration design, and future deployment strategies. Standardized methods allow comparison across years, sites, and regions.

Assess Key Socioeconomic and Ecological Monitoring Components

Socioeconomic Considerations

A mixed-methods socioeconomic monitoring approach that combines structured grower surveys with analysis of independent economic datasets can be powerful (Grabowski et al., 2022). To the extent possible, surveys should be administered across multiple years to capture farm characteristics, demographic information, business impacts, program benefits, and growers' future participation preferences. These perceptions can be complemented by quantitative analyses of independent national and state datasets capturing wild and public harvests, as well as commercial aquaculture landings, prices, and grower numbers, allowing comparison between participating and nonparticipating states. Together, these methods enable assessment of both producer-level experiences and broader market-scale economic trends attributable to program interventions

Existing Oyster Populations

Understanding the current oyster population within the broader system that a program is operating within (tributary, bay, estuary, or watershed) helps contextualize recruitment potential and likely program outcomes.

Recruitment and Recruitment History

Recruitment time series (recruits/m²) are extremely informative but not always available. Recruitment can be measured using a variety of methods, such as settlement tiles, quadrat counts, and spat per shell bags or shell strings (convertible to approximate densities).

If no historical data is available, it is recommended that oyster recruitment monitoring begin during the project planning phase, before restoration activities start. Establishing long-term data can help identify areas with strong larval retention that are well suited for restoration, show how environmental factors such as rain-fall (which affects salinity) influence recruitment, and track how adding adult oysters through a restoration program contributes to future recruitment.

Oyster Density and Size Frequency

Diver-based random quadrat surveys provide direct measures of recruitment and adult populations within restoration sites and can be used to approximate total population size (i.e., mean density x area seeded), mortality, and size-class structure. These surveys are best conducted in the fall when recruits are of sufficient size to differentiate confidently. Depending on the waterbody, it may be possible to conduct surveys after a spawning event at a different time of the year.

Tracking changes in oyster abundance, oyster density, or both, before and after deployment, can further strengthen survival estimates and help distinguish between mortality, recruitment, and growth. These paired measures provide a clearer picture of how the restoration effort influences overall population structure.

Survival

Survival is a central metric in restoration because diseases like Dermo, MSX, and others, as well as predation, can sharply limit oyster lifespan and, in turn, reduce the number of spawning seasons available to each individual (Ford & Tripp, 1996). Although aquaculture lines have been selectively bred to reach market size despite disease pressure, restoration success depends on multiyear reproductive output and therefore benefits from oysters capable of surviving longer. This is especially relevant for Eastern oysters, where Dermo and other pathogens are endemic; Olympia oysters may face lower pressure but still benefit from survival monitoring. Tracking survival also helps identify broodstock with greater disease tolerance and longevity. In addition to disease, other mortality sources, such as predation and sediment smothering, can strongly shape population dynamics. Understanding these pressures requires direct, reliable survival measurements.

To assess program impact, survival should be measured both before and after deployment. Establishing pre-deployment survival of the existing oyster population provides critical context, while post-deployment measurements allow comparison of how newly introduced oysters perform relative to any existing stocks.

Reliable Methods for Measuring Survival

Population-level estimates or live-to-dead ratios (e.g., assuming paired valves indicate recent mortality) are often unreliable. More accurate approaches involve following a known cohort of oysters over time. There are several methods to consider. One such method is using anchored, open-top trays placed on the substrate. Open-top trays expose the selected cohort of oysters to natural predation while allowing consistent resampling of known individuals. Another method is to revisit marked oyster groups within the restoration site annually. A third option is comparing seeded and natural populations to understand differential survival.

Tray Design and Deployment

Trays should have open tops and should be anchored securely to withstand site conditions.

Key considerations include:

- **Wall height:** 4 in. (10 cm) for protected sites; up to 12 in. (30 cm) for higher-energy environments.
- **Anchoring:** Use rebar, screw anchors, or both. A rope between multiple trays helps divers locate replicates.
- **Surface marker:** Attach a float to an independent anchor so that a curious boater cannot drag trays away.
- **Access:** Secure and clearly mark trays for consistent retrieval and repeated sampling.

This approach allows divers to monitor the same cohort over time, providing robust data on survival, mortality sources, and potential differences among broodstock populations.

Reef Characteristics

Size and structure are essential parameters to document during construction and through long-term monitoring. These characteristics should be measured in terms of both horizontal extent (e.g., acres) and vertical structure (e.g., height or elevation). Depending on goals, shoreline-protection benefits associated with the project may also be important to track (e.g., adjacent shoreline profiles to determine any impact on shoreline erosion or sediment accretion).

A standard approach to measuring reef and bed elevation is to survey along fixed transects relative to a permanent benchmark. For example, on the Atlantic and Gulf coasts, reef elevations typically range from above mean higher high water (MHHW) down through the intertidal zone to about 1 m deep at low tide. Measurements can be collected using an optical level, following established monitoring guidelines, or through more advanced three-dimensional mapping with GPS-referenced, vessel-mounted sonar at high tide. Reef height, shoreline position, and total restored area can be quantified from these same transects or from broader GPS, sonar, or diver surveys (Baggett et al., 2015).

Additional guidance on monitoring can be found in *Restoration Guidelines for Shellfish Reefs* (Fitzsimons et al., 2019).

Conduct Monitoring

Programs can draw on multiple ecological monitoring approaches depending on their capacity, geographic scope, and partnerships. Established academic protocols provide structured, repeatable methods suitable for long-term monitoring. For example, in New York, SOAR partnered with Stony Brook University to use a tray-based method that enabled the recovery of nearly all the oysters set aside for evaluation. These standardized approaches are particularly valuable when managing multiple sites across a large geographic area, as they ensure consistency and comparability of results across the entire program.

Alternatively, programs may collaborate with state resource agencies that already conduct routine oyster population assessments. For example, the Virginia Marine Resources Commission integrates the monitoring of restoration sites into its annual stock assessment (known as the Virginia Oyster Stock Assessment and Replenishment Archive, or VOSARA), offering a cost-effective pathway to long-term evaluation. Where internal capacity is limited, whether in staffing, field expertise, or geographic coverage, contracting experienced academic or consulting partners can ensure high-quality, standardized ecological monitoring across all participating sites.



Collect Data

Monitoring data should be entered promptly, backed up securely, and stored in a system accessible to all relevant partners. A shared data platform improves communication, supports QA/QC, and allows for efficient review of site-specific trends in restoration performance. Maintain paper field sheets as backups, and regularly back up all digital files.

Program Tracking

Alongside ecological monitoring, programs should maintain a robust system for tracking participating oyster growers, both current and past. This system can also support the administration of contracts, insurance, billing, transportation logistics, and other operational needs tied to program participation.

Logistics

As monitoring progresses, opportunities will emerge to improve program efficiency and delivery. For example, if oysters must be transported over long distances, it may be more cost-effective to contract a commercial shipping company. Programs may also consider partnering with a grower cooperative or association; these groups can receive funds and manage product handling using experienced professionals, streamlining logistics and reducing administrative burden on the program.

Adapt the Program Based on Monitoring and Feedback

Set aside time after each monitoring cycle to evaluate results and incorporate lessons learned. Adaptive adjustments will almost always be necessary to meet the evolving needs of growers, partners, and restoration sites and to respond to market conditions and community perspectives. Continual refinement based on monitoring and stakeholder feedback is key to long-term program success and permanence.

TNC staff member in Washington measures oyster growth using calipers. © Debbie Ross-Preston

CHAPTER 4:

CONCLUSIONS AND FINAL THOUGHTS

A successful program that purchases native oyster aquaculture products for use in restoration must balance ecological effectiveness with meaningful benefits for the industry and community at large. Where recruitment is limited and natural population recovery is slow, relocating large adult oysters to restoration sites can accelerate reef development, increase reproductive biomass, and enhance ecosystem services. In other contexts, oyster aquaculture products, such as spat on shell, may offer an effective restoration approach and industry benefits. In all cases, ecological gains are strengthened by rigorous monitoring that distinguishes program-driven outcomes from background environmental variation.

Operational practicality is equally important. Programs must ensure reliable access to oysters of appropriate size, reproductive capacity (e.g., diploid vs. triploid), genetic suitability, and health status, while also confirming that growers are interested and able to meet program needs. Transportation logistics, distance to restoration sites, and handling requirements should be evaluated early, ideally through the same program-tracking and data-collection systems used for monitoring. Where oyster movement is substantial, efficiency may be improved through additional partnerships with commercial shippers or grower cooperatives that can manage handling and transportation professionally.

Program durability depends on setting clear goals and using standardized monitoring to show measurable ecological and socioeconomic results. Monitoring data can also support program expansion, complement public policy development, and integrate into broader coastal management frameworks and new or existing restoration markets. Tracking socioeconomic indicators—such as grower satisfaction, economic impacts, market opportunities, and industry participation—helps ensure programs remain aligned with industry needs and continue to deliver tangible benefits. Lastly, community engagement further strengthens program legitimacy. Incorporating community perspectives into program design, monitoring, and evaluation builds trust, supports transparency, and helps embed restoration within broader community priorities.

Ultimately, successful programs require an adaptive, evidence-based approach suited to the specific native oyster species purchased from the aquaculture industry for use in restoration. Monitoring results should be reviewed regularly to refine restoration design, adjust deployment strategies, improve logistics, and respond to changing environmental and market conditions. Expanding partnerships across the oyster supply chain—from hatcheries to farms to shell recycling networks—can further strengthen and help scale collaborative restoration efforts.

As demonstrated by programs such as SOAR, leveraging aquaculture in reef restoration supports a resilient oyster industry and can be a win-win for people and nature.

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APPENDIX: ADDITIONAL CASE STUDIES FROM THE SOAR PROGRAM

The Supporting Oyster Aquaculture and Restoration (SOAR) program was developed by The Nature Conservancy and The Pew Charitable Trusts from 2020 to 2026 to engage oyster farmers in restoration by purchasing surplus oysters and shells for deployment at restoration sites. Chapter 3 of this handbook features several case studies from the eight SOAR-focus states. This appendix offers more, along with key lessons learned.

Biosecurity (NH, NY and WA)

Biosecurity is a critical consideration across oyster restoration programs to prevent the spread of disease and protect genetic integrity. In New Hampshire, oyster transfers from Maine to Great Bay followed strict testing protocols, but unexplained mortality events in 2023–2024 prompted a precautionary pause and expanded regional monitoring efforts. These actions underscore the importance of adaptive biosecurity frameworks that can respond to emerging threats.

New York’s restoration strategy emphasized prohibiting oyster transfers between certain waterbodies to protect against the unintended transfer of transient organisms. Restoration sites were supplied only with locally sourced oysters, complemented by site-level sanitation measures such as washing, tumbling, or brine dips. These safeguards minimized the risk of introducing invasive species or pathogens.

In Washington, when broodstock is collected for hatchery production of Olympia oysters, the Washington Department of Fish and Wildlife (WDFW) requires the Puget Sound Restoration Fund conservation hatchery to conduct a disease test on 60 oysters collected at the broodstock location in late summer of each year, during peak disease occurrence. If the oysters are pronounced clear of pathogens of concern by a qualified lab, broodstock is collected at the approved location in winter and transferred to the hatchery for seed production. WDFW also requires annual disease tests of oysters produced in the hatchery to demonstrate hatchery health and allow for the transfer of restoration-grade oysters to restoration sites. To protect genetic diversity, WDFW requires that broodstock be sourced from the same basin intended for seed outplant. There is also a requirement to collect a minimum of 1,200 wild broodstock for each Olympia oyster production cycle. Transfer permits are needed for broodstock collection and for the return of broodstock to its source location.

Biosecurity measures are also in place for the use of shell (cultch) substrate in native oyster habitat enhancement projects. For restoration activities, shell must be inspected, approved, and permitted to transfer from land-based storage locations to tidelands. These requirements reflect the ecological sensitivity of native populations and the need for proactive collaboration with regulators and researchers to integrate biosecurity into restoration planning and implementation.

Key lessons for practitioners

- Integrate biosecurity planning at the earliest stages of project design.
- Source oysters locally whenever possible to protect genetic integrity.
- Maintain flexibility to pause or modify activities in response to emerging disease risks.
- Coordinate regionally with researchers and agencies to track and respond to mortality events.

Grower Engagement and Pricing Models (MD, MA, NH, NY)

Successful restoration efforts consistently relied on strong partnerships with oyster growers. In Maryland, close collaboration between conservation organizations, growers, and policymakers helped align ecological goals with economic realities. Grower input shaped program design, fostering trust and long-term engagement.

Pricing innovation was a key component. Maryland adopted a standardized bushel-based pricing model with tiered rates reflecting production methods, while Massachusetts worked through its aquaculture association to set per-oyster and volumetric prices that growers deemed fair. New York refined its approach by shifting from volume-based to per-piece pricing to ensure consistent oyster size and equitable participation.

Several programs also compensated growers for services rather than the product alone. Spat-on-shell grow-out programs in New Hampshire and New York paid farmers for husbandry and logistics, expanding restoration capacity while supporting farm operations. Across states, equitable compensation and early grower involvement strengthened restoration outcomes and industry support.

Key lessons for practitioners

- Engage growers early and treat them as partners, not just suppliers.
- Align pricing structures with existing industry practices to build trust.
- Be willing to revise pricing models based on feedback and observed outcomes.
- Consider compensating growers for services (e.g., grow-out, logistics) in addition to product.

Permitting and Policy Challenges (ME, CA, MA, WA)

Permitting emerged as a major barrier to restoration, particularly where regulatory frameworks were designed for commercial harvest rather than habitat recovery. In Maine, restoration relies on aquaculture permits, prompting longer-term efforts to develop restoration-specific regulatory pathways through policy research and agency partnerships.

California's experience highlighted how regulatory uncertainty can stall projects. When new permit requirements emerged mid-project, partners used the challenge to improve interagency coordination and clarify approval processes, laying the groundwork for future restoration efforts.

Massachusetts addressed permitting limitations by securing federal funding to identify and permit new sites and bolster state agency capacity. And in Washington, the state permitting process required more time to navigate than anticipated. Aquaculture and restoration partnerships in Washington had a considerable advantage, though: Restoration practitioners are allowed to outplant native oysters on farmed tidelands under existing farm permits if the grower has informally made those tidelands available for restoration and if the species is already listed on the farm's Aquatic Farm Registration. Across regions, sustained engagement with regulators proved critical to advancing restoration within existing legal frameworks.

Key lessons for practitioners

- Expect permitting to be a limiting factor and plan timelines accordingly.
- Use pilot projects to demonstrate restoration benefits and inform regulatory reform.
- Invest in relationships with regulatory agencies and legal experts.
- Where possible, support agency capacity-building to institutionalize restoration.

Restoration Deployment and Methods (NH, NY, WA)

Effective deployment strategies emphasized coordination, site preparation, and logistical efficiency. In New Hampshire and New York, growers delivered oysters to centralized locations where staff conducted quality checks before same-day deployment. Sites were pre-marked and mapped to facilitate long-term monitoring.

Innovative methods such as spat-on-shell cultivation expanded restoration capacity by introducing multiple oyster age classes. These approaches diversified supply and improved reef development potential. Washington explored shell recycling and alternative substrates to address material shortages while maintaining biosecurity safeguards.

Across states, successful deployment relied on meticulous planning, clear communication with growers, and adaptability to local environmental conditions. Standardized protocols ensured consistency while allowing flexibility for site-specific needs.

Key lessons for practitioners

- Coordinate closely with growers to streamline delivery and deployment logistics.
- Prepare and map restoration sites in advance to support monitoring and evaluation.
- Diversify restoration products (e.g., single oysters, spat on shell) to enhance resilience and opportunities for industry.
- Document all deployment activities to support adaptive management and reporting.

Adaptive Management and Monitoring (MA, NH, NY, MD)

Adaptive management was central to long-term success. In Massachusetts, heavy algal growth caused near-total oyster mortality at one site, leading partners to adjust restoration methods rather than abandon the effort. New Hampshire's response to unexplained oyster mortality included halting transfers and enhancing monitoring before resuming activities.

Programmatic adaptations also emerged from monitoring results. New York revised its pricing and purchasing model after identifying quality issues, while Maryland refined SOAR 2.0 based on grower feedback and market conditions. Monitoring tools such as trays, standardized surveys, and drone imagery supported data-driven decision-making.

Across regions, continuous learning through monitoring and stakeholder feedback allowed programs to evolve, improving ecological outcomes and operational resilience over time.

Key lessons for practitioners

- Design monitoring programs that directly inform management decisions.
- Use failures as learning opportunities rather than reasons to abandon sites.
- Regularly revisit assumptions about methods, pricing, and site selection.
- Share lessons learned across regions to accelerate collective progress.



Scaling Restoration through Aquaculture: Partnering with Oyster Growers to Rebuild Reefs

Learnings from the Supporting Oyster Aquaculture
and Restoration (SOAR) Program

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The oyster reef near Pine Neck Nature Sanctuary in Shinnecock Bay, NY. SOAR purchased and deployed over a quarter million single aquacultured oysters, and spat on shell grown by oyster farmers, at the site from 2024-2025 © Adam Starke

