Shellfish Aquaculture Ecosystem Services and Eelgrass Interactions

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1. Introduction

This report outlines the ecosystem services (ES) of alternative oyster aquaculture gear types. It examines the general ES provided by oyster aquaculture, followed by the specific provisioning, regulating, supporting and cultural services provided through cultured shellfish. The major focus of this report is to better understand the interactions between eelgrass and oyster aquaculture. Therefore, the final section of this chapter illuminates the ES of alternative gear types as well as the interactions between these gear types and eelgrass to better understand the co-generation of benefits and ecological functionality.

2. Ecosystem Services (ES) Overview

The ES provided by shellfish aquaculture are numerous, with goods from provisioning services (including meat) worth an estimated $23.9 billion, pearls, shell and poultry grit with a global potential worth of $5.2 billion, and global non-food bivalve aquaculture services estimated at $6.47 billion dollars annually [1]. However, this value is likely an underestimate given the many benefits and key services provided by bivalve aquaculture to people and ecosystems alike. Many recognize the benefits of bivalve aquaculture to be linked to food supply, yet there is growing appreciation for the large-scale ecosystem benefits provided by cultured bivalves. Some of these benefits include carbon sequestration, nutrient transfer[1], water filtration, shoreline defense, and many more.

Ecosystem services can be defined as the many direct and indirect impacts of ecosystems to the wellbeing of people, other organisms, and contributions to habitats. Ecosystem services are often divided into four distinct categories: provisioning services, regulating services, supporting services and cultural services (Figure 1).

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[1] Such as the removal of nitrogen and phosphorus from the water.

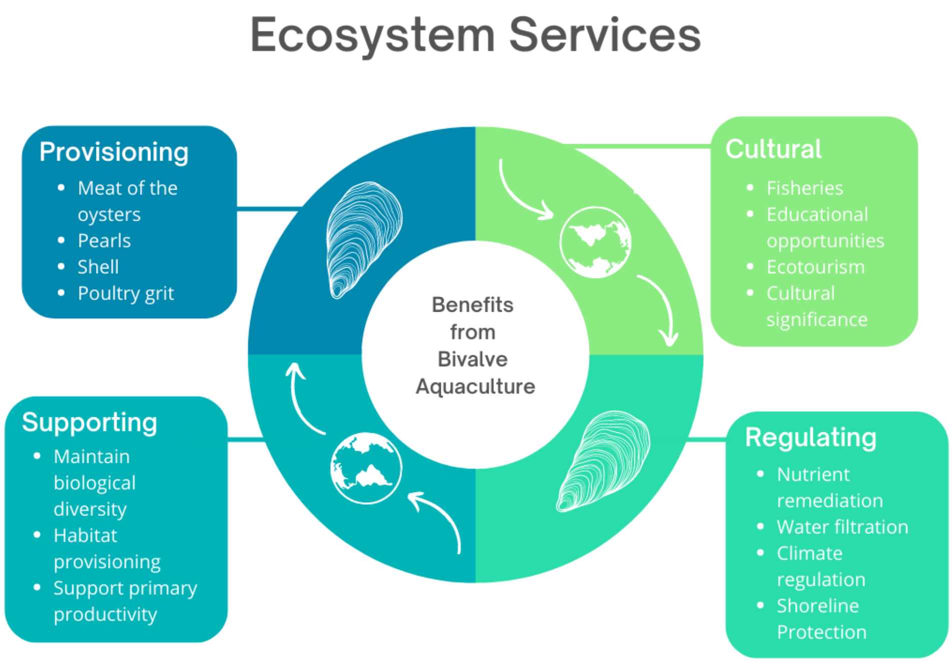

Figure 1: Ecosystem Services of Bivalve Aquaculture

2.1 Provisioning Services

Provisioning services are the goods provided by the ecosystem itself. In the case of oyster aquaculture, provisioning services include the meat of the oysters, pearls, shell and poultry grit. The value of bivalve aquaculture is typically regarded in the meat provided, however, discarded shells from the oyster meat are vessels for long-term carbon storage, a regulating service [1]. On a global scale, oyster meat was estimated to be worth $23.9 billion, while oyster shells had a potential worth of $5.2 billion [1].

2.2 Regulating Services

Regulating services are the benefits provided by nature while acting as regulators in an environment. For oyster aquaculture, some of the notable regulating services include nutrient remediation, water filtration, climate regulation and shoreline protection.

Cultured bivalves not only facilitate nutrient extraction through harvesting, but they also have the potential to mitigate the effects of excessive nutrient loading through their filtration of the water column. Bivalve aquaculture has the ability to remove 49,000 tonnes of nitrogen and 6,000 tons of phosphorus from the water column through harvest. This has been estimated to be worth $1.2 billion [1]. Overall, cultured bivalves, including oysters, have increased water clarity, light penetration and sediment nutrient enrichment which has enhanced overall productivity of seagrass[2] in shallow coastal

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[2] In this report, both seagrass and eelgrass are mentioned. Seagrass is a term that broadly encompasses all the true, flowering plants that live completely submerged underwater. There are 60 species of seagrass found around the globe, however, one of the main seagrasses of focus in this report is the native eelgrass, *Zostera marina,* due to

ecosystems [2]. Bivalve filtration also supports regulating services through modifying other biogeochemical cycles such as carbon sequestration, mediation of waste, and the accumulation of pathogens [1].

Cultured bivalves, such as oysters, are integral ecosystem engineers in intertidal and coastal environments. Their reef-building abilities coupled with the complex structures they form influence hydrodynamics as well as nearby habitats and species [3]. As the impacts of climate change worsen, reef-building bivalves are being increasingly utilized as an alternative to artificial shoreline hardening as they are able to dampen the impacts of waves, provide erosion control, and protect shorelines [3].

2.3 Supporting Services

Supporting services go beyond regulating services and encompass the maintenance of biological diversity as well as the provisioning of habitats. Farmed oysters and other bivalves provide habitat through the aquaculture gear needed for cultivation [4]. Oyster gear creates several habitat niches including hard and soft substrata, areas for refuge, foraging and nursery habitat. This attracts species that occupy various trophic levels in the water column. In northern New England, oyster farms even provided additional seaweed habitat that attracted fish and other invertebrates [5]. Due to their ability to attract other species as well as provide structured habitat, reef-building bivalves can increase finfish and other invertebrates, providing cultural and economic benefits to commercial, and recreational fisheries. Additionally, cultured bivalves provide food and habitat to predators. Therefore, bivalve aquaculture has the ability to enhance certain species while subduing others. This leads to alterations in food web relationships as well as changes in community composition and structure [6].

Supporting services also often includes nutrient cycling, which was also mentioned in the regulating services section. The nutrient cycling provided by oyster and bivalve aquaculture assists with control of pests and pathogens and climate regulation (regulating services), however, it also impacts primary production of phytoplankton (supporting service). In filtering the water, bivalves are able to reduce phytoplankton concentrations, serving as direct ecosystem health indicators [3]. Through this process, oysters and other bivalves can reduce water turbidity, increase water clarity, lower the risk of hypoxic conditions as well as improve the conditions needed for submerged aquatic vegetation to grow [6]. In limiting phytoplankton concentrations and blooms, oysters have the ability to increase phytoplankton primary production, exerting bottom-up nutrient control [2]. There is, however, a limit to which this feedback can occur. Too many cultured bivalves will reach a grazing capacity on phytoplankton that will begin to slow rates of primary production [2].

2.4 Cultural Services

Cultural services acknowledge the educational, recreational and spiritual aspects provided by ecosystems. Currently, there is not much evidence on the yearly cultural services of bivalve aquaculture,

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its widespread distribution in Washington waters. Given that eelgrass is a species of seagrass, seagrass and eelgrass are used interchangeably in this report.

however, the cultural services provided are broad and wide-ranging despite not being easily quantifiable [1]. Bivalves contribute to recreational fisheries, historic artisanal fisheries, educational opportunities such as tidepooling, ecotourism, seafood festivals, as well as provide culturally significant and spiritual benefits [1]. The cultivation and harvesting of shellfish through aquaculture has provided important job opportunities that support economic growth and community development in rural areas along the coast [3]. This has led to economic opportunities in areas that may struggle with financial hardships.

Along with bivalve aquaculture producing jobs for communities, it is a culturally significant staple in many Indigenous communities. The practice of sea gardening, or clam gardening, allows for communities to come together, grow bivalves and other marine food staples, share stories and language, all while growing culturally significant foods that are a staple to many coastal Indigenous communities.[7]

3. The Interactions between Oyster Aquaculture Gear & Eelgrass

The goal of this report is to review alternative oyster gear types to better understand the interactions between seagrass and aquaculture. This section will review the various gear types utilized for cultured oysters, as well as the ES associated with each gear type as it relates to marine vegetation.

Cultured bivalves have positive, neutral and negative effects on seagrass, such as eelgrass. Both on and off bottom cultures allow for increased bivalve filtration which can improve water quality and reduce epiphytes which assists in the growth of seagrass [8]. Additionally, biodeposits from shellfish provide nutrients to the seafloor, assisting in seagrass and vegetated seabed growth. The increased nutrient concentration in the sediments, coupled with oyster aquaculture reducing water turbidity and increasing light availability can assist with seagrass growth [8]. Furthermore, aquaculture gear introduces complex habitat as well as increases vertical structure compared to natural oyster reefs or seagrass beds. This enhances fish biomass at aquaculture sites compared to seagrass beds, increases invertebrate species richness and promotes increased diversity and abundance of species [9]. Lastly, aquaculture gear allows farms to approach stable algal and macrofaunal communities, however, aquaculture farms will likely not develop towards mature communities given the disturbances within this cultivated system [9].

While cultured bivalves provide notable benefits to seagrass beds, there are also some negative interactions often recorded between these two systems. Cultured bivalves cause shading and increased sediment buildup at farmed sites, impacting seagrass in that immediate area [8]. Additionally, the husbandry of farmed shellfish leads to physical damage of seagrass through the placement of gear and some harvesting methods [10]. Many of the negative effects of cultivated bivalves on seagrass occur on the farm directly, and rapidly diminish as you increase distance from the farm [8].

4. Ecosystem Services of Alternative Gear Types

Seagrass vegetation is an incredibly important component of marine ecosystems, especially in the presence of climate change. These vegetated habitats not only sequester and store blue carbon, mitigating greenhouse gas emissions, but they also provide a buffer against ocean acidification and support water quality improvement [11]. To better protect seagrasses, such as eelgrass, in the management of oyster aquaculture, understanding the trends of eelgrass responses to cultured bivalves is a crucial step [12]. This section details the responses of seagrasses to both on and off bottom aquaculture, illustrating some of the benefits and drawbacks to various grow out methods.

4.1 On Bottom Culture

For the purposes of this report, on bottom culture refers to laying shellfish on the sediment directly through cages, trays or spat on shell, as some on bottom cultivation does not require gear. Typically, the growing period for on bottom culture is between 5-8 years [13]. Many regulators have suggested that there is potentially a more direct impact on eelgrass with on bottom methods [14]. While the impacts on the eelgrass from cultured bivalves vary by region, studies have supported a space-competition hypothesis for on bottom culture [12]. This hypothesis suggests that on bottom grow out methods compete with eelgrass for space, which could lead to a decrease in eelgrass density. One study examined these impacts, finding that on bottom culture corresponded to significant increases in eelgrass growth and reproduction, while density and biomass in eelgrass decreased [12]. In one study, eelgrass growth increased by 25%, and there was a 39% increase in eelgrass reproduction with on bottom grow out gear [12]. However, there was a 51% decrease in eelgrass biomass and a 49% decrease in density [12]. This decrease in density supports the space competition hypothesis, despite the increased growth and reproduction from on bottom cultures. The increase in growth and reproduction may be due to the space competition hypothesis as well. When bivalves and eelgrass are competing solely for space, but not other resources, the decrease in density can often result in the competitive release of eelgrass shoots, consequently enhancing eelgrass growth [12].

4.2 Off Bottom Culture

Off bottom culture, for the purposes of this report, includes any gear that is off the sediment and in the water column or on the water's surface. Some of the popular off bottom gear types that emerged in the literature are longline, rack and bag, and floating cages. In the Pacific Northwest, many growers have shifted some of their growing techniques to off bottom culture due to increased demand for half shell oysters, as well as the realized effect of less predation and decreased impacts of pests [14].

There are many benefits associated with the multiple growing out methods of off bottom cultures. Using off bottom methods allows oysters to be grown in more favorable environments, as well as environments where they might otherwise not be able to survive (i.e. poor substrate or predation) [15]. Much of the off bottom gear grows bivalves near the water's surface, allowing the oysters to grow in warmer environments with more phytoplankton food sources, supporting more growth in a shorter cycle. Therefore, the growth period for off bottom is a bit shorter than on bottom, taking 3-4 years [13]. Additionally, most off bottom grow-out methods protect stocks from benthic predators better than on bottom gear [13]. The equipment used for off bottom culture also helps control fouling from organisms like mudworms and barnacles, while simultaneously providing habitat structure to other organisms [15, 4]. Given that there are multiple methods of growing off bottom oysters, the following sections will address each of the primary off bottom gear types from the literature, and address their corresponding ecosystem benefits and consequences.

4.2.1 Rack and Bag

Rack and bag is a method of off bottom aquaculture that improves upon intertidal culture methods. This system uses steel racks that are anchored into the sea floor, with mesh bags laid on the racks filled with oysters. As the tide comes in, the oysters are surrounded by water, when the tide recedes, the bags and oysters are out of the water. This method minimizes biofouling given that the exposure of oysters during a low tide will cause fouling organisms to dessicate [16]. While this method helps control populations of unwanted organisms, rack and bag also supports added populations of marine macrofauna that provide significant ecological and economic benefits to the ecosystem when compared to oyster reefs, such as recreational and commercial fish and invertebrate species [17, 4]. This is due to the habitat complexity created by the gear, which allows for more biodiversity than a non-vegetated bottom [17]. While some studies have suggested that rack and bag culture contributes to the near disappearance of seagrasses due to the disturbance caused by gear placement and increased sedimentation, other studies have demonstrated there is no significant decline in seagrass density or leaf length in the presence of this grow out method [18, 8]. Despite these impacts, research has frequently found one strategy for reducing the impacts of rack and bag on eelgrass populations is to increase the spacing of the gear [8].

4.2.2 Longline

Longline aquaculture is another method for cultivating oysters using an off bottom approach. This type of aquaculture includes longlines without floats or containers and clusters of spat on shell. It also includes longlines with floats or cages attached. Longline technologies allow for nursery rearing as well as the final growth stages. They are beneficial in high exposure areas and are used to grow a variety of organisms. Farmers benefit from using this system as it is easier to harvest on a longline than other systems [19]. Additionally, this system, like some other off bottom systems, provide greater protection from predators when compared to on bottom systems [19]. However, longlines without floats can impact the biophysical environment through modifying the flow regime, and increasing oyster deposits [20].

The literature suggests the interactions between longline aquaculture and eelgrass varies depending on the site. One study found eelgrass overlapping in areas with longline aquaculture in similar densities to nearby, uncultivated areas [21]. However, one year of that study period was an exception, and indicated smaller eelgrass with lower production rates in the presence of longline aquaculture [21]. A second study examined the impact of longline gear on light availability for seagrass, finding that longline baskets reduced the amount of light available to seagrass by 52.8% - 90.8% [18]. This finding correlated to a 4-fold decline in seagrass shoot density in the presence of longline baskets [18]. While longline culture has been regulated as the least impactful to seagrasses, many studies have illustrated the plant biomass and production has still declined within longline sites [14]. One way to reduce the harmful impacts of longline aquaculture on seagrass is to increase gear spacing [8]. Despite some of the impacts of longline culture on seagrasses, there has also been paradoxical evidence that demonstrated that reductions in the abundance and density of eelgrass could actually result in increased eelgrass growth and reproduction [8].

4.2.3 Floating Cages

Floating cages are a third example of off bottom aquaculture. Floating cages have oysters grown in mesh bags that sit inside the cages, buoyed by twin floats. The cages are strung together by lines anchored at both ends, and the floats are able to be adjusted in the water column due to their end caps. Like other off bottom technologies, floating cages allow for greater protection from predators, especially compared to on bottom methods like spat on shell [19]. Additionally, this method allows for easier harvesting access for farmers, similar to some longline techniques and rack and bag [19]. When floating cages are on the water's surface, they are more susceptible to wave action, negatively impacting filtration rates for oysters [19]. This exposure to wave action potentially reduces the oyster's ability to fight off Vibrio bacteria [19].

One study explored the habitat value of floating cages and compared it to that of eelgrass beds and non-vegetated bottoms. This research indicated that floating cages have similar diversity and abundance of macrofauna in oyster cages when compared to seagrass beds [17]. While there were not any specific studies highlighting the impacts of floating cages on eelgrass, there were mixed results regarding floating bag aquaculture. Floating bags are also suspended in the water column, and connected to two floats. Some studies have concluded that the light limitation associated with floating bag aquaculture significantly decreases the total percentage of eelgrass cover, density, as well as reproduction, however, other research has demonstrated that floating bags were not linked to declines in seagrass density or growth [12,18].

5. Report Overview

This report expands on the ecosystem services provided by oyster aquaculture gear and how that additionally impacts seagrass environments. The report begins with identifying the ecosystem services provided by oyster aquaculture, defining the four main categories of ecosystem services and the specific services provided by oyster aquaculture in each of those categories. The report then expands on the specific grow out methods, on bottom and off bottom, analyzing the impacts of each method on eelgrass growth. While on and off bottom cultures both have their benefits and drawbacks on eelgrass populations, the literature viewed off bottom grow out methods to have a lesser impact on eelgrass environments, with longline aquaculture being viewed by regulators as the least impactful to shellfish.

References:

[1] van der Schatte Olivier, A., Jones, L., Le Vay, L., Christie, M., Wilson, J. & Malham S. (2018). A global review of the ecosystem services provided by bivalve aquaculture. Reviews in Aquaculture Volume12, Issue 1, February 2020, Pages 3-25. https://doi.org/10.1111/raq.12301

[2] Filgueira, R., Comeau, L., Guyondet, T., McKindsey, C. & Byron, C. (2015). Modeling Carrying Capacity of Bivalve Aquaculture: A Review of Definitions and Methods. Encyclopedia of Sustainability Science and Technology pp 1–33. DOI:10.1007/978-1-4939-2493-6_945-1

[3] Smaal, A. C., Ferreira, J. G., Grant, J., Petersen, J. K., & Strand, Ø. (2019). Goods and Services of Marine Bivalves. Springer.

[4] Bastien-Daigle, S., Hardy, M. & Robichaud G. (2007). Habitat Management Qualitative Risk Assessment: Water Column Oyster Aquaculture in New Brunswick. Canada Department of Oceans and Fisheries.

[5] Glenn, M., Mathieson, A., Grizzle, R. & Burdick, D. (2020). Seaweed communities in four subtidal habitats within the Great Bay estuary, New Hampshire: Oyster farm gear, oyster reef, eelgrass bed, and mudflat. Journal of Experimental Marine Biology and Ecology Volume 524. https://doi.org/10.1016/j.jembe.2019.151307

[6] Reum, J., McDonald, P.S., Ferriss, B., Farrell, D., Harvey, C. & Levin, P. (2015). Qualitative network models in support of ecosystem approaches to bivalve aquaculture. ICES Journal of Marine Science, Volume 72, Issue 8, Pages 2278–2288. https://doi.org/10.1093/icesjms/fsv119

[7] Pacific Sea Garden Collective. (2022). Sea Gardens Across the Pacific: Reawakening Ancestral Mariculture Innovations.

[8] Howarth, L.M., Lewis-McCrea, L.M., Kellogg, L.M., Apostolaki, E.T. & Reid, G.K. (2022). Aquaculture and eelgrass Zostera marina interactions in temperate ecosystems. Aquaculture Environment Interactions, 14(15), 34. DOI: 10.3354/aei00426

[9] Glenn, M. (2016). A comparison of macrofaunal and algal communities in oyster aquaculture gear, an eelgrass bed, oyster reef, and a mudflat in Great Bay, New Hampshire. University of New Hampshire Master's Theses and Capstones.

[10] Dumbauld, B., Ruesink, J. & Rumrill, S. (2009). The ecological role of bivalve shellfish aquaculture in the estuarine environment: A review with application to oyster and clam culture in West Coast (USA) estuaries. Aquaculture 290(3-4):196-223. DOI:10.1016/j.aquaculture.2009.02.033

[11] Hori, M., Hamaguchi, M., Sato, M., Tremblay, R., Correia-Martins, A., Derolez, V., Richard, M. & Lagarde, F. (2021). Oyster aquaculture using seagrass beds as a climate change countermeasure.

[12] Ferriss, B. E., Conway-Cranos, L. L., Sanderson, B. L., & Hoberecht, L. (2019). Bivalve aquaculture and eelgrass: A global meta-analysis. Aquaculture Volume 498, Pages 254-262. https://doi.org/10.1016/j.aquaculture.2018.08.046

[13] Comeau, L. A. (2013). Suspended versus bottom oyster culture in eastern Canada: Comparing stocking densities and clearance rates. Aquaculture Volumes 410–411, Pages 57-65. https://doi.org/10.1016/j.aquaculture.2013.06.017

[14] Clarke, L. (2017). Functional Comparison of Longline Oyster Aquaculture and Eelgrass (Zostera marina L.) Habitats Among Pacific Northwest Estuaries, USA. Graduate Thesis Oregon State University.

[15] Walton, W., Davis, J. & Supan, J. (2013). Off-Bottom Culture of Oysters in the Gulf of Mexico. Southern Regional Aquaculture Center.

[16] University of Maryland Extension. (2019). Oyster Aquaculture Production Systems.

[17] Erbland, P. J., & Ozbay, G. (2008). A Comparison of the Macrofaunal Communities Inhabiting a Crassostrea virginica Oyster Reef and Oyster Aquaculture Gear in Indian River Bay, Delaware. Journal of Shellfish Research, 27(4):757-768. https://doi.org/10.2983/0730-8000(2008)27[757:ACOTMC]2.0.CO;2

[18] Ferretto, G., Vergés, A., Poore, A.G.B., Gribben, P.E. & Glasby, T.M. (2022). Floating bags have the potential to minimise oyster farming impacts on Posidonia australis seagrass meadows. Aquaculture 560:738594. DOI:10.1016/j.aquaculture.2022.738594

[19] Pruente, V. L., Walton, W. C., & Jones, J. L. (2021). Effect of Gear Type on Vibrio spp. Levels in Farm-Raised Oysters (Crassostrea virginica) after Routine Handling and Resubmersion. Journal of Food Protection 84(3):381-388. DOI:10.4315/JFP-20-318

[20] Coe, Hannah. (2019). Effects of longline oyster aquaculture on benthic invertebrate communities in Humboldt Bay, California. Graduate Thesis Humboldt State University.

[21] Tallis, H., Ruesink, J., Dumbauld, B., Hacker, S. & Wisehart, L. (2006). Eelgrass responds to oysters and grow-out methods in an aquaculture setting.

Appendix A: Summary of Oyster Gear

Water Column Positioning	Gear Type	Benefits and Limitations of Gear Types
On Bottom	General Overview	● Increases in eelgrass growth and reproduction [1] ● Decreases in eelgrass density and biomass [1] ● Growing period is 5-8 years on substrate [2]
Off Bottom	General overview (applies to most off bottom gear types)	● Protects stocks from benthic predators [2] ● Facilitates product grading and harvesting methods [2] ● The water near the surface is often warmer and provides an environment with more fluxes in food, leading to enhanced growth and a shorter production cycle [2] ● Growing period is 3-4 years [2] ● Can provide protection from predators based on gear type [3] ● Eliminates sediment burial [3] ● Allows oysters to be cultured in environments where they otherwise might not survive (i.e. predation, poor substrate) [3] ● Utilizes phytoplankton availability to improve growth [3] ● Control fouling of organisms like barnacles, mudworms, etc [3] ● Provides community and habitat to other organisms [4]
Off Bottom	Rack and bag	● Minimizes biofouling: the bags are out of the water during low tide so many organisms that foul will desiccate and die [5] ● Supports added populations of ecologically and economically significant macrofauna when compared to oyster reefs [6] ● Beneficial addition to estuaries and other natural, communities as it supports habitat complexity and greater biodiversity than a non vegetated bottom [6] ○ This supports recreational and commercial fish and invertebrate species in early life stages [4] ● Previous studies have indicated rack and bag aquaculture can cause the near disappearance of seagrasses due to the physical disturbance when placing the gear as well as increased sedimentation [7] ● Other studies have demonstrated no significant declines in seagrass density or leaf length when rack and bag culture is present [8]
Off Bottom	Longline	● Greater protection from predators compared to on bottom [9] ● Easy access for farmers when harvesting [9] ● Can impact physical environment and benthic community through altered flow regime, oyster biodeposits, and active suspension feeding [10]

		● Eelgrass: ○ One study found eelgrass in longline areas with similar densities to eelgrass in nearby uncultivated areas [11] ■ 2004 was an exception, smaller eelgrass and lower production rates ○ Spaced out gear allowed for reduced impacts on seagrass [7] ○ Paradoxical trends could occur where reductions in eelgrass cover and density allow for increased growth and reproduction [7] ○ Longline baskets reduced light availability for seagrass by 52.8% - 90.8% [8] ○ Declines in seagrass shoot density were 4-fold with longline baskets [8]
Off Bottom	Floating cages	● Greater protection from predators compared to on bottom [9] ● Easy access for farmers when harvesting [9] ● Susceptible to wave action, negatively impacting filtration rates for oysters [9] ● Exposure to wave action could reduce oyster's ability to purge Vibrio spp. Bacteria [9] ● Birds densely aggregate on floating cages, could lead to water contamination by fecal coliforms [12]

References:

[1] Ferriss, B. E., Conway-Cranos, L. L., Sanderson, B. L., & Hoberecht, L. (2019). Bivalve aquaculture and eelgrass: A global meta-analysis. Aquaculture Volume 498, Pages 254-262. https://doi.org/10.1016/j.aquaculture.2018.08.046

[2] Comeau, L. A. (2013). Suspended versus bottom oyster culture in eastern Canada: Comparing stocking densities and clearance rates. Aquaculture Volumes 410–411, Pages 57-65. https://doi.org/10.1016/j.aquaculture.2013.06.017

[3] Walton, W., Davis, J. & Supan, J. (2013). Off-Bottom Culture of Oysters in the Gulf of Mexico. Southern Regional Aquaculture Center.

[4] Bastien-Daigle, S., Hardy, M. & Robichaud G. (2007). Habitat Management Qualitative Risk Assessment: Water Column Oyster Aquaculture in New Brunswick. Canada Department of Oceans and Fisheries.

[5] University of Maryland Extension. (2019). Oyster Aquaculture Production Systems.

[6] Erbland, P. J., & Ozbay, G. (2008). A Comparison of the Macrofaunal Communities Inhabiting a Crassostrea virginica Oyster Reef and Oyster Aquaculture Gear in Indian River Bay, Delaware. Journal of Shellfish Research, 27(4):757-768. https://doi.org/10.2983/0730-8000(2008)27[757:ACOTMC]2.0.CO;2

[7] Howarth, L.M., Lewis-McCrea, L.M., Kellogg, L.M., Apostolaki, E.T. & Reid, G.K. (2022). Aquaculture and eelgrass Zostera marina interactions in temperate ecosystems. Aquaculture Environment Interactions, 14(15), 34. DOI: 10.3354/aei00426

[8] Ferretto, G., Vergés, A., Poore, A.G.B., Gribben, P.E. & Glasby, T.M. (2022). Floating bags have the potential to minimise oyster farming impacts on Posidonia australis seagrass meadows. Aquaculture 560:738594. DOI:10.1016/j.aquaculture.2022.738594

[9] Pruente, V. L., Walton, W. C., & Jones, J. L. (2021). Effect of Gear Type on Vibrio spp. Levels in Farm-Raised Oysters (Crassostrea virginica) after Routine Handling and Resubmersion. Journal of Food Protection 84(3):381-388. DOI:10.4315/JFP-20-318

[10] Coe, Hannah. (2019). Effects of longline oyster aquaculture on benthic invertebrate communities in Humboldt Bay, California. Graduate Thesis Humboldt State University.

[11] Tallis, H., Ruesink, J., Dumbauld, B., Hacker, S. & Wisehart, L. (2006). Eelgrass responds to oysters and grow-out methods in an aquaculture setting.

[12] L.A. Comeau, P. St-Onge, F. Pernet, L. Lanteigne. (2009) Deterring coastal birds from roosting on oyster culture gear in eastern New Brunswick, Canada. Aquacultural Engineering 40(2). https://doi.org/10.1016/j.aquaeng.2008.11.003.