The role of ecosystem services in the decision to grow oysters: a Maryland case study

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Abstract

Ecosystem services provided by oysters are regularly cited to gain support for the continued development of oyster aquaculture, but we have limited understanding of whether and how these benefits influence those who grow oysters. Participant observation and semi-structured interviews occurred with 57 oyster growers in Maryland (United States) to detail factors motivating entry into the oyster aquaculture industry. Results, framed under a lens of ecosystem services, indicate that cultural services are more likely to motivate aquaculture participation than provisioning, regulating or supporting services. This study emphasizes the significance of cultural ecosystem services and defines the need to better understand those provided by oysters and other farmed shellfish. A more complete description of the ecosystem services provided through shellfish aquaculture could serve to enhance support of farmed shellfisheries. In addition, this participatory approach highlights challenges within the ecosystem services framework regarding linked services and their complexity.

Keywords: oysters; oyster aquaculture; cultural ecosystem services; linked services.

1. Introduction

Oyster aquaculture, the growing or cultivation of oysters, is promoted as a sustainable complement or alternative to wild harvest oyster fisheries, many of which have declined relative to historic production (Alleway et al., 2018; Beck et al., 2011). Underlying the idea of oyster aquaculture's sustainability is an emphasis on the suite of benefits provided to the social-ecological system (Alleway et al., 2018; Coen et al., 2007; Dumbauld et al., 2009; Grabowski and Peterson, 2007; van der Schatte Olivier et al., 2018). Here, we seek to understand whether

and how these benefits affect the decisions that lead individuals to enter the industry and begin growing oysters. Through ethnographic fieldwork and semi-structured interviews with oyster aquaculturists in Maryland, we investigate the motivation behind participation in oyster aquaculture and how perceived ecosystem benefits, within the framework of ecosystem services, influence that decision. To ground this discussion of oyster-associated ecosystem services, we first introduce our approach to conceptualizing ecosystem services and provide a summarized review of benefits provided by oysters.

1.1 Ecosystem services

Ecosystem services are the benefits people obtain from ecosystems and are typically categorized into four types: cultural, provisioning, regulating, and supporting services (MA, 2005). An ecosystem services approach integrates environmental, economic, and sociocultural aspects of ecosystem management, often with the aim of valuation (Beaumont et al., 2007; de Groot et al., 1992). The framework introduced by the Millennium Ecosystem Assessment (MA) serves as the conceptual foundation for this study, but we have adapted it to more appropriately fit participant-provided viewpoints and allow for a more complete understanding of ecosystem services. In particular, the MA framework is lacking in its ability to address cultural ecosystem services. More recent conceptions, for example the framework introduced by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), feature a more developed understanding of sociocultural benefits and nature's contributions to people (Díaz et al., 2015).

61 The MA defines cultural services as the nonmaterial benefits obtained from ecosystems (MA,
62 2005). They differ from other types of services in that they are enabled and shaped through
63 human interactions with the environment (Chan et al., 2011; Fish et al., 2016). As such, cultural
64 services are best understood through these interactions or practices. Here, we use the framework
65 proposed by Fish et al. (2016) to structure our understanding. This idea of cultural services
66 emphasizes the interaction of environmental spaces and cultural practices as they contribute to
67 the production of cultural benefits. Cultural benefits, in turn, are outputs of the identities,
68 experiences, and capabilities that human-ecosystem interactions enable (Fish et al., 2016).
69 Approaching cultural services in this manner enables a greater consideration of cultural
70 ecosystem services and provides a means to more readily identify such services and benefits as
71 they relate to oysters.
72
73 Our organization of provisioning, regulating, and supporting services is likewise arranged to
74 more appropriately fit the study and participant notions of services. Provisioning services are
75 products obtained directly from the ecosystem (MA, 2005). They take shape as food, water,
76 fiber, and fuel, and are typically market-mediated goods (Chan et al., 2012a; MA, 2005). These
77 services are often the most easily recognizable as raw materials and products for direct use. In
78 this study, we discuss provisioning services as raw materials (i.e., oyster shell and meat) and
79 their utility.
80
81 Regulating services are the benefits received through regulation of ecosystem processes (MA,
82 2005). Paired with supporting services, these two groups are the most studied of oyster-related
83 ecosystem services and tie most directly to the environmental benefits associated with oysters.

Supporting services are those necessary for the production of other services (MA, 2005). The MA (2005) gives general examples of nutrient cycling, soil formation, and primary production. Because of their linkages, regulating and supporting services are often comingled when discussing oyster-related ecosystem services (Hancock and zu Ermgassen, 2019; Saurel et al., 2019; Ysaebert et al., 2019). Additionally, some ecosystem services frameworks do not include supporting services (e.g., the Common International Classification of Ecosystem Services) and others group supporting services with (or as) habitat and genetic diversity (Alleway et al., 2018; Costanza et al., 1997; Haines-Young and Potschin, 2018; TEEB, 2010). With these connections and distinctions in mind, regulating and supporting services are presented here together and are grouped according to the oyster function or role that provides the service. Though imperfect, the ecosystem services framework is useful to understand human-nature relationships related to oysters because oysters are such well-documented providers of ecosystem benefits.

1.2 Oysters and cultural ecosystem services

Within cultural services, employment, recreation, and tourism have received most attention and oysters benefit all three. Oysters contribute to local livelihoods and, in some cases, enable the continuation of family traditions of work (Alleway et al., 2018; Gentry et al., 2019; Krause et al., 2019). Krause et al. (2019) indicate the potential of shellfish aquaculture-based livelihoods to contribute to meaning-making, cultural identities of place, and identities of ownership. Oysters also heighten opportunities for recreation. Specifically, habitat associated with oyster reefs enhances recreational fishing opportunities and the contribution of oysters toward improved water quality may enrich beach experiences (Lipton, 2004; Northern Economics, Inc., 2009; van der Schaate Olivier et al., 2018). Oysters contribute to tourism both through recreational fisheries

and food culture (Krause et al., 2019). Improved water quality and fish abundance associated with oyster reefs may inspire increased tourism targeting recreational fishing, in addition to recreational oyster harvesting (Lipton, 2004; van der Schaate Olivier et al., 2018). Gastronomic tourism and the growing number of seafood festivals are also evidence for cultural benefits obtained through oysters (Gasparri, 2019; van der Schaate Olivier et al., 2018).

Seafood festivals, celebrations and other traditions tied to local food culture not only recognize the significance of local food systems, but they also strengthen place-based identities (Buestel et al., 2009; Krause et al., 2019; Northern Economics, Inc., 2009). In some cases, place-based identities connected to shellfish are integrated with cultural heritage. Many Native American and First Nations groups have extended histories that involve a variety of relationships with shellfish, including subsistence, emblematic, and spiritual uses (Dubin, 1999; Kuhm, 2007; Marlett, 2019). Family traditions and heritage may also be linked to oysters (Bauer, 2006; Buestel et al., 2009).

The history of human relationships with oysters has contributed to cultural services related to knowledge creation, research, and education. Though not often identified as a cultural service in action, oysters are regularly used in archaeological research to understand marine resource use and environmental change (Faulkner et al., 2019). Shells unearthed from layered 'natural archives' help inform about the past (Butler et al., 2019). The associated benefit of education continues with community restoration projects such as oyster gardening and shell-recycling (DeAngelis et al., 2019; Northern Economics, Inc., 2009). Community-based oyster restoration programs can enhance community investment and provide physically and psychologically rewarding experiences, on top of the ecological benefits acquired through restoration (DeAngelis

et al., 2019; Reynolds and Goldsborough, 2008; Saurel et al., 2019). Additionally, projects may heighten public awareness and contribute to an overall stronger environmental ethos (DeAngelis et al., 2019; Reynolds and Goldsborough, 2008; Saurel et al., 2019).

A final cultural service associated with oysters is through the hobby of shell collection and other forms of aesthetic appreciation and emblematic use (Duncan and Ghys, 2019). Throughout history, shellfish have been used for more than just subsistence, as archaeological evidence indicates (Dupont et al., 2019). Bivalve shells have been featured as symbols in architecture, furniture, and fabric design (Fontana, 2003). Shell collecting overall is a hobby that involves economic input, scientific components, education, and recreation (Duncan and Ghys, 2019).

Although this summary of oyster-related cultural services gives the impression of a large body of research on the topic, it is important to point out that much of this work was not conducted with cultural ecosystem services in mind and some relates to bivalve shellfish broadly. Instead, it represents a review of existing literature, some explicit to ecosystem services, but much of it emphasizing the relevance of the human-bivalve relationship. Overall, cultural ecosystem services related to oysters are poorly researched, and related to oyster aquaculture, "not assessed in any capacity yet" (van der Schaate Olivier et al., 2019, p. 2).

As indicated above, we use the framework introduced by Fish et al. (2016) to organize our understanding of cultural services. The existing literature on shellfish-related cultural services was not generated with this framework in mind, thus it does not completely fit this conception, however one can see how these types of benefits may be organized. To illustrate this, Table 1

focuses on the cultural practices discussed and how they contribute to cultural benefits as capabilities, experiences, and identities.

Table 1. Cultural ecosystem services via oysters. The summarized literature is adapted into the framework proposed by Fish et al. (2016), exploring cultural practices, services, and benefits (as capabilities, experiences, and identities).

	Cultural Ecosystem Services and Benefits via Oysters		
Cultural Practice ⟷	**Capabilities**	**Experiences**	**Identities**
Celebrations Seafood Festivals	None cited	None cited	Cultural heritage Sense of place
(Krause et al., 2019; Northern Economics, Inc., 2009; van der Schaate Oliver et al., 2019)			
Community Projects Restoration Oyster gardening	Knowledge Physical health Psychological rewards	None cited	Environmental ethos
(DeAngelis et al., 2019)			
Education and Research Archaeology Coastal ecology Formal/informal programs	Knowledge	None cited	Environmental ethos
(Butler et al., 2019; DeAngelis et al., 2019; Faulkner et al., 2019; Hopkins et al., 2019)			
Recreation Beach-going Fishing Oyster harvesting Shell collecting	Knowledge	None cited	Aesthetic benefits Social benefits
(Alleway et al., 2018; Duncan & Ghys, 2019; Henderson & O'Neill, 2003; van der Schaate Olivier et al., 2019)			
Shellfish-Based Livelihoods Commercial aquaculture Commercial wild fisheries	None cited	Meaning-making	Family tradition Ownership Sense of place
(Alleway et al., 2018; Gentry et al., 2019; Krause et al., 2019)			
Spiritual Practices Ceremony Pilgrimage Worship	None cited	None cited	Cultural heritage Spirituality

(Dubin, 1999; Fulcanelli, 1984; Hoena, 2003)			
Subsistence Oyster harvesting Oyster processing Oyster consumption	None cited	None cited	Cultural heritage Family heritage
(Bauer, 2006; Buestel et al., 2009; Kuhm, 2007; Trauner, 2004)			
Tourism Beach-going Gastronomic/food Recreation	Knowledge	None cited	None cited
(Alleway et al., 2018; Gasparri, 2019; Gentry et al., 2019; Lipton, 2004; Krause et al., 2019; van der Schaate Olivier et al., 2019)			

1.3 Oysters and provisioning ecosystem services

Oysters yield provisioning services in the form of tissue, shells, pearls, and biotechnology (Table 2). These raw materials are most easily recognized relative to other services. Oyster meat provides a healthy source of protein harvested through commercial, recreational, and subsistence fisheries sourced from both the wild and aquaculture (Alleway et al., 2018; Brumbaugh and Toropova, 2008; Northern Economics, Inc., 2009; van der Schaate Olivier et al., 2018). Oyster aquaculture is suggested as one means to replace provisioning services lost due to a declining wild harvest (Gentry et al., 2019).

Table 2. Provisioning ecosystem services via oysters. Oyster provisioning services are summarized by the product and its application. *Biotechnology is listed as a product or material, however in practice the material is microlevel components of oyster shell and tissue.

Provisioning Services and Benefits via Oysters

Product/Material	**Application/Benefit**
Biotechnology*	Bioengineering Pharmaceuticals
(Alleway et al., 2018; Venier et al., 2019)	
Meat/tissue	Food for human consumption

	(Alleway et al., 2018; Gentry et al., 2019; Northern Economics, Inc., 2009; van der Schaate Olivier et al., 2018)	
Pearls	Jewelry, decorative	
	(Zhu et al., 2019)	
Shells	Construction materials Chicken grit Fertilizer Food supplements Reef restoration	
	(Borsje et al., 2011; Brumbaugh & Coen, 2009; Northern Economics, Inc., 2009; van der Schaate Olivier et al., 2018)	

Oyster shells are increasingly used in restoration and coastal protection efforts. Collected shell is used as substrate for reef restoration as well as for aquaculture operations (Brumbaugh and Coen, 2009). Shells also provide construction material for shoreline protection projects (Borsje et al., 2011; Northern Economics, Inc., 2009). Crushed shell may be used for fertilizer and building materials (lime), chicken grit, calcium carbonate food supplements, and mulch (Brumbaugh and Toropova, 2008; Northern Economics, Inc., 2009; van der Schaate Olivier, 2018). Shells may also be used for decorative purposes and in jewelry (van der Schaate Olivier, 2018). Likewise, pearl-producing oysters supply pearls used in jewelry (Zhu et al., 2019).

The third utility of oysters as provisioning services is through the possibilities of biotechnology and biomedicine (Alleway et al., 2018; Venier et al., 2019). Though not as common, this area of research has potential as investigators work to find ways to implement the structure and material

qualities of bivalve shells in engineering designs and continue the search for biotechnological innovation.

1.4 Oysters and regulating and supporting services

Regulating and supporting services are well-documented relative to other oyster-associated ecosystem services. Though there are still unanswered questions regarding the conditionality of service delivery for many of these benefits, a lengthy series of references are available for each example and reflect the breadth of research on these services. Unlike the discussion of cultural services, here, we present a subset of references for each documented service or benefit example.

1.4.1 Filter-feeding

As filter or suspension-feeders, oysters play an important role in water quality maintenance overall (e.g., Brumbaugh et al., 2006; Grabowski et al., 2012; zu Ermgassen et al., 2013). Oysters enhance water clarity as they filter and feed on phytoplankton, reducing the presence of algae in the water as well as other suspended solids (e.g., Brumbaugh et al., 2006; Newell, 2004; Ulanowicz and Tuttle, 1992). Oysters can reduce the effects of harmful algal blooms like red and brown tides (Newell and Koch, 2004; Peabody and Griffin, 2008). As water clarity improves, the expansion of submerged aquatic vegetation, another critical habitat type, is also enhanced (Newell and Koch, 2004; Peabody and Griffin, 2008).

The benefits provided to systems by filtering oysters continue with their role in nutrient cycling. Oysters reduce the effects of eutrophication as they filter and sequester excess nutrients, like nitrogen and phosphorus (e.g., Beseres Pollack et al., 2013; Carmichael et al., 2012; Cerco and

Noel, 2007; Fukumori et al., 2008; Rose et al., 2014; Songsangjinda et al., 2000). Because of their role in nitrogen sequestration and denitrification, oysters are increasingly offered as an approach to nitrogen mitigation (e.g., Bricker et al., 2018; DePiper and Lipton, 2016; Ferreira and Bricker, 2016, 2019; Newell et al., 2005). Oysters sequester nitrogen from the water in their shells, tissue, and biodeposits (feces and pseudofeces) and when harvested, much of the nitrogen is removed from the system (Carmichael et al., 2012; Kesler, 2015; Shumway et al., 2003). Biodeposits are also utilized by nitrogen-fixing bacteria in the sediment to contribute to denitrification (e.g., Carmichael et al., 2012; Cerco and Noel, 2007; Kellogg et al., 2013; Newell, 2004). To a lesser extent, the role of oysters in carbon sequestration is also highlighted (e.g., Peterson and Lipcius, 2003; Tang et al., 2011). The relationship between carbon sequestration and storage relative to carbon dioxide released during bivalve respiration, however, is uncertain (Han, 2017; van der Schaate Olivier et al., 2018). The sequestration of carbon dioxide in the shell may not compensate for its release during the respiration of organic matter (Filgueira et al., 2019).

Finally, oysters filter substances other than nutrients and phytoplankton. They also filter and bioaccumulate things that may be harmful to humans, such as bacteria, protozoa, viruses, and more generally sewage (e.g., Daskin et al., 2008; Kovacs et al., 2010; van der Schaate Olivier et al., 2018). This benefit could pose a risk to humans if oysters in unhealthy or unsafe waters were consumed, but represents another aim of oyster aquaculture and restoration - to mitigate and improve unclean waters (Kellogg et al., 2014).

1.4.2 Habitat creation

240 The second functional grouping for regulating and supporting services is the provision of habitat
241 and structure. Oyster reefs provide benefits of shoreline protection against erosion, wave action,
242 and severe weather events (Arkema et al., 2013; La Peyre et al., 2015; Ysaebert et al., 2019).
243 These natural breakwater benefits occur through several finer scale processes facilitated by
244 oyster habitat (Grabowski and Peterson, 2007; Marsh et al., 2002; Meyer et al., 1997). Oyster
245 reefs also contribute to stabilized sediment of submerged lands (Grabowski et al., 2012). Both
246 natural reefs and oyster farms absorb wave energy and reduce the impacts of boat wakes, rising
247 sea levels, and storms on adjacent shorelines (Piazza et al., 2005).
248
249 Oyster habitat contributes to enhanced biodiversity across trophic levels through the provision of
250 refuge and settlement substrate (e.g., Brumbaugh et al., 2006; Grabowski et al., 2012; Herbert et
251 al., 2012; Luckenbach et al., 2005). Typically, oyster reefs are structurally complex, providing
252 surface area and hiding places for a diversity of invertebrates including worms, snails, sea
253 squirts, and crabs, in addition to small fish (Craeymeersch and Jansen, 2019; Peterson et al.,
254 2003; Rodney and Paynter, 2006). Community dynamics may differ slightly from a wild reef,
255 but oyster farms also host higher levels of biodiversity than surrounding areas (Hancock and zu
256 Ermgassen, 2019; Tallman and Forrester, 2007). Oyster habitat provides foraging opportunities
257 for larger fish, birds, and marine mammals and many of the fish that rely on oyster reefs as a
258 nursery or feeding grounds are commercially important (Fernandez-Gonzalez et al., 2014;
259 Grabowski and Peterson, 2007).
260
261 Oyster reefs have added effects beyond the reef itself. In addition to diversifying bottom types,
262 they provide corridors between shelter and foraging grounds (Peterson and Lipcius, 2003), and

protect the ecological integrity of other adjacent habitat like seagrasses and marsh (Scyphers et al., 2011; Ysaebert et al., 2019). Additionally, other filter feeders that live on shellfish reefs as fouling or encrusting organisms contribute to the overall filtering capacity of the reef (Northern Economics, Inc., 2009).

1.4.3 Spawning

The final supporting function that oysters provide is that of spawning. Spawning contributes to genetic diversity and overall gene flow (Alleway et al., 2018). It may be more associated with wild seed, particularly with the prevalence of triploid oysters (Nell, 2002), but some aquaculture operations utilize diploid animals that can contribute to wild populations (Thompson et al., 2017). Genotypes created for aquaculture could benefit wild populations through enhanced genetic diversity, disease resistance, or other targeted traits (Brumbaugh et al., 2000; Thompson et al., 2017).

Through the combined processes of filter-feeding, habitat-formation, and spawning, oysters provide many regulating and supporting services that influence the systems they are part of. Table 3 summarizes these examples.

Table 3. Regulating and supporting ecosystem services via oysters. The review of oyster regulating and supporting services is presented by oyster roles, associated processes, and benefits delivered. Refer to text (1.4) for additional detail on cited references.

Regulating and Supporting Ecosystem Services and Benefits via Oysters

Oyster Role/Function	Process	Intermediate/Overall Benefits
Filter-feeding	Phytoplankton control Removal of suspended solids	Water clarity Nutrient cycling Improved water quality

	Nutrient removal/sequestration Denitrification Bioaccumulation	
(e.g., Beseres Pollack et al., 2013; Bricker et al., 2014, 2018; Brumbaugh et al., 2006; Carmichael et al., 2012; Cerco & Noel, 2007; DePiper & Lipton, 2016; Ferreira & Bricker, 2016, 2019; Fukumori et al., 2008; Gifford et al., 2004; Gifford et al., 2005; Grabowski et al., 2012; Hickey, 2008, 2009; Higgins et al., 2011; Humphries et al., 2016; Kellogg et al., 2013; Kovacs et al., 2010; Newell, 2004; Newell & Koch, 2004; Newell et al., 2005; Peabody & Griffin, 2008; Peterson & Lipcius, 2003; Rose et al., 2014; Songsangjinda et al., 2000; Tang et al., 2011; Ulanowicz & Tuttle, 1992; zu Ermgassen et al., 2013)		
Habitat creation	Sediment stabilization Wave attenuation Foraging grounds Nursery provision Refuge provision Substrate provision	Shoreline protection Adjacent habitat protection Enhanced biodiversity Enhanced productivity (other spp.)
(e.g., Coen et al., 2007; Craeymeersch & Jansen, 2019; Grabowski & Peterson, 2007; Grabowski et al., 2012; Hancock & zu Ermgassen, 2019; Herbert et al., 2012; Henderson & O'Neill, 2003; Kesler, 2015; Peterson et al., 2003; Peterson & Lipcius, 2003; Piazza et al., 2005; Rodney & Paynter 2006; Tallman & Forrester, 2007; Waser et al., 2016; Ysaebert et al., 2019)		
Reproduction	Spawning	Genetic diversity/gene flow Population abundance
(Brumbaugh et al., 2000; Thompson et al., 2017)		

As illustrated through this overview of the ecosystem services typically associated with oysters, oysters provide a diversity of benefits. For the most part, these benefits are similar whether they are wild or farmed. Most studies comparing the services of wild and farmed oysters, unsurprisingly, feature regulating and supporting services (e.g., Coen et al., 2007; Higgins et al., 2001; Humphries et al., 2016; Rose et al., 2014; Tallman and Forrester, 2007; Tang et al., 2011). No work has been carried out to evaluate potential differences within cultural services.

1.5 Ecosystem services and livelihood decision-making

As detailed, a wealth of literature exists describing the benefits humans derive from oysters through ecosystem services, and likewise the ecosystem services provided by oyster aquaculture,

but there has been no effort to examine whether ecosystem services affect individual decisions to begin oyster aquaculture. It is important to correct this omission. If resource managers and others involved in industry development hope to maximize industry access and participation as they continue to build oyster aquaculture opportunities, it is critical to understand the motivations and values guiding those involved and those who would be potentially involved. The concept of ecosystem services is relevant to industry development discussions because of its utility in policy-making and frequent usage in oyster aquaculture promotion (e.g., Preston, 2019; Sheehan et al., 2019; Theuerkauf et al., 2019).

Related existing research is limited and aims to understand questions of motivation and participation in wild fisheries, recreational fisheries, and even finfish aquaculture, but rarely are these studies framed to incorporate ecosystem services or shellfish aquaculture. Scholars note that fisheries managers often unwisely ignore fisher motivation, instead presupposing economic rationality when making management decisions (Peterson, 2014). This disregards other variables that shape livelihood-related decision-making, such as the pressures of economic markets, family and community expectations, and cultural and personal value systems (Peterson, 2014). Research suggests that individuals remain in commercial fisheries, even though it may not make good economic sense, due to a suite of other factors that resemble cultural services rather than other ecosystem service types (e.g., Cinner et al., 2009; Cinner, 2014; Pollnac and Poggie, 2006; Young et al., 2016).

Fewer researchers have looked at decision-making related to involvement in aquaculture and most have focused on finfish (e.g., Bosma et al., 2004, 2006; Harrison et al., 1996). Specific to

319 oyster aquaculture, case studies and cited examples do not exist that describe why individuals
320 choose to participate. Research may indicate who is growing oysters (with emphasis on gender),
321 but not why beyond the potentials of additional income, livelihood diversification tied to income,
322 etc. (e.g., Felsing and Baticados, 2001; Siar et al., 1995; Szuster et al., 2008). Even though
323 motivation may seem apparent – oyster aquaculture is a source of income, it is sustainable, etc. –
324 no effort has been made to understand and detail why individuals choose to enter the oyster
325 aquaculture industry. This is a troublesome oversight because oyster aquaculture continues to
326 expand due to market demand and industry promotion (Duarte et al., 2009; Klinger and Naylor,
327 2012; USDA, 2018). It is important to understand not only who shapes this growing industry, but
328 why they are doing so. Are the ecosystem services so frequently cited in the literature and
329 industry marketing as motivational for oyster growers as they are for scientists, regulators, and
330 policy-makers? Does oyster aquaculture provide even more for growers than the documented
331 services? Answering these broad questions can support oyster aquaculture industry development
332 and management, as well as contribute to greater understanding of ecosystem services perception
333 and value.
334
335 ***1.6 Study aims***
336 In this article, we ask: do oyster growers think about ecosystem services, directly or indirectly,
337 when deciding to engage in oyster aquaculture? If so, what ecosystem services influence their
338 decision to get involved? We hypothesize that cultural services, though understudied, are more
339 important to oyster growers than other types of ecosystem services. We approach these questions
340 using ethnographic methods in Maryland's Chesapeake Bay, but implications of this study are

relevant to oyster-producing regions broadly. This study represents the first to understand motivation to participate in oyster aquaculture within a framework of ecosystem services.

2 Methods

2.1 Study site

The state of Maryland (United States) has a 200-year history of oyster aquaculture on leased bottom, however, 2009 legislative changes enhanced opportunity for industry growth and inspired an increase in actively managed leased bottom and oyster aquaculture production throughout many coastal areas (Michaelis et al., *accepted*). Fieldwork and interviews occurred with eastern oyster (*Crassostrea virginica*) growers working in Maryland's portion of the Chesapeake Bay and its Atlantic coastal bays (Figure 1). This included participants in the tidewater counties of: St. Mary's, Calvert, Anne Arundel, Kent, Talbot, Dorchester, Wicomico, Somerset, and Worcester. Other coastal counties (Baltimore, Harford, and Cecil) were not represented, but low salinity water conditions near those counties render aquaculture operations unlikely. Prospective participants were contacted in Queen Anne's county, but none took part in the project.

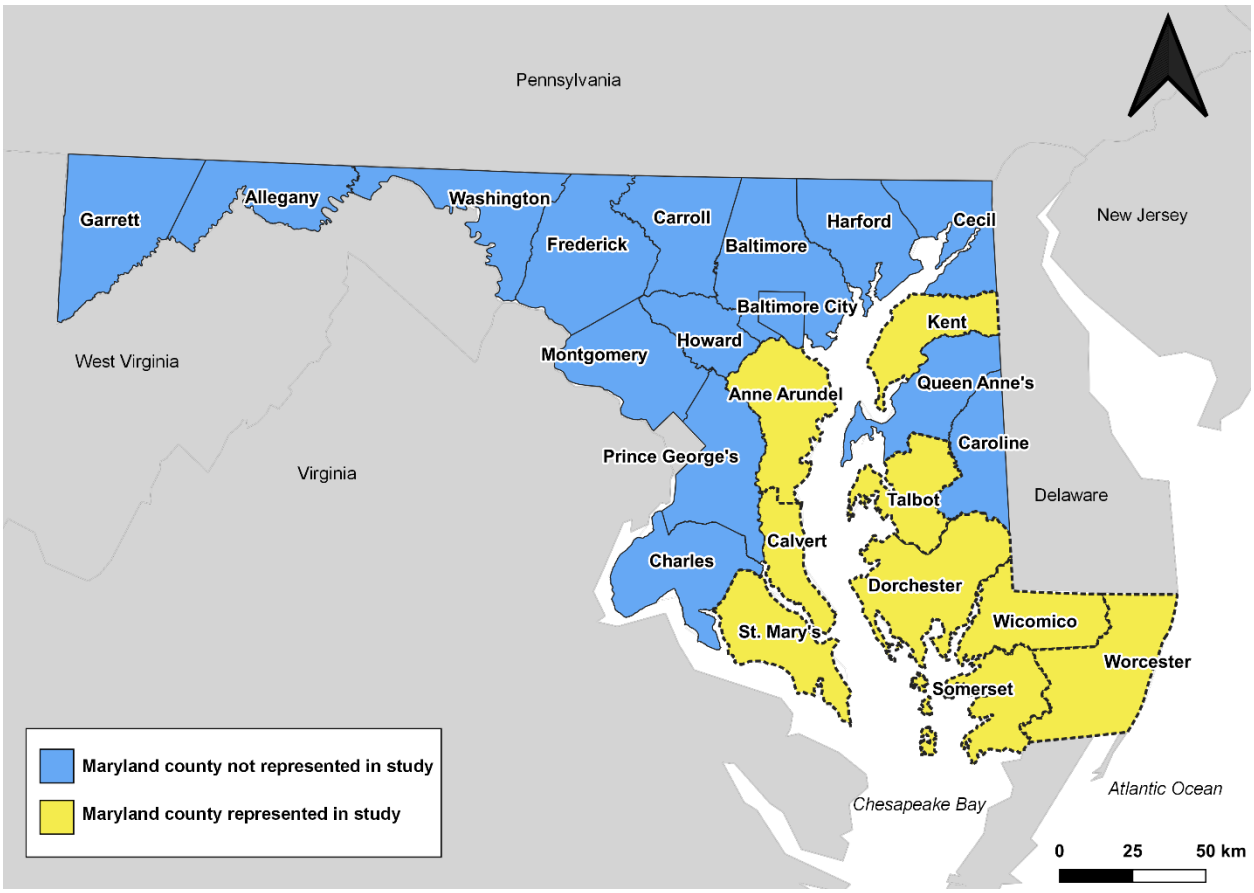


Figure 1. Map of study area. Maryland (shown with counties in blue and yellow) is located on the eastern coast of the continental United States and has an active aquaculture industry along its portion of the Chesapeake Bay as well as its Atlantic coastal bays. Fieldwork occurred in nine tidewater counties (shown in yellow with dashed-line boundaries).

2.2 Participant selection and description

Participants were identified through a combination of snowball sampling and targeted solicitation to create a diverse participant sample by location, age, involvement in wild fisheries, and scale of aquaculture operation. Based on previous work with Maryland watermen, we had existing relationships with industry members and began interviews for this study with them. They subsequently helped to recommend and make introductions to other potential participants.

All aspects of participant solicitation were approved by the University of Maryland Institutional Review Board (Project Number 917459).

In total, 57 participants were interviewed, with the majority of participants (81%) from Dorchester, Talbot, and St. Mary's counties. County proportions parallel the relative number of oyster growers in each county as these three counties contribute most to industry activity in the state. Approximately half of participants had a background in wild commercial fisheries, in that they are or were commercial watermen. Most participants added aquaculture as an additional source of income, but for 25% of participants, aquaculture was their sole source of income. The majority (86%) of participants were male and participants represented a range of ages: 18-30 years old (14%), 31-40 (23%), 41-50 (25%), 51-60 (26%), and 61 or older (12%).

Most participants were relatively new growers, but overall participants represented a range of aquaculture involvement: within first year (16%), 1-5 years (50%), 6-10 (18%), 11-20 (9%), and greater than 20 years (7%). This is reflective of Maryland's industry as many growers entered the industry after 2009 legislative changes. Within the overall group of participants, 39 were leaseholders while 18 did not have their own lease but worked on someone else's lease. Fifty-three were involved in oyster farm operations, while six worked in oyster hatcheries. Two were involved in both hatcheries and farm work. Nine participants also made oyster gear and eight bought and sold other oysters in addition to selling their own. Thus, while all participants were oyster growers, a subset were also involved other aspects of the oyster aquaculture industry.

2.3 Data collection

392 Fieldwork involved a combination of participant observation and semi-structured interviews that
393 occurred between June 2016 and September 2018.
394
395 *2.3.1 Participant observation*
396 Participant observation is the "process of learning through exposure to or involvement in the
397 day-to-day or routine activities of participants in the [research] setting" (Schensul et al., 1999, p.
398 91). It is a means of establishing rapport in a community and enables the researcher to better
399 understand the research setting or community as well as resulting data (Bernard, 1994). In this
400 project, participant observation occurred in an array of settings. We worked with participants on
401 their boats and oyster farms, attended or led extension programs, and spent time with participants
402 over meals, etc., as invited. This included repeat interactions with many participants throughout
403 the two-year fieldwork period and beyond.
404
405 *2.3.2 Semi-structured interviews*
406 As indicated, we interviewed 57 shellfish growers using a semi-structured approach. A semi-
407 structured interview uses a guide that contains topics, themes, or areas to be covered rather than a
408 sequenced script of standardized questions typically associated with a structured interview
409 (Lewis-Beck, 2004). Open-ended prompts have demonstrated utility in enabling participants to
410 express a diversity of ecosystem-related values, including those for which the researcher did not
411 explicitly target (Gould et al., 2015).
412
413 This study was part of a larger project intended to understand multiple aspects of participation in
414 Maryland oyster aquaculture. Interviews were guided by questions that investigated motivation

for participation, but did not target ecosystem services directly. Participants were not guided to talk about ecosystem services in general, or specifically. Results thus indicate whether ecosystem services played a part in the decision to grow oysters without prompting from researchers. For the purposes of this study, we consider only one question for analysis: "Why did you decide to start growing oysters?"

2.4 Data Analysis

Interviews were audio-recorded and subsequently transcribed. We coded interview text to identify examples of each type of ecosystem service within participants' responses to the basic question of "why did you decide to start growing oysters?" In examples where participants mentioned multiple services, all those described were coded. The MA definition of each type of service was used to guide coding, however, service classification was amended to incorporate more recent views on cultural services and to better suit this system and analysis (Table 5). We coded all data using MAXQDA (VERBI Software, 2019).

Table 5. Ecosystem service code guidelines. MA (2005) definitions of each service type were used as the foundation for coding, however slight modifications were made and are reflected here.

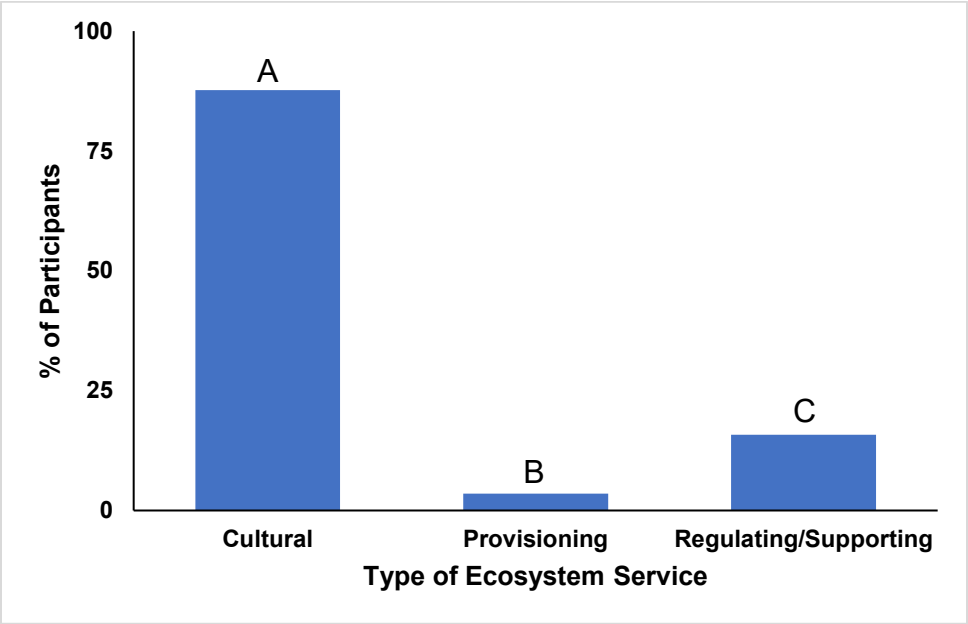
Ecosystem Service Category	Description for Coding
Cultural Service	Involvement was motivated by, or contributes to, participant identities, experiences, and/or capabilities (Fish et al., 2016).
Provisioning Service	Participant mentions their role in the production of a food item or raw material (e.g., shell) as motivation.
Regulating/Supporting Service	Participant mentions desire to improve water quality, restore wild oyster populations, help the bay in general, or other environmental benefits.

Following Fish et al. (2016), we considered cultural services as "the contributions ecosystems make to human well-being in terms of the identities they help frame, the experiences they help enable, and the capabilities they help equip" (p. 212). Using these categories to frame our identification of cultural services – identities, experiences, and capabilities – we coded any such examples connected to the decision to grow oysters. Cultural services were then recoded to more nuanced subcategories (Table 6 in 3. Results). For example, a cultural service motivation may have first been coded as contributing to "identities" and recoded to designate how or what type of identity. Subcategories of cultural services were generated from examples in existing literature as well as through open-coding to incorporate novel subcategories as appropriate (Barnes-Mauthe et al., 2015; Bryce et al., 2016; Fish et al., 2016; Raymond et al., 2009). Open-coding is a component of grounded theory analysis that allows key themes and concepts to emerge during data collection and analysis (Birk et al., 2008; Morse et al., 2009; Shaffer et al., 2010). In this case, data collection was complete but subcategories of cultural services were added to the codebook as new, more descriptive, and more appropriate themes arose during the coding process. Once a complete list of subcategories was created based on emerging themes, all interviews we reanalyzed to enable comprehensive subcategorization.

Employment or livelihoods are typically recognized as cultural services, however, we did not code as such in this scenario. In our analysis, every participant was employed in oyster aquaculture, thus such coding would bias results toward cultural services. Instead, it was more important to understand what services - cultural or otherwise - made aquaculture a more appealing source of income than other occupations and inspired participants to enter the industry.

457 Provisioning services were coded when a participant mentioned the harvest or production of a
458 food item or shell resulting from processing as motivation to grow oysters. Because most
459 participants referred to regulating and supporting services in a broad sense, we coded these two
460 service types as a single group. Participants who acknowledged their role in or desire to improve
461 water quality, restore wild oyster populations, or help the bay were coded as mentioning
462 regulating and supporting services.
463
464 To identify potential differences among mention of ecosystem service types, we used the
465 Cochran's Q extension of the McNemar test. Cochran's Q test is a nonparametric test that
466 enables comparison of two or more matched samples when the response variable is dichotomous
467 and there are either: 1) multiple times for a repeated measure or 2) multiple categories with
468 paired responses (Mangiafico, 2016). For this study, response variables were "mentioned" or
469 "did not mention" for each of the three types of ecosystem service categories. Chi-square
470 analyses tested for differences among participant groups based on attributes that might influence
471 the types of ecosystem service mentioned. All analyses were completed using R statistical
472 software with α equal to 0.05 (R Core Team, 2019).
473
474 **3 Results**
475 In response to the question of "why did you decide to grow oysters?" most participants
476 mentioned cultural ecosystem services rather than provisioning, regulating, or supporting
477 services. The mention of each service type differed from one another (Figure 4; Cultural:
478 Provisioning $P<0.001$; Cultural: Regulating/Supporting $P<0.001$; Provisioning:

479 Regulating/Supporting P=0.02). Patterns were similar when comparing data within and among
480 groups based on participant attributes.
481



482

483 **Figure 4. Ecosystem services mentioned by oyster growers.** Participants mentioned cultural services more
484 frequently than any other service in response to the question of "why did you decide to grow oysters?" (P<0.001).
485 All types of ecosystem services were different from one another in frequency of mention (P<0.001; Groups A, B,
486 and C).
487

488 Qualitatively, participants mentioned a larger range of services within the category of cultural
489 services relative to others (Table 6). Participants discussed cultural services as they relate to
490 identities, experiences, and capabilities in a variety of ways; some of these easily fit into
491 examples from the literature while others were novel and possibly situation or aquaculture-
492 specific. Provisioning services were rarely mentioned and featured examples related to food
493 production. Participants discussed regulating and supporting services infrequently but broadly
494 and responses connected to how aquaculture benefits the bay in several ways.

495 **Table 6. Cultural, provisioning, regulating and supporting services mentioned by participants.** Ecosystem services as discussed by participants are listed.

Ecosystem Service	Benefit Category	Sub-Category	How discussed relative to aquaculture
Cultural	Identities	Cultural heritage	Connection to fishing communities.
		Family heritage	Family history in seafood industry.
		Past experiences	Previously worked the water.
		Responsibility of care/bequest	Desire to leave something for children or community.
		Sense of place	Working in an area they feel connected to.
		Sense of purpose	Sense of being part of something larger than self.
	Experiences	Aesthetic appreciation	Beauty of physical land/bayscape and wildlife.
		Freedom	Freedom associated with being own boss.
		Inspiration	Hobby inspired commercial expansion.
		Lifestyle/Job Satisfaction	Lifestyle connected to job satisfaction. Ex: hours, perceived reward, on the water.
		Relationship with nature	Connection to outdoors/nature/water and pleasure in related activities.
		Security	Additional/replacement income in case of other failures.
		Social bonds/capital	Introduced to industry by, or entered with, a friend or family member.
		Transformation	Looking for a change of life/livelihood.
		Variety	Diverse and variable daily activities.
	Capabilities	Knowledge	Able to apply/acquire knowledge.
		Skills	Able to apply/acquire skills.
Provisioning	Food production	Food	Able to produce food for self/others.
Regulating and Supporting	General	Environmental good	Environmentally beneficial.
		Oysters	Helping restore wild oyster population.
		Restore bay	Helping restore bay overall.
		Sustainable fisheries	Sustainable relative to others.
	Habitat	Habitat provision	Contribute habitat for other species.
	Water quality	Water improvement	Help with bay water quality.

496

4 Discussion

Oysters, both wild and farmed, provide many ecosystem services, yet no effort has been made to understand the role ecosystem services play in the decision to engage in oyster aquaculture. Eliciting perceptions of ecosystem services can be challenging, and addressing this through a resource-based livelihood or activity is one means of more effectively capturing these values (Gould et al., 2015). In this study, we used oyster aquaculture as a resource-based activity, or cultural practice, to gauge the importance of ecosystem services to Maryland oyster growers.

When asked about the motivation behind their role in oyster aquaculture, most participants mentioned reasons identified as cultural ecosystem services rather than provisioning, regulating, or supporting services. The data suggest that cultural services created and acquired through work in oyster aquaculture are more important than other ecosystem services in influencing the decision to begin growing oysters. While perhaps unsurprising, it is useful in directing future research as well as highlighting challenges related to ecosystem services.

4.1 Cultural ecosystem services and oyster aquaculture

Participants discussed cultural services as they relate to identities, experiences, and capabilities. In this way, the framework introduced by Fish et al. (2016) was useful in trying to understand these oyster-related services. Within the contributions made to identities, oyster growers discussed how aquaculture connected them to the fishing communities that they grew up in, and, for some, family members who worked in commercial fisheries. Notions of heritage and sense of place were frequently mentioned by those who previously worked in wild fisheries as well as those who did not. Several participants discussed the legacy that aquaculture enabled them to

leave, both in terms of a healthier Chesapeake Bay and a business they could pass down to their children. Additionally, some growers talked about being part of a more abstract community, in that aquaculture allowed them to be part of something outside of or larger than themselves.

> *"People in my family have been in the seafood business for 10 generations. Watermen. My grandfather…he was a commercial fisherman. They fish trapped... He fish trapped by Cove Point, over there by Holland's Island. And his father before him was an oyster dredger, and his father before him was an oyster dredger, and his father before him was an oyster dredger…They all made their living on oysters and fish… So the answer to how did we get here, is we've always been here. This is what we've always done for a living."*
>
> *Maryland Oyster Grower*

Growers talked about the experiences that their involvement in aquaculture enabled. Many experiences were connected to job satisfaction, although in different ways. Beyond mere lifestyle, the career or trade of an oyster grower gave participants the opportunity to experience nature in multiple ways, contributed to perceptions of freedom as well as security, and in some cases was transformative, leading to more fulfilled and enriched lives overall. Many growers were introduced to the industry by friends or family, or entered it with them, and emphasized the importance of these social bonds.

> *"Everything felt like I wanted a change…I went from [my previous job], which was very egocentric and not really bettering the world…to finding something that*

was so environmental it actually restored part of its environment rather than minimize its impacts. …It was something for me to get excited about again."

Maryland Oyster Grower

Aquaculture contributed to individual capabilities through both knowledge and skills. Growers discussed the ability to apply previously acquired knowledge or skills to their new aquaculture endeavor. They also mentioned the opportunity to develop additional knowledge and skills not only for themselves, but also for their employees. Included in these mentions were several participants who were attracted to aquaculture because of its potential to bring jobs and skills to rural communities, and provide training and opportunity to people with limited options for employment.

"My goal is to educate people, young people. One of the problems here in these coastal communities, these working waterfronts, is that we have a lot of urban drift. Kids are going out of the area to get jobs in the city. They could make a sustainable living here staying on the water in aquaculture."

Maryland Oyster Grower

4.2 Provisioning services and oyster aquaculture

A small number of oyster growers (N = 2) discussed the associated provisioning services that interested them. In one example, the grower liked the visible outcomes of his work as oysters created both habitat in the water and a food product for people. Another grower shared how his

family's passion for oyster consumption led them to think about a more reliable way to harvest or supply oysters.

> *"We were harvesting wild oysters and wanted to make sure we had a sustainable amount next year. We were just eating them for ourselves. We love oysters. So we were just pulling oysters out of the water... It was great. And we started asking ourselves, are there going to be oysters there next year? If we just keep taking them?"*
>
> *Maryland Oyster Grower*

4.3 Regulating and supporting services and oyster aquaculture

Participants discussed regulating and supporting services broadly as motivation for entering the aquaculture industry and included examples such as environmental benefits or bay health. In some cases, growers mentioned their role in contributing to the wild oyster population or sustainable fisheries overall. Several growers discussed specifically how their oysters provide habitat for other animals as one of the features that drew them to the business.

> *"[At my last job] you were just caught up in the process and couldn't…really see any tangible environmental improvements. Whereas here with the farm, you see all the oysters, you see all the habitat you're creating, you see the food product you're producing. So I think from the very beginning it was 100% environment. With the idea that you could make enough to live on, too."*
>
> *Maryland Oyster Grower*

588 *4.4 Implications for ecosystem services research*

589 Through this analysis, we encountered several findings relevant to ecosystem service studies
590 overall and cultural services in particular. We showed that cultural services are important, though
591 infrequently studied as they relate to oysters (van der Schatte Olivier et al., 2018). This is in line
592 with other work that acknowledges the rank of cultural services over others for many people
593 (Daniel et al., 2012; Gould et al., 2015; Milcu et al., 2013; Pascua et al., 2017). Our results also
594 support earlier work that illustrates the substantial effect that cultural services have in fishing
595 communities, relative to the provisioning services provided by commercial fisheries that
596 economically drive many working waterfronts (Urquhart and Acott, 2014).

597

598 Understanding motivation to participate in aquaculture using the framework of ecosystem
599 services is challenging because participant responses, as well as the services themselves, are not
600 cut and dried. Ecosystem services are complex and integrated; many participant responses,
601 including the examples shared above, featured more than one example of an ecosystem service.
602 Additional effort is needed to understand the linkages between ecosystem services, especially
603 cultural services (Baulcomb et al., 2015). This underscores arguments that the ecosystem service
604 framework does not adequately account or allow for complexity (Lebreton et al., 2019; Winthrop
605 et al., 2014). Thorough understanding of linked services may only be possible within well-
606 studied systems (Lebreton et al., 2019). The effort put into at least three types of ecosystem
607 services related to oysters thus far provides a detailed, though incomplete, library on the topic.
608 Additional research focused on oyster-related cultural services can provide a better candidate
609 system to detail linked services and benefits.

610

A second aspect of the complexity of ecosystem services is that their benefits are not unidirectional. Research tends to emphasize what humans receive or obtain from the ecosystem, but, while doing so, they are actively creating, shaping, and enabling services. This relational understanding is emphasized in more recent literature, particularly as it pertains to cultural ecosystem services (Bieling, 2013; Chan et al., 2012a; Comberti et al., 2015; Fish et al., 2016). In our study, oyster growers emphasized both what oyster aquaculture provides for them as well as their role in generating benefits to the system. Even if the typical ecological benefits were not mentioned as frequently, growers acknowledged their role in providing them.

Ecosystem services are context-dependent and have potential to vary based on an infinite number of social and environmental factors (Chan et al., 2012b). Thus far, efforts have not addressed this type of variability as it relates to ecosystem services and their delivery (Alleway et al., 2018; Berbés-Blázquez et al., 2016; Chan et al., 2012b; Cranford, 2019; Small et al., 2017). Specific to shellfish aquaculture, there is a need to understand ecosystem disservices and the drivers that affect perception and receipt of services (Diana, 2009; Naylor et al., 2000). In our study, the majority of oyster growers interviewed entered the industry after 2010 changes in state law. Efforts to understand how perceived benefits vary when compared to those who have been in the industry for more than 10 years would be valuable. Additionally, work directed at understanding disservices, particularly as perceived by those outside of the industry, would be useful in guiding industry development strategies.

Continued work investigating the relationship between ecosystem services and oyster-based livelihoods would benefit the oyster aquaculture industry through a greater understanding of its

connection to the local social-ecological system, as well as build knowledge surrounding ecosystem services in general. Oyster-based livelihoods are of particular relevance to perceived ecosystem services because of the oyster's role as an environmental engineer. Based on this initial study, we see that cultural services are strongly connected to oyster aquaculture and additional research is needed to better detail this relationship.

5 Conclusion

This analysis was the first to investigate the role of ecosystem services in motivating participation in oyster aquaculture. As the many ecosystem services provided by oysters continue to be studied and promoted, it is important to understand their perception by members of the social-ecological system, especially those involved in oyster production. Our results show that, in Maryland, cultural services are the most important type of ecosystem service in leading individuals to oyster aquaculture rather than other livelihoods. This finding suggests that, as documented in wild fisheries, the 'nonmaterial' benefits are important, potentially more important than other benefits (e.g., Cinner et al., 2009; Cinner, 2014; Pollnac and Poggie, 2006; Young et al., 2016). This result is problematic, however, because little attention or research has focused on cultural services related to oysters, or shellfish aquaculture in general.

These findings are relevant to dimensions beyond that of the oyster aquaculture industry itself. Extending this discussion to consider community leaders, regulators, and other decision-makers in social-ecological systems shaped by oysters provides another utility of this research. As stated above, the suite of environmental benefits provided by oysters are regularly cited to support development of oyster aquaculture. Failure to integrate cultural services into these discussions

creates a critical gap in understanding what oyster aquaculture may provide at the community-level, as well as any linked disservices. Better recognition and description of oyster-related cultural services would provide an important component to community planning related to working waterfronts with both wild and/or aquaculture oyster fisheries. Inclusion of cultural services may also refine understanding of external obstacles to both oyster fisheries. Decision-makers impact community and industry development according to their own perception of oyster-related services in addition to their constituents. Incomplete information can influence decisions in ways that may negatively impact communities and social-ecological systems more broadly. As such, there is a need for more focused efforts to build and share knowledge related to oysters and cultural ecosystem services. It is also pertinent to understand nuances in the creation and delivery of ecosystem services related to oysters in multiple arenas – not only aquaculture, but also wild harvest, and restoration.

Continued work to recognize the cultural services associated with oysters, and enabled through oyster-based livelihoods, is essential. A more comprehensive approach that incorporates multiple regions, industries of varying ages and scales, as well as a larger participant sample would enhance the understanding of cultural services enabled and shaped through work with oysters. More broadly, results presented here illustrate that pursuit of additional work in this area would enrich our knowledge of integrated or linked services as well as the factors that influence their access and delivery. The list of cultural services created as an outcome of this study provides more detail than previously existed related to oyster aquaculture, but it is not complete. This study, however, illustrates the need and provides the necessary foundation for subsequent studies.

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