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OPINION PIECE

Ecolabels can improve public perception and farm profits for shellfish aquaculture

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ABSTRACT: Ecolabels are increasingly being used to notify consumers that the labeled product imposes minimal harm to the environment or other natural resources. A growing number of studies have signaled that consumers respond to these labels, which can promote environmentally friendly production of consumable goods and incentivize growers to produce sustainably sourced goods. Shellfish are noticeably absent among these labeled products, but they are arguably the most sustainable source of animal protein. Additionally, while in the water, oysters and other shellfish provide numerous ecosystem services that improve environmental quality. We argue that shellfish aquaculture is uniquely positioned to take advantage of ecolabeling to improve public perception and steer consumers towards a highly sustainable source of animal protein. However, we also argue more research is needed to better understand how ecosystem services vary among different production modes of oyster aquaculture to ensure products are correctly labeled and inspire consumer confidence.

KEY WORDS: Ecolabel · Ecosystem services · Oyster · Shellfish · Sustainability

1. INTRODUCTION

Aquaculture has been the dominant source of aquatic animal protein since 2013, due to the plateauing of wild capture fisheries in the early 2000s. However, a recent meta-analysis has revealed that public opinion of aquaculture is not always favorable, in part due to a perceived lack of ecological sustainability during production (Froehlich et al. 2017). This negative public perception is not without cause, as it is true that some forms of aquaculture consume precious resources (e.g. wild fisheries) (FAO 2020) while producing waste to the surrounding environment (Dauda et al. 2019). It is also difficult for the general public to appreciate how environmental impacts of aquaculture vary among countries, cultivated species, or husbandry practices (Mazur & Curtis 2006). As a result, environmentally friendly sectors of the aquaculture industries may be incentivized to distinguish themselves from those that are less sustainable to improve public perception, branding, and sales.

Shellfish aquaculture is arguably one of the most ecologically sustainable sources of animal protein (Shumway et al. 2003, Ray et al. 2019). Highlighting the ecological benefits of shellfish farming may prevent damage to its reputation and actually help the

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expansion of its industry (D'Anna & Murray 2015), which is steadily growing in the Chesapeake Bay and in other locations along the US coastline (NOAA 2015). We suggest that this industry is a unique candidate for ecolabeling — a voluntary certification program that identifies environmentally preferable products — and should further explore its opportunities. Ecolabels within the shellfish aquaculture industry are largely absent, despite it being recognized as having low impact on the environment. For example, Monterey Bay Aquarium's Seafood Watch program gives aquacultured oysters a 'green light', but their guides are not widely distributed (Roheim 2009). Therefore, consumers may be unaware that unlabeled, cultured oysters meet Seafood Watch's definition for sustainability. Additionally, Seafood Watch and other labeling programs may only note the minimal harm associated with oyster production while failing to acknowledge the ecological benefits of shellfish farming, which we argue are important to highlight for the benefit of growers and to help usher in a more sustainable economy.

The goals of this Opinion Piece were to educate readers on the value of ecolabels, to highlight the numerous ecosystem services (ESS) that accompany shellfish production that could be included in a labeling scheme, and to encourage discussion about ecolabels within the shellfish aquaculture research community. The certification process of an ecolabel is not easy — nor should it be, since it demands a full accounting of all practices. Therefore, it is important to acknowledge the potential adverse impacts of shellfish production. We also intended to identify knowledge gaps on how, where, and under what conditions ESS associated with bivalves are altered or diminished when being cultivated.

2. ECOLABELS

Ecolabels are market-based mechanisms which advance the sustainable production and consumption of natural resources (Washington & Ababouch 2011, Gopal & Boopendranath 2013). As a standard, ecolabels provide visual seals of approval for products, signifying fewer negative or unsustainable impacts to the environment compared to similar products (think dolphin-safe tuna). Many ecolabels are applied to products that have undergone a certification process affirming their compliance with sustainability criteria established by an accredited certification body (Ward & Phillips 2008, Gopal & Boopendranath 2013). Ecolabels aim to positively influence consumer decisions and the policies of distributors, as well as to reward producers for sustainable practices (Gopal & Boopendranath 2013).

Ecolabeling can also serve to bridge the information gap between consumers and producers by establishing communication and trust (Nelson 1970). Importantly, environmentally conscience consumers are more likely to select oysters and other seafood products that are sustainably sourced if they can be identified; however, supply chains are fragmented (with thousands of small producers and traders), and labels have been suggested as a way to help promote consumer assurance (Santeramo et al. 2017). The perceived high quality of ecolabeled items satisfies a niche market by significantly increasing the probability of a consumer choosing an ecolabeled item (McCluskey & Loureiro 2003). Importantly, consumers may also be willing to pay additional premiums and higher prices for products that accompany more expensive sustainable production (Jaffry et al. 2004, Zhou et al. 2016). This willingness to pay premiums may also be extended to products that confer ESS (Li et al. 2018). Therefore, enhancing marketability of aquaculture products through ecolabeling not only adds value to existing products but may also provide a financial incentive to stimulate oyster aquaculture operations and increase growers' net revenues (Bosch et al. 2008).

There are several factors that likely prevent oyster farmers from participating in certification programs. First, consumers view shellfish as being environmentally benign and there is relatively low market pressure for shellfish growers to label their products. Conversely, salmon and shrimp producers have been the targets of critical environmental and consumer campaigns, forcing producers to adopt environmentally preferable practices and enroll in certification programs (Hargreaves 2011). Third, some certification requirements may be daunting to satisfy. For example, Global Aquaculture Alliance's Best Aquaculture Practices (2016) and Whole Foods Market's (2015) quality standards for farmed bivalve molluscs both require standards to be met on a variety of production processes ranging from animal transport to predator controls to drug and synthetic chemical use. Additionally, these standards also may require a dedicated person to track production standards and ensure certification compliance but also increasing labor costs. Fourth, and perhaps most notably, the lack of incentives for participation in ecolabeling programs. Program participation costs land solely on the producers and may seem prohibitively expensive for small farms. Although producers can expect a

5–10% premium for their labeled products (Wessells et al. 2001), the prime beneficiaries of programs are the high-volume large transnational grocery chains (e.g. Whole Foods) that seek out certified sources of seafood (Hargreaves 2011).

Consumer demand for ecolabeled seafood is growing, and enabling shellfish growers to participate in certification programs may require new or special efforts to surmount barriers (Hargreaves 2011). For example, creation of cooperatives among farms that share the same water and farming practices could conceivably split certification costs. Alternatively, if ESS can be monetized, they could defray program participation costs. Indeed, cultured shellfish in Maryland are now being used in trading nitrogen credits, providing an additional source of revenue for growers (Miller 2020).

Seafood ecolabeling schemes can be classified into 3 tiers: single attribute labels, resource-focused multi-attribute labels, and holistic multi-attribute type labels (Thrane et al. 2009). These classifications are based on one or more of the characteristics used for certification, such as direct and indirect impacts on target and non-target species, adverse impacts on the surrounding ecosystems, industry effects on the external environment (i.e. emissions), and any impacts incurred later in the product life cycle. Some worldwide ecolabel programs that include oyster aquaculture products are Friend of the Sea (FOS), Global Aquaculture Alliance (GAA)/Aquaculture Certification Council (ACC)/Best Aquaculture Practices (BAP), and Aquaculture Stewardship Council (ASC). Their certification standards regulate the culture methods and industry production systems of shellfish operations.

Some certification programs have failed to recognize the ESS of oysters and other cultured shellfish. Although marked as a 'best choice' or 'good alternative' by Seafood Watch ('oyster recommendations'; https://www.seafoodwatch.org/recommendation/oysters/green-oysters-eastern-oyster-united-states-delaware-northwest-atlantic-ocean-towed-dredges?species=78w) and recommended as a 'sustainable seafood option' by Ocean Wise (Ocean Wise 2020), the ESS provided by oysters, and by extension the aquaculture industry, remains largely unacknowledged in these ecolabeling schemes. Furthermore, other popular, multi-attribute ecolabel programs (e.g. BAP and ASC), which include broad certification criteria for the environment, food safety, and social responsibility, fail to capture ESS of oyster aquaculture (e.g. biofiltration, habitat creation, etc.) as part of their sustainability indicators, overlooking the inherent attributes of oysters that enhance environmental quality (Kuminoff et al. 2008), which may be of great interest to consumers.

3. ESS OF OYSTERS AND SHELLFISH AQUACULTURE

The ESS of oysters have been explored for decades, with most studies focused on wild or restored oyster reefs. It is often presumed that these services also apply to farmed oyster production, but this has not been extensively examined. As the ESS of oysters are widely acknowledged, we wish to briefly highlight the ESS that are most likely to be retained by oysters set on cultch and grown in benthic habitats (i.e. on-bottom culture). Additionally, we focus on services we believe to be readily accessible by consumers as part of an ecolabel.

Arguably the most well recognized services provided by oysters are their abilities to improve water quality while having minimal environmental impact. Top-down control of microphytoplankton by oysters may improve light penetration that promotes benthic microalgae and macroalgae growth and production, which provides critical habitat and oxygenates the water column (Newell et al. 2002). Importantly, as filter feeders, oysters rely on natural sources of algae for food and can aid in reducing nutrients in eutrophic waters (Kellogg et al. 2013, 2014). The fact that shellfish aquaculture may be a net sink for nitrogen and nutrients stands in stark contrast to finfish aquaculture, which still relies heavily on other wild fisheries to fuel production (Tacon & Metian 2015) and is frequently a source for local water pollution (Dauda et al. 2019). And while shellfish production may be a source for some greenhouse gas production, their production rates are negligible (<0.05%) compared to terrestrial farming (Ray et al. 2019).

Other notable ESS of on-bottom oyster aquaculture include the habitat creation that extends from reef formation. Reefs can represent essential habitat in an otherwise homogeneous soft-sediment benthic ecosystem. The vertical relief and hard substrate shell represent valuable nursery and foraging grounds for a variety of ecologically and commercially valuable species (Grabowski et al. 2012). Oyster reefs increase both landscape and species diversity, serving as a wildlife corridor for mobile fauna (Grabowski & Peterson 2007, Scyphers et al. 2011). Oyster reefs have transformative effects on local and neighboring habitats and have been associated with the expansion and restoration of endangered 'blue carbon' habitats, such as saltmarshes and submerged aquatic vegetation (Newell & Koch 2004, Grabowski et al. 2012). Reefs also stabilize shorelines by dampening wave energy and preventing storm surge (Meyer et al. 1997, Brandon et al. 2016)

As the shellfish farming industry continues to mature, practices have become more sophisticated and shifted away from on-bottom culture. Off-bottom production of oysters, which includes cages sitting on the seabed, mid-column cages, and surface floats, has grown rapidly over the past decade (Fig. 1a). In Maryland, for example, 42% of total production in 2018 was derived from off-bottom gear (van Senten et al. 2019). To date, studies conducted with off-bottom gear have demonstrated that this production mode contributes significant ESS, including habitat provision for local fish and invertebrate species (Marenghi & Ozbay 2010), biofiltration (Turner et al. 2019), and biogeochemical cycling (Testa et al. 2015). A more thorough review of ESS associated with shellfish aquaculture can be found elsewhere (e.g. Dumbauld et al. 2009); for brevity, we wish to discuss the factors that alter ESS generated by off-bottom aquaculture and the knowledge gaps that are important to consider when developing ecolabel criteria.

4. FACTORS AFFECTING ESS FROM SHELLFISH AQUACULTURE

Although some ESS of shellfish are thought to be maintained under aquaculture, the act of planting, maintaining, and harvesting crops can also alter and

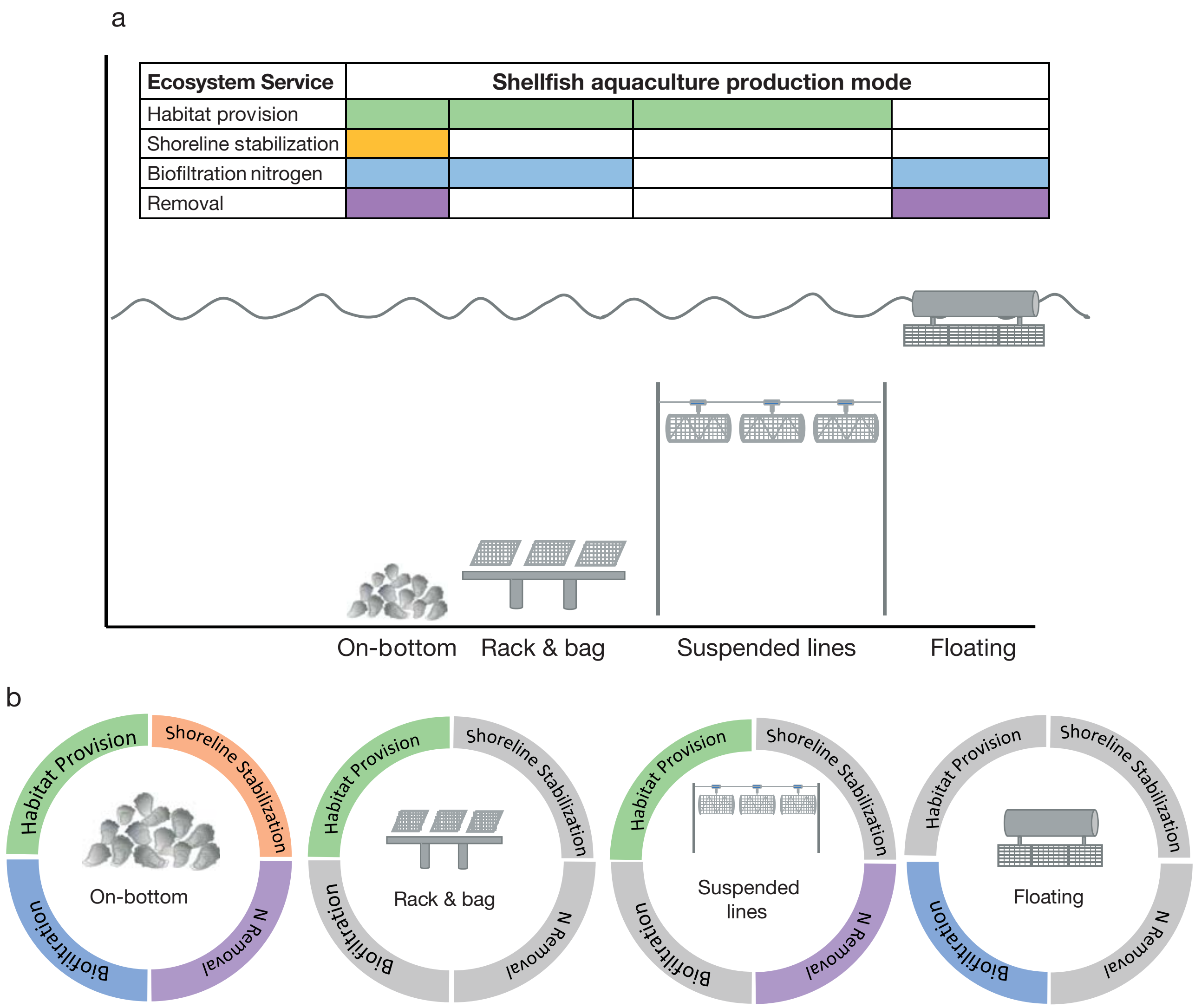

Fig. 1. (a) Culture methods of oyster shellfish aquaculture and ecosystem services suggested by the literature; (b) hypothetical gear-specific ecolabels. Brightly colored portions of circle segments indicate the ecosystem service is equal to or greater than natural oyster reefs, while grey segments indicate the ecosystem service is diminished or unknown, as indicated in Table 1

Table 1. Ecosystem services generated by various aquaculture gear, with arrows indicating if services are greater (white arrows) or less than (black arrows) that of bottom culture and oyster reefs. Question marks indicate differences in ecosystem service are unknown. NA: no observable difference of gear type

Gear	Nutrient cycling • Nitrogen sequestration/removal • Benthic–pelagic coupling	Shoreline stabilization • Wave dampening • Sediment deposition	Habitat provision • Structure • Species diversity	Biofiltration • Water clarity • Water quality
Floating cages	▼[a]	?	?	△[g]
Suspended lines	△[b]	?	NA[e]	?
Rack and bag	▼[c,d]	?	△[f]	?

[a]Testa et al. (2015); [b]Lee et al. (2011); [c]Lunstrum et al. (2018); [d]Humphries et al. (2016); [e]Connolly & Colwell (2005); [f]Marenghi & Ozbach (2010); [g]Comeau (2013)

disrupt generation of ESS relative to unharvested natural reefs (Table 1). For example, regularly harvested oyster reefs have fewer and smaller oysters than natural reefs, which has a cascading negative effect on the ESS generated by this habitat, including decreased benthic–pelagic coupling, fewer larval fish refuges, and less large fish (Plunket & La Peyre 2005). The impact of harvesting on oyster abundance and habitat quality is dependent on the harvest method used during cultivation. Interestingly, hand harvesting of oysters represents an intermediate level of disturbance, which can actually promote species diversity and abundance (Dumbauld et al. 2009). It is clear that ESS associated with bottom-culture should be explored to understand how they differ from those of natural reefs, how sustainability varies among the modes of bottom production (dredging, tonging, hand harvest), and how these services differ from those of off-bottom shellfish production.

There are numerous factors that influence the production of ESS associated with off-bottom shellfish production. Elevated sediment sulfide levels have been observed as a result of bivalve biodeposition and physical disturbance during harvest (Beck et al. 2011). Accumulation of nitrogen-rich biodeposits downstream of shellfish farms has been observed (Ray et al. 2015), which is often associated with high rates of oxygen uptake and nutrient release from sediments adjacent to shellfish farms. There are several factors that can influence the magnitude of ESS provided by shellfish aquaculture: primarily site selection with respect to hydrodynamic forces and local wildlife, scale of operation, and variety of consumer products cultivated in one space. These factors highlight potential risk factors that may alter off-bottom aquaculture ESS and should be considered for ecolabel criteria.

The environmental characteristics of an aquaculture site have a large influence over the magnitude of ESS delivered from the operation. For example, flushing rates can alter particle concentration and plankton abundance in culture regions and result in varied environmental impacts (Cranford 2019). Additionally, operations in shallow water depths (0.5–1.5 m) in well oxygenated systems may alter the fate of biodeposit dispersal and nutrient fluxes (Testa et al. 2015). Both the culture scale and the species cultured play a role in assessing the sustainability of an off-bottom aquaculture operation. Dense mussel rope culture has been found to increase drag and reduce the residence time of water and downwelling of phytoplankton (Lin et al. 2016). Animal filtration rates can be influenced by water quality (Hoellein et al. 2015), culture method (Comeau 2013), and culture scale (Asmus & Asmus 2005), which may alter the capability of shellfish to filter water effectively and provide ESS. At large scales, the social or ecological carrying capacity of an off-bottom operation can be exceeded and negatively influence the local ecosystem (Byron et al. 2011).

5. A PATH FORWARD

Currently, there are more than 450 ecolabels available for different products around the world, 50 of which are specific to fisheries and aquaculture (Barry et al. 2012). Greenwashing, the marketing practice in which a company offers misleading claims to be environmentally conscious, devalues legitimate eco-friendly labels for consumers (Shahrin et al. 2017). There is real concern that developing additional labeling schemes may have the unintended consequence of confusing consumers (Messer et al. 2017), potentially making the experience of shopping responsibly an exhausting experience. For brevity, we direct readers elsewhere for greater discussion on strategies to improve the ecolabeling processes (e.g.

Vermeer et al. 2010, Messer et al. 2017). Therefore, we suggest that the development of any new label that accurately characterizes the unique ecological benefits thought to accompany shellfish aquaculture be conducted slowly and carefully. As understanding of ESS generated by each production mode improves (e.g. bottom culture vs. off-bottom culture, etc.), there may be opportunity in the future to develop gear-specific labels (Fig. 1b).

Additionally, we urge current labeling programs to examine the environmental sustainability of shellfish aquaculture. We also strongly suggest that, aside from promoting the low environmental impact of production for oyster aquaculture (i.e. oysters requiring no feed inputs during their growout), ecolabeling organizations consider recognizing the numerous ESS that accompany oyster production. As aquaculture continues to expand and represent a larger portion of seafood production, quantifying and valuing the ESS of finfish aquaculture (Gentry et al. 2020) and shellfish aquaculture (van der Schatte Olivier et al. 2020) has gained prominence. At the same time, we emphasize how the net environmental impact of shellfish farming is dependent on local environmental factors (e.g. hydrodynamics) as well as the various modes of production (e.g. bottom vs. off-bottom). Our review of the literature indicates that many of the ESS often attributed to oyster aquaculture are derived primarily from ecologically focused studies on natural oyster beds and not from studies of farmed oysters. Importantly, the research community must investigate and test the broad-scale assumptions about the environmental benefits of cultured shellfish and how benefits may vary across space, time, and modes of production. This and other work will greatly help weigh and value the variety of services provided by shellfish aquaculture, which can be of use during ecolabel creation and certification.

Ecolabeling programs, which are intended to help growers inform consumers about the ecological sustainability of their products, have largely been overlooked by the shellfish industry. We conclude that the certification programs need to address this issue by both informing consumers about the environmental benefits of shellfish aquaculture and differentiating it from less sustainable forms of aquaculture. Additionally, if the goal of certification programs is to promote sustainable aquaculture, certifiers must work with small operators to develop creative solutions for overcoming economic barriers to program participation. More research on quantifying and valuation of ESS that extend explicitly from shellfish aquaculture is warranted. Filling such knowledge gaps will lead to the improvement of certification schemes wishing to highlight production benefits to the environment. Quantifying services may eventually lead to their monetization and a new source of revenue for farmers (e.g. nitrogen credits). We encourage shellfish farmers and the research community to explore ecolabels as a means to improve product desirability and, in turn, profitability. If the ESS of the shellfish are well conserved across cultivation methods, we are confident that consumer appreciation for sustainably sourced animal protein will create a potential feedback loop that stimulates the local economy and benefits local ecosystems.

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