**Cultural Ecosystem Services Enabled through Work with Shellfish**

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**Highlights:**

- A multi-regional ethnographic study took place with 218 US shellfish industry participants in three US regions: Chesapeake Bay, Gulf of Mexico, and New England.
- The project generated the first comprehensive list of cultural ecosystem services associated with bivalve shellfish.
- Results suggest that work in shellfish aquaculture and wild shellfisheries enable similar benefits.
- Knowledge of shellfish-enabled cultural ecosystem services can enhance management and policy actions with a more complete understanding of bivalve role in social-ecological system.

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**Author contributions**

**Adriane K. Michaelis:** Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Project Administration, Funding Acquisition. **William C. Walton:** Conceptualization, Methodology, Resources, Writing – Review & Editing, Supervision. **Donald Webster:** Conceptualization, Methodology, Resources, Writing – Review & Editing, Supervision. **L. Jen Shaffer:** Conceptualization, Methodology, Resources, Writing – Review & Editing, Supervision, Project Administration, Funding Acquisition.

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## Abstract

Cultural ecosystem services are understudied relative to other types of ecosystem services. This is especially true as they relate to bivalve shellfish. Approaching these services through shellfish-based livelihoods, this study utilized ethnographic field methods to detail the benefits received and enabled by individuals through work with shellfish. A total of 218 shellfish growers, wild harvesters, and others working in roles that support shellfisheries in the United States regions of Chesapeake Bay, Gulf of Mexico, and New England were interviewed to create a list of shellfish-enabled cultural, provisioning, regulating, and supporting ecosystem services as well as their related benefits. Results illustrated that individuals involved in both wild and aquaculture shellfisheries perceive and receive similar benefits, though the interpretation of these benefits may vary depending on industry role. In addition to describing benefits overall, attention was given to linked services as well as how services and benefits may be enhanced or diminished with a changing social-ecological system. The comprehensive dataset is useful for understanding the myriad benefits associated with shellfisheries and provides the foundation necessary for continued research and analysis of shellfish-associated services. Findings underscore the importance of cultural services relative to their noted absence in shellfish management and policy discussions and, ultimately, policy decisions. Beyond shellfisheries, the study showcases the combined utility of a participatory approach and flexible framework with which to describe cultural services.



**Key words:** shellfish, oyster, aquaculture, cultural ecosystem services


## 1 Introduction

The important role bivalves play in supporting ecosystems is well-documented and used to justify management decisions and policies related to shellfish aquaculture. Discussions of bivalve-provided ecosystem services, the benefits obtained from an ecosystem, tend to focus on the ecological rather than the social-ecological and emphasize provisioning, regulating, and supporting services over cultural services (Tables 1 and 2).

***Table 1. Provisioning ecosystem services via bivalve shellfish.*** Documented bivalve provisioning services and benefits, summarized by product and application (Adapted from Michaelis et al., 2020). *Micro-level components of shell and tissue are the materials potentially used in biotechnology.

| **Provisioning Ecosystem Services via Bivalve Shellfish**<br>*Provisioning Services: products obtained directly from the ecosystem (MEA, 2005)* | |
|---|---|
| **Product** | **Application/Benefit** |
| Biotechnology[1*] | Bioengineering, pharmaceuticals |
| Meat/tissue[2] | Food for human consumption |
| Pearls[3] | Jewelry, decorative |
| Shells[4] | Construction materials, chicken grit, fertilizer, food supplements, reef restoration |

**References**: [1](Alleway et al., 2018; Gentry et al., 2019; Northern Economics, Inc., 2009; van der Schaate Olivier et al., 2020), [2](Alleway et al., 2018; Venier et al., 2019), [3](Zhu et al., 2019) [4](Borsje et al., 2011; Brumbaugh and Coen, 2009; Northern Economics, Inc., 2009; van der Schaate Olivier et al., 2020)

***Table 2. Regulating and supporting ecosystem services via bivalve shellfish.*** Documented bivalve regulating and supporting services, summarized by bivalve function, associated processes, and benefits delivered (Adapted from Michaelis et al., 2020).

| **Regulating and Supporting Ecosystem Services via Bivalve Shellfish**<br>*Regulating Services: benefits obtained through regulation of ecosystem processes*<br>*Supporting Services: services necessary for the production of other services (MEA, 2005)* | | |
|---|---|---|
| **Function** | **Process** | **Benefits** |
| Filter-feeding[1] | Phytoplankton control, removal of suspended solids, nutrient removal/sequestration, denitrification, bioaccumulation | Water clarity, nutrient cycling, improved water quality |
| Habitat creation[2] | Sediment stabilization, wave attenuation, | Shoreline protection, adjacent habitat |

| | | |
|---|---|---|
| | foraging grounds, nursery provision, refuge provision, substrate provision | protection, enhanced biodiversity, enhanced productivity (other spp.) |
| Reproduction[3] | Spawning | Genetic diversity/gene flow, population abundance |

**References**: [1](e.g., Beseres Pollack et al., 2013; Bricker et al., 2018; Brumbaugh et al., 2006; Carmichael et al., 2012; Cerco and Noel, 2007; DePiper et al., 2017; Ferreira and Bricker, 2016, 2019; Fukumori et al., 2008; Gifford et al., 2004, 2005; Grabowski et al., 2012; Higgins et al., 2011; Humphries et al., 2016; Kellogg et al., 2013; Kovacs et al., 2010; Newell, 2004; Newell and Koch, 2004; Newell et al., 2005; Peabody and Griffin, 2008; Peterson and Lipcius, 2003; Rose et al., 2014; Songsangjinda et al., 2000; Tang et al., 2011; Ulanowicz and Tuttle, 1992; zu Ermgassen et al., 2013), [2](e.g., Coen et al., 2007; Craeymeersch and Jansen, 2019; Grabowski and Peterson, 2007; Grabowski et al., 2012; Hancock and zu Ermgassen, 2019; Kesler, 2015; Peterson et al., 2003; Peterson and Lipcius, 2003; Piazza et al., 2005; Rodney and Paynter, 2006; Tallman and Forrester, 2007; Waser et al., 2016; Ysaebert et al., 2019), [3](Thompson et al., 2017)

Though underrepresented in research, literature, and the discussions that inform shellfish-related policy, cultural ecosystem services are important motivators toward participation in shellfish aquaculture and warrant greater attention in both industry promotion and ecosystem management (Michaelis et al., 2020). Recognition of their significance is growing, however limited work has specifically identified cultural services enabled by shellfish. Existing literature often poses potential or presumed benefits rather than benefits detailed through structured research, with common reference to impacts on recreation or emblematic use of bivalves in art (e.g., Alleway et al, 2018; Gentry et al, 2019; Michaelis et al., 2020; van der Schatte Olivier et al., 2020). Identifying and understanding shellfish-associated cultural services are necessary to enable more comprehensive, effective, and equitable approaches to aquaculture policy and management, and require a more participatory method than typically used to detail other types of ecosystem services (Blicharska et al., 2017; Cabana et al., 2020; Turner & Daily, 2008). While all ecosystem services are evaluated according to human perception, cultural services especially are actively created and perceived by people (Bieling, 2013; Brondizio et al., 2010; Small et al., 2017). They are directly experienced and intuitively appreciated (Daniel et al., 2012). As such, to adequately capture cultural ecosystem services, in-depth, community-focused efforts are

essential. This study utilized a participatory, ethnographic approach, whereby the lead researcher worked directly with shellfish harvesters, growers, and others to detail the cultural ecosystem services associated with shellfish.[1]

### 1.1 Capturing Cultural Ecosystem Services

Cultural services, defined as the nonmaterial benefits obtained from an ecosystem, are challenging to quantify and even qualify, in part because they may be uniquely experienced by individuals or communities (Gould et al., 2015; MEA, 2005). The value attached to cultural services may be fluid, messy, spatially varied, as well as scale- and context-dependent (Chan et al. 2012b; Church et al., 2014; Small et al., 2017). Relative to other types of services, their inclusion in traditional ecosystem service approaches that target economic valuation is more complicated (e.g., Costanza et al., 1997). Their delivery is often contingent upon other services, making attempts at service or benefit 'counting' difficult (Fisher et al., 2009). The same, however, could also be said of other ecosystem service types and this is no reason to exclude cultural services from management discussions (Costanza et al., 2017). Some question the appropriateness of economic valuation for cultural services, pointing to concerns over the commodification of culture, as well as ambiguity in the term 'culture' (Small et al., 2017; Winthrop, 2014). Many indicate that most ecosystem service frameworks are designed for material values, and thus inclusion of cultural, non-material values necessitates a new vision (Cabana et al., 2020; Chan et al., 2012b; Kirchoff, 2012; Pröpper and Haupts, 2014; Small et al., 2017; Winthrop, 2014). Additionally, common frameworks that include cultural ecosystem

[1] An ethnographic approach utilizes systematic observation in the field, often paired with interviews, recording what is seen and heard and how things are done, in order to learn the meanings that people attribute to what they make and do. It typically involves longer term, face-to-face interaction with research communities (Lecompte and Schensul, 1999).

services may be limiting in terms of how cultural services are categorized or understood in policy and practice (e.g., Costanza et al., 1997; MEA, 2005; TEEB, 2010; CICES, 2017). For a service or benefit category that is so dependent upon individual experiences, it is essential to have a framework that allows for breadth, flexibility, and comprehension.

This study uses the framework introduced by Fish et al. (2016) to understand 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.[2] Using these categories - identities, experiences, and capabilities - to guide cultural ecosystem service analyses provides more flexibility and specificity related to bivalve shellfish and the ecosystems they structure, allowing for a more comprehensive knowledge set. As noted above, because cultural services are directly experienced, it is imperative to understand them from the perspective of those who interact with the ecosystem (Daniel et al., 2012). Targeting ecosystem-based practices using participatory methods allows for more focused discussion of what could be a very expansive task to detail the cultural services associated with an ecosystem (Bryce et al., 2016; Fish et al., 2016; Gould et al., 2015). Ecosystem-based practices, called cultural practices by Fish et al. (2016), are activities that relate people to each other and the natural world. They are human actions, like exercising, that connect an individual to an ecosystem or provide a means for people to utilize that system. Here, shellfish-based livelihoods were used as the focal practice; working as an oyster farmer, for example, is an activity that relates someone to their ecosystem.

This practice-focused approach is a deviation from some conceptions of cultural services. Here, benefits enabled through work with shellfish are investigated. In some frameworks,

[2] This approach to cultural services is also reflected in the framework used by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019).

system-based livelihoods themselves are a cultural service (e.g., Gentry et al., 2019; Haines-Young and Potschin, 2018; TEEB, 2010). This study aimed to show benefits of shellfish-based livelihoods beyond simple employment. Individuals who work in shellfisheries engage with the ecosystem in myriad ways and, likewise, the benefits they enable and receive are numerous. A discussion of the benefits that individuals receive by working in fisheries is not unprecedented and many illustrate high levels of associated job satisfaction (e.g., Pollnac & Poggie, 2006; Smith & Clay, 2010; refer to Michaelis 2020 for review of fisheries-related benefits). This study was the first, however, to focus on shellfish aquaculture using the concept of cultural ecosystem services at this geographic scale and depth of investigation.

The focus on shellfish-based livelihoods to understand cultural services is practical because of the large existing body of knowledge on other shellfish-associated ecosystem services. It is also extremely relevant to management and policy, as communities worldwide consider bivalve aquaculture as a sustainable complement or alternative to traditional wild shellfisheries. In this vein, this study provides a lens with which to understand the sociocultural implications of a transition to shellfish aquaculture. Expansion of shellfish aquaculture involves an increase in the direct ecosystem services provided by bivalves as more shellfish are present in the water, but how might indirect services be affected, and how might this affect human communities within the system? Shifting livelihoods from a public to private fishery via aquaculture may entail a different suite of cultural ecosystem services as well as the potential for both enhanced and diminished services (Garrity-Blake, 2000). A thorough understanding of the full suite of services associated with a system and its fisheries is imperative to predicting how potential changes will affect the system and likewise how fisheries should be effectively and equitably managed.

## 1.2 Objectives

This study detailed the cultural ecosystem services provided by and enabled through work with bivalve shellfish using a multiregional, participatory ethnographic approach. Though targeting communities with varying stages of oyster aquaculture development, all work with shellfish was considered. Work included individuals commercially harvesting wild shellfish in a public fishery, those growing or cultivating farmed shellfish commercially, and those earning income outside of commercial shellfish production but supportive to shellfisheries. In addition to creating a comprehensive list of benefits enabled through work with shellfish, this study aimed to help understand whether farmed shellfisheries provide the same kind of benefits as those already noted of wild fisheries. This study also used the case of shellfish aquaculture to better understand linked services and how ecosystem services change in a dynamic social-ecological system, both areas in need of research within the ecosystem services framework (e.g., Baulcomb et al., 2015; Chan et al., 2012; Costanza et al., 1997; Small et al., 2017; Turner & Daily, 2008).

This project involved a sizable effort to document the cultural ecosystem services associated with shellfish. Aims can be summarized through a series of guiding research questions:

- What are the cultural ecosystem services obtained through work with shellfish?
- Can shellfish aquaculture provide the same types of cultural ecosystem services as wild fisheries?
- How might a transition from wild shellfisheries to shellfish aquaculture affect the delivery of cultural ecosystem services?

# 2 Material and Methods

Research efforts spanned three shellfish-producing regions in the United States, working with individuals earning income from shellfish in a multitude of ways. An integrated approach utilizing participant observation, semi-structured interviews, and photovoice interviews occurred over 15 months of fieldwork. The complete methodological approach is detailed below.

## 2.1 Site Selection

Sites were selected with a focus on oyster aquaculture, though participants worked with multiple shellfish species. Limiting the scope to the natural range and aquaculture production of the eastern oyster (*Crassostrea virginica*), research occurred in three geographically disparate regions: New England, the Chesapeake Bay, and the Gulf of Mexico (Figure 1). To ensure a broad and diverse participant population, and likewise results that represent the industry rather than a single community, sites were selected to include two states in each region with corresponding differences in management approaches, industry ages, and scales of oyster production.

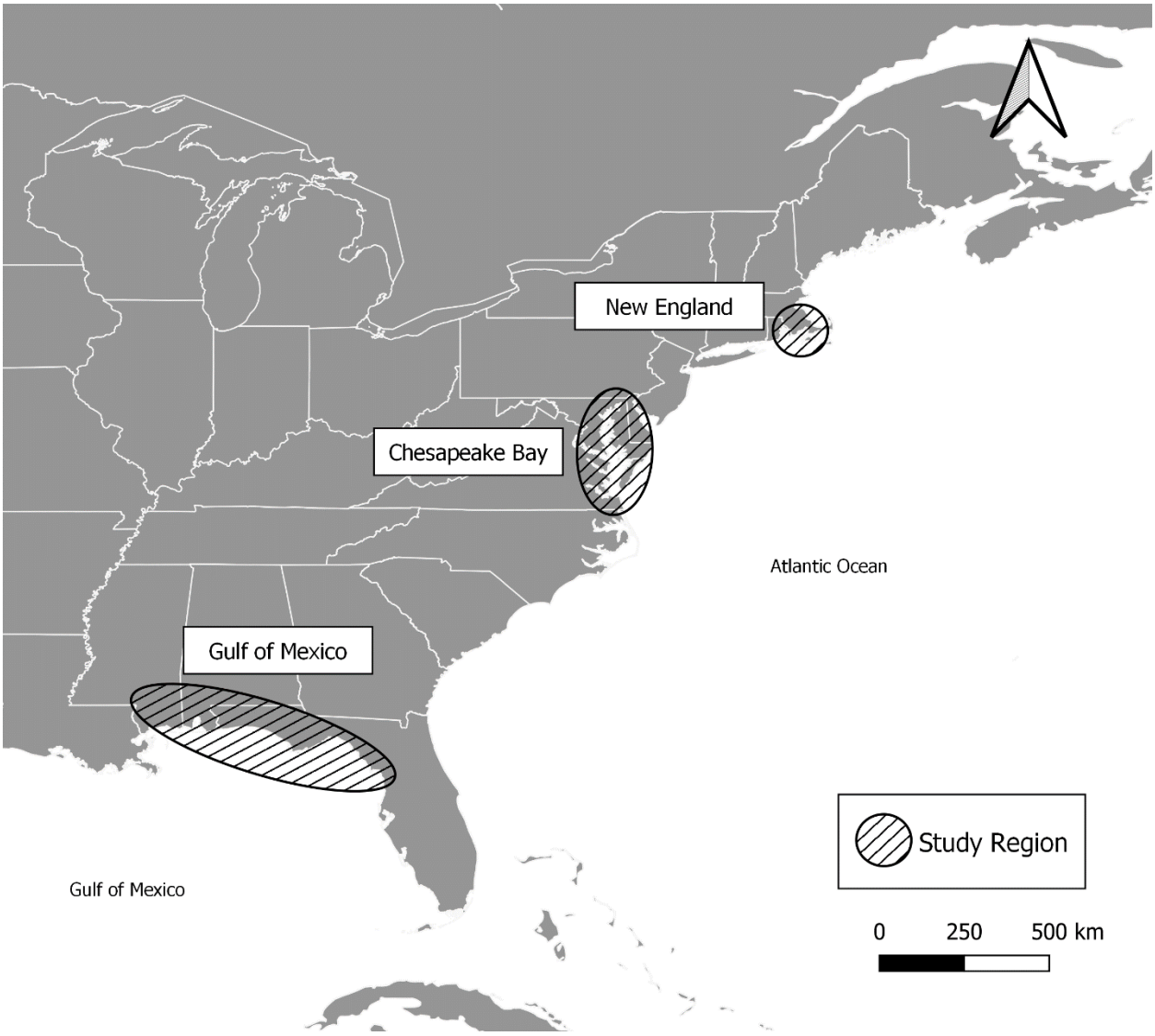


***Figure 1. Regional Study Sites***

Study sites included three regions and seven states within the United States: New England (Rhode Island and Massachusetts), Chesapeake Bay (Virginia and Maryland), and the Gulf of Mexico (Mississippi, Alabama, and Florida). (Map made with QGIS, 2021).

In each state, one site or community was identified as the focal site, but interviews extended beyond the individual city or town. Geographic range within a state was dependent upon travel time and participant interest. Along the Gulf Coast, Mississippi was added as a third state as oyster farmers were in their first year of production nearby. Harvest data are not tracked

similarly among states, making landings comparison impractical, however full site characterization and discussion of production can be found in Michaelis 2020.

### 2.2 Participant Selection

Participant solicitation occurred via a combination of targeted, snowball, and opportunistic sampling. In each region, extension personnel and other industry contacts assisted with introductions to potential participants. Participants were also contacted via email, social media, and telephone using contact information of shellfish farms, fishermen's associations, and other industry associations. All aspects of participant selection and study involvement were approved by the University of Maryland Institutional Review Board (Project Number 1242746).

Participants were selected to represent a broad suite of individuals working in shellfisheries. This included shellfish growers or farmers (aquaculturists), wild shellfish harvesters, and others who earn an income from shellfish in ways beyond production and harvest (Table 3). This latter group, categorized as industry support, included individuals involved in research, regulation, extension, wholesale, gear manufacture, lobbying, industry associations, and other roles. Because commercial fishermen were entering aquaculture from wild fisheries other than shellfish, commercial fishermen involved in all types of wild fisheries were included and are grouped here as "wild harvesters"; the majority, however, had worked with shellfish. In many cases, participants were involved, either presently or in the past, in multiple roles.

***Table 3. Participant Attributes.*** Participants are detailed according to industry role, region, state, gender, and age. *Some participants were involved in more than one industry role.

| **Participant Description** | | **# of Participants (% of 218)** |
|---|---|---|
| **Industry Role*** | Industry Support | 40 (18%) |
| | Shellfish Grower | 176 (81%) |
| | Wild Harvester | 87 (40%) |
| **Region** | Chesapeake Bay | 67 (31%) |

| | | |
|---|---|---|
| | Gulf of Mexico | 91 (42%) |
| | New England | 60 (28%) |
| **State** | Alabama | 34 (16%) |
| | Florida | 51 (23%) |
| | Massachusetts | 24 (11%) |
| | Maryland | 29 (13%) |
| | Mississippi | 5 (2%) |
| | Rhode Island | 36 (17%) |
| | Virginia | 38 (17%) |
| **Gender** | Female | 52 (24%) |
| | Male | 166 (76%) |
| | Other | 0 (0%) |
| **Age** | 18-30 | 50 (23%) |
| | 31-40 | 43 (20%) |
| | 41-50 | 34 (16%) |
| | 51-60 | 39 (18%) |
| | 61-70 | 43 (20%) |
| | > 70 | 9 (4%) |

Participants involved in aquaculture were largely oyster growers (84%), but included clam and mussel growers. For the majority of shellfish grower participants (57%), aquaculture was their only form of income. Shellfish growers entered the industry from a diversity of professions. Of those who left another job to work in aquaculture, 21 were formerly wild harvesters, while 71 entered from other industries.

Representation from all three study regions was obtained, including seven states. Mississippi participants were added opportunistically while working in Alabama; their industry was in its first year, and smaller than other industries. As such, Mississippi was not as represented as other states but provided an interesting perspective from participants who were brand new to the industry.

More male participants took part in the project than female, and this is representative of fisheries at large (FAO, 2013). In terms of age, the number of participants over 70 was less than

other age groups, but all other ages were evenly represented. Race and ethnicity data were not collected.

### 2.3 Data Collection

A thorough description of cultural services can best be achieved through a discursive, open-ended, and participatory approach (Bieling, 2014; Chan et al., 2012; Daniel et al., 2012). This allows for prioritization of what matters to individuals and provides a richness of detail that cannot be achieved with closed-ended questions (Chan et al., 2012). Relevant to the question of linked services, it allows for understanding of influences and interactions between services, activities, and benefits (Chan et al., 2012). Finally, through its embedded rapport-building, a participatory approach enables a better understanding of research between researchers and participants (Chan et al., 2012). With that in mind, a series of complementary data collection methods were employed in this project. Specifically, an ethnographic approach utilizing combined methods of participant observation, semi-structured interviews, and photovoice interviews was employed in order to fully capture participant-perceived and defined benefits of their work. Fieldwork took place between June 2018 and September 2019, when approximately two months were spent in each study state.

Participant observation assisted in further site characterization and enhanced the ability to build rapport with participants. It allowed for greater familiarity with the research site and topic, and enabled a more thorough interpretation of data. The lead researcher worked with participants on their boats and shellfish farms, attended extension programs, and spent time with participants over meals, etc., as invited. This study also presented opportunities to attend industry association and town hall meetings relevant to shellfisheries in several states. This included repeat interactions with participants, as well as conversations with and observations of individuals who

did not participate in interviews. Informal conversations provided additional context and affirmed patterns or group opinions in certain cases, particularly for those wild harvesters not involved in shellfish aquaculture.

Interview methods used in this study yielded more engaged participation than structured interviews or surveys allow. In total, 218 participants were interviewed using a semi-structured approach. Interviews involved a short series of broad questions intended to inspire discussion of work-related benefits that were later coded as ecosystem services (Table 4). Interviews occurred with individual participants as well as in groups, depending on participant preferences. Interviewed participants were also asked to complete a supplementary form that requested information on their involvement with shellfish, specifically: 1) type of shellfish work, 2) length of time in industry, 3) species harvested or cultivated, 4) full or part-time status, and 5) previous occupation if it was left for aquaculture. All interviews were documented via handwritten note-taking and transcribed to an electronic document within 48 hours.

***Table 4. Semi-Structured Interview Guide.*** Questions used to guide interviews are listed.

| **Semi-Structured Interview Questions** |
|---|
| What do you like best about your job? |
| What are some of the good things about [working on the water]/[working on a shellfish farm]/[working in (other shellfish-related role)]? |
| Why did you decide to [fish]/[work on a shellfish farm]/[work in (other role)] instead of another job? |
| What sort of things do you like about your job that you can't quite put a dollar value on? |
| Do you think farming shellfish is much different from other fisheries? How so? |
| What sort of benefits do you get from farming shellfish that you can't get from a public fishery? (And vice-versa) |

Interested participants also took part in photovoice interviews. Photovoice is a form of participatory research in which participants use photographs and stories to identify and represent issues, according to researcher prompts (Nykiforuk et al., 2011). It allows participants to share through photos what may be difficult to explain through words alone (Wang & Burris, 1997). Its enhanced engagement with participants relative to other methods also demonstrates to participants their value and role in the research (Moffitt & Robinson-Vollman, 2004). For researchers, photovoice allows them to better understand the issue at hand as different ideas may be discussed through photos that were not mentioned in other interviews (Nykiforuk et al., 2011). Photovoice interviews created the opportunity for 1) enhanced participant involvement and engagement with the project and 2) a greater likelihood to capture benefits not mentioned in the initial interview. Photovoice interviews were important in this project both to facilitate active researcher-participant relationships as well as generate stronger data.

Photovoice interviews occurred at least one week after semi-structured interviews. All participants were invited but 38 participants (17%) took part in photovoice interviews, representing all regions, study states, and industry role designations. Photovoice participants were asked to provide three to five photos that represented some of the good things, benefits, or aspects they enjoyed about their work. Interviews took place largely in-person, though several occurred over the phone after the researcher had left that study state. Participants were asked to describe their photos through a series of prompts (Table 5). Photovoice interviews were audio-recorded with participant permission and transcribed.

***Table 5. Photovoice Interview Prompts.*** Questions used to guide photovoice interviews are listed.

| **Photovoice Interview Prompts** |
| --- |
| Please describe the image and what it shows. |
| Why did you choose this image? |

What benefits or good aspects of your work are shown?

Is the quality or characteristic you've captured in the image something unique to your work? Why or why not?

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### 2.4 Data Analysis

All interviews - semistructured and photovoice - were transcribed and coded via an open-coding approach using MAXQDA software (VERBI Software, 2019). Interviews were coded using primary themes of cultural, provisioning, and regulating/supporting services. Regulating and supporting services were treated as a single theme because of results detailed in Michaelis et al. (2020) that indicated participants often think of these types of services similarly and broadly. Using themes that the lead researcher compiled throughout fieldwork and interviews, interviews were additionally coded to identify secondary benefit themes (Lewis-Beck, 2004). These themes were based on other cultural service examples identified in the literature as well as novel benefit conceptions that arose through interviews and discussions (Alleway et al., 2018; Barnes-Mauthe et al., 2015; Bryce et al., 2016; Chan et al., 2012; Fish et al., 2016; Raymond et al., 2009). In addition, new benefits were added as identified during the initial coding process.

The complete list of secondary benefits was used to re-code all interviews. This resulted in a list of all types of ecosystem services and the related benefits they provide, as discussed by participants. Benefits were examined and organized to fit within the Fish et al. (2016) cultural services framework, grouping cultural services by their influence on capabilities, experiences, and identities. Provisioning and regulating/supporting services were further categorized to represent the process that yielded each benefit type, similar to the format in Michaelis et al. (2020). Coded data were used to detail linked services and potential changing services, identified in interviews as ways that aquaculture may diminish or enhance particular benefits relative to a wild fishery.

The list of benefits was qualitatively analyzed to compare patterns in frequency of mention. Because interviews were designed to create an overall list of benefits for use in a subsequent study with quantitative analysis, statistical analysis of frequency data was not mathematically practical. For a general understanding and relative comparison, however, the frequency of mention for each benefit was totaled; benefits mentioned by 60 or more participants were identified as "high frequency". Benefits discussed as changing with a transition from a wild fishery into shellfish aquaculture were identified as enhanced or diminished with such a change.

It was not prudent to attempt to quantitatively analyze linked services, services whose delivery was related to that of another service or benefit, but it was useful to illustrate their complexity and integration. To create a suitable visual display of linked services, data were converted to resemble a network dataset. They were organized as a network adjacency matrix and visualized to illustrate benefit relationships as a network plot (Flourish Studio, 2020). This was not carried out as a network analysis and was strictly for data visualization.

## 3 Results

In total, 46 unique benefits enabled through work with shellfish were identified in interviews (Table 6). They are presented by their ecosystem service type as well as subcategories appropriate to each group. Cultural ecosystem services (CES) are organized according to three subcategories: 1) identities framed by work with shellfish, 2) experiences enabled by work with shellfish, and 3) capabilities equipped by work with shellfish. Provisioning services (PES) mentioned by participants are grouped by benefits associated with the production of 1) food and 2) shells. Regulating and supporting services (RSES) as discussed in interviews are detailed by the functions provided by bivalve shellfish: 1) general, 2) filter-feeding, 3) reef formation, and 4) spawning. Appendix 1 describes each benefit, linked services, and frequency of mention.

***Table 6. Ecosystem Services and Benefits Mentioned in Interviews***

Benefits are presented by ecosystem service type and benefit categories. (*) indicates benefits mentioned by more than 60 participants. Perceived change with a transition to aquaculture is noted as: enhanced (+), diminished (-), equivalent (=), or both enhanced and diminished (+/-). Link ID corresponds to Figure 2.

| Ecosystem Service | Benefit Category | Sub-Category | Perceived Change | Link ID |
|---|---|---|---|---|
| **Cultural** | **Identities** | Contribution to community* | +/- | 1 |
| | | Cultural heritage | +/- | 2 |
| | | Family heritage* | +/- | 3 |
| | | Novel occupation* | +/- | 4 |
| | | Occupation | +/- | 5 |
| | | Responsibility of care – environment | + | 6 |
| | | Responsibility of care – husbandry | + | 7 |
| | | Sense of belonging | +/- | 8 |
| | | Sense of place* | +/- | 9 |
| | | Sense of purpose | = | 10 |
| | **Experiences** | Adventure | - | 11 |
| | | Aesthetic appreciation* | - | 12 |
| | | Challenge* | +/- | 13 |
| | | Independence* | +/- | 14 |
| | | Innovation | = | 15 |
| | | Job satisfaction | +/- | 16 |
| | | Lifestyle* | +/- | 17 |
| | | Pride | + | 18 |
| | | Relationship with nature | +/- | 19 |
| | | Safety | + | 20 |
| | | Security and reliability* | +/- | 21 |
| | | Shared experiences | + | 22 |
| | | Social capital* | +/- | 23 |
| | | Spiritualism | = | 24 |
| | | Therapy | +/- | 25 |
| | | Transformation | = | 26 |
| | | Variety* | +/- | 27 |
| | **Capabilities** | Income* | +/- | 28 |
| | | Knowledge* | = | 29 |
| | | Mental health | = | 30 |
| | | Physical health | = | 31 |
| | | Skills | +/- | 32 |
| **Provisioning** | **Food Production** | Food (general)* | = | 33 |
| | | Healthy product | = | 34 |
| | | High quality product | +/- | 35 |
| | | Local product | + | 36 |
| | | Safe product | + | 37 |
| | | Sustainable product* | + | 38 |
| | **Shell Production** | For decorative purposes | = | 39 |
| | | For hobby trade | = | 40 |
| **Regulating and Supporting** | **General** | Environmentally positive* | + | 41 |
| | **Filter Feeding** | Improved water quality | + | 42 |
| | **Reef Formation** | Shoreline protection | + | 43 |
| | | Supports other species and fisheries | +/- | 44 |
| | **Spawning** | Contributes to wild shellfish population | + | 45 |
| | | Supports other species and fisheries | = | 46 |

The methodological approach for this research discouraged placing too much emphasis on frequency of mention for any one benefit, but the data warranted broad qualitative examination. More specific ecosystem function-based RSES were less frequently mentioned relative to other services and also less than the general RSES benefit of 'environmentally positive'; this may be indicative of a valuation pattern which can be assessed in continued work. Several benefits were mentioned by fewer than five participants. Uncommon benefits included two PES connected to the use of shells, one RSES emphasizing how shellfish spawning supports other species, and one CES that focuses on spiritual experiences enabled through work with shellfish. Overall, there was a greater number and diversity of CES benefits mentioned than other types of services, however this is not surprising given the broader definition of cultural ecosystem services. No regional or state-level patterns were observed related to benefits mentioned.

When considering how benefits may change with a transition from wild shellfisheries to shellfish aquaculture, only 2 benefits were recognized overall as diminished with such a transition while 12 were identified as enhanced. Twelve benefits were discussed as unchanged. The remaining twenty benefits were discussed as both enhanced and diminished, depending on participant perspective.

Linked services were evaluated as discussed generally in participant interviews. Interview questions did not specifically target linkages, instead benefits were identified as linked when a participant discussed benefits that were related or whose delivery was contingent upon other services. As such, links identified here are likely an underrepresentation of linked services and benefits in this system and caution should be taken before scrutinizing specific linkages. Even so, visualization of linkage patterns illustrates the complexity of these connections (Figure

2). Interview data suggests that all benefits are linked to at least one other benefit, and many are linked to multiple.

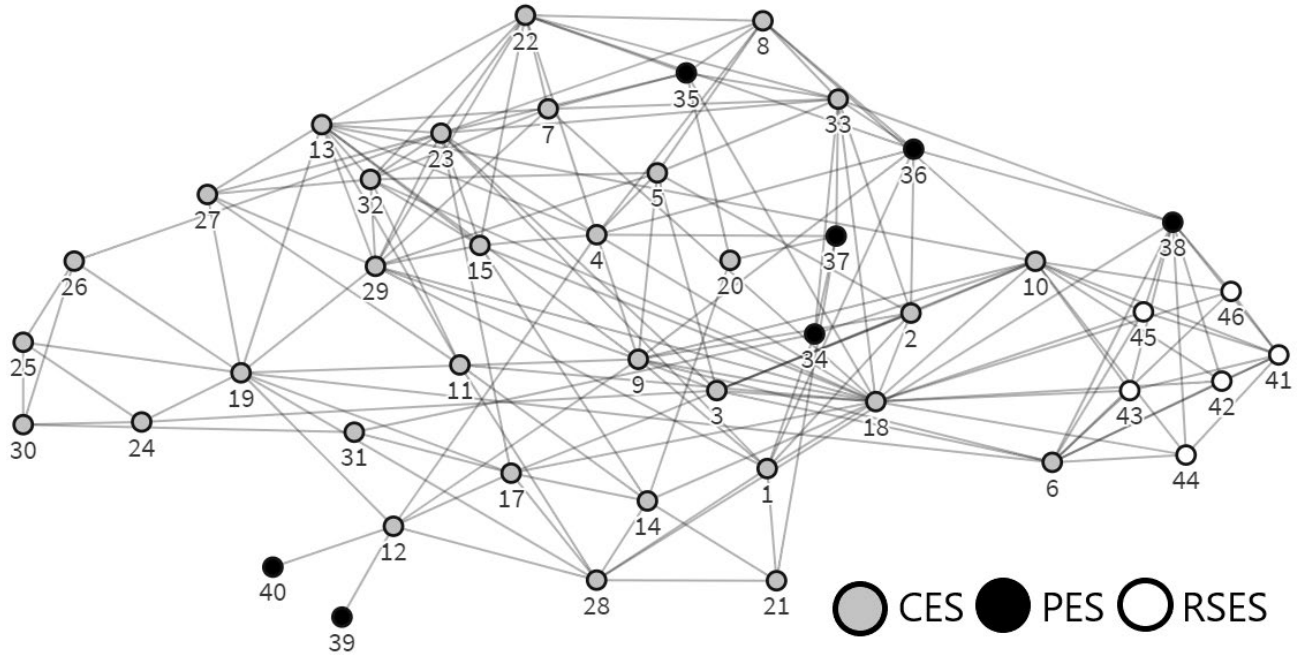


***Figure 2. Visualization of Linked Services.*** Each circular node represents a different benefit, as identified in Table 6. Cultural ecosystem services (CES) are shown in gray, provisioning ecosystem services (PES) in black, and regulating and supporting ecosystem services (RSES) in white. All benefits were linked to at least one other benefit. Job satisfaction (16) is not depicted because it was linked to all benefits. For full details on connections refer to Appendix 1.

## 4 Discussion

### 4.1 Services and Benefits Enabled Through Work with Shellfish

Shellfish harvesters, growers, and others connected to shellfisheries in three regions contributed to the creation of a detailed list of cultural ecosystem services (CES) enabled through work with shellfish (Table 6, Appendix 1). Because interviews broadly targeted the benefits that individuals receive through their work, the list also included provisioning ecosystem services (PES) as well as regulating and supporting ecosystem services (RSES). The complete list is too

lengthy to discuss each benefit in detail here, however, this section features broad discussion with noteworthy examples with quotes from participants. For a full description of all benefits, refer to Appendix 1.

Identified benefits were greater in number and more nuanced when compared to the research that preceded and inspired this study, which focused on motivation to participate in aquaculture (Michaelis et al., 2020). This same prior study presented a synthesis of cultural services affiliated with shellfish to date. As noted, many of the cultural services or benefits suggested previously were potential, presumed, or observed (e.g., the use of shell imagery in classic art), and not necessarily investigated via systematic primary data collection. Similarly, in Michaelis et al. (2020), cultural services were not targeted in interviews and results did not represent a complete list of cultural services or benefits related to shellfish aquaculture. The comprehensive list presented as part of the current study, through its standardized participatory approach, refines and expands the initial list published by Michaelis et al. (2020) and is the first attempt to do so.

Critical to the ability to create such a comprehensive list was the flexibility granted by grouping cultural benefits in terms of identities, experiences, and capabilities. This framework was not as restrictive as others and enabled a broader and clearer understanding of cultural benefits. Compared to other ecosystem service frameworks, this approach was able to capture all of the ways that participants discussed benefits of their work, and did so in a form that can be easily reported back to participants and others. Translatability to resource managers, policy-makers, and resource users is as important as documenting benefits. Here, identities, experiences, and capabilities allowed for greater specificity and rich detail related to bivalve shellfish. In this way, participants helped to identify new benefits and re-envision previously suggested benefits

in more nuanced ways that are more readily accessible and applicable to a broad audience, as illustrated with several benefits below.

Occupational identity is not new to CES discussions, but the idea of a novel occupational identity is (Kaltenborn et al., 2017; Urquhart and Acott, 2013). Participants discussed their occupational identity as a benefit beyond simply *being* a fisherman, a shellfish farmer, or a shellfish biologist, for example. They appreciated the fact that a limited number of people worked in their profession, and that provided a sense of notoriety or even celebrity as described by some.

> *"We're also bringing a product to market that Mississippi chefs can have. Who else is doing that? This is the first opportunity to do that. We're breaking new ground. We're pioneers. I never would have thought that."*
>
> -*Shellfish Farmer*

As with all benefits listed, it is important for resource managers and policy-makers to recognize that a novel occupational identity is something important to shellfish industry members. Additional effort to investigate its value to certain groups over others could be useful in helping to rejuvenate working waterfronts through industry recruitment (i.e., is a novel occupational identity more appealing to those who haven't worked the water before?; Krause et al., 2020; Stoll et al., 2019). Recognizing which benefits are important to different groups can facilitate more productive stakeholder discussions and positively received management outcomes.

Responsibility of care as it related to animal husbandry was also a benefit not seen in other cultural service lists. Distinct from responsibility of care for the environment, in the sense of stewardship or bequest (e.g., Oleson et al., 2015 ), this identity was discussed more as the

satisfaction gained through being a caretaker for oysters, clams, etc. It was largely connected to shellfish aquaculture, both for commercial growers and those involved in industry support. Similar to novel occupational identity, adequately understanding and acknowledging this benefit could contribute to industry development, attract different types of industry participants, and serve to enhance social acceptance or license if it contributes to positive messaging with appropriate target audiences (Baines and Edwards, 2018; Mather and Fanning, 2019; Sinner et al., 2020).

> *"I think that's the most fun part for me about this job - it's a challenge and I look forward to coming in every morning and being able to see the differences between the previous day and the next day. To see if those larvae have progressed a little bit more. It takes usually about two and half weeks to get through that larvae stage, so anything that I can be doing to help them get to that stage… and there's a lot of different variables that go into growing these guys."*
>
> *-Shellfish Hatchery Employee*

Some scholars have indicated the need for better inclusion of social capital in the discussion of ecosystem services (Barnes-Mauthe et al., 2015). Here, social capital was listed as an experience enabled through work with shellfish, and was the most frequently mentioned benefit. Social capital, as the relationships strengthened through work with shellfish, was an appreciated aspect of work. It is slightly surprising that, in a field typified by job-related independence (e.g., Apostle et al., 1985) and with many participants discussing independence as a benefit (>60, expanded on below), social capital would be so frequently mentioned and perhaps highly valued. This high frequency may be indicative of the potential for collective efforts related to shellfish management, such as fishermen's associations and cooperatives, in some settings (Fairbanks, 2016; Pomeroy, 2010).

*"The most gratifying part is the camaraderie. The band of brothers. The shared hardship. I can trust these guys with my life. It's that shared experience of hardships. Figuring out your limits and pushing through them."*

*-Shellfish Farmer*

Though only a few benefits have been highlighted, discussions with participants throughout this project illustrate the recognition of numerous benefits enabled through work with shellfish that, thus far, have not been well-documented or integrated into management and policy decisions. Their absence represents a substantial oversight in attempts to effectively manage resources and gain stakeholder support. As noted above, cultural services are often more important or more salient to individuals because of the way they are experienced and perceived. Effective policy-making must account for these benefits as resource managers and policy-makers play a role in determining what cultural services are delivered, and to whom (Roux et al., 2020). Data suggest that there is much to value within shellfisheries, but delivery of benefits is further complicated by linkages and changing systems.

**4.2 Linked Services**

As indicated above (3), the possibility of linked services was one focus of this study. Interview questions were not designed to exhaustively identify every link, but provided participants the opportunity to discuss how benefits were connected - specifically benefits that were important or valuable. This was most significant, perhaps, as it relates to provisioning services. Although participants mentioned PES, with 2 in the 16 most discussed benefits, what was noteworthy was that participants discussed these services beyond their mere involvement in food production. Many valued being part of the food production process, but this PES benefit

was linked to cultural services. Participants appreciated that they were involved in the production of healthy, high quality, local, safe, or sustainable food.

> *Shellfish Farmer 1: "Having something you know you grew. There's something cool about eating your oysters or clams."*
>
> *Shellfish Farmer 2: "And sharing that with other people. Like a pie that you made or a cookie. Sharing your work with them, you know it's important."*
>
> *Shellfish Farmer 1: "I think you nailed it. Giving someone something [you produced] carries more weight."*

Linked services were present throughout the list of benefits enabled through work with shellfish. Using strictly interview data, every benefit was connected to at least one other benefit. All benefits contributed to overall job satisfaction; thus, job satisfaction was heavily embedded in this 'network' of linked services. Subsequent investigation and theoretical analysis of each individual benefit would likely yield even more relationships. Links highlight the complexity inherent in understanding ecosystem services, a complexity which traditional ecosystem service approaches are not adequately designed to address (Lebreton et al., 2019; Villegas-Palacio et al., 2013; Winthrop, 2014).

Linked services present a challenge when trying to tabulate benefits, as is often attempted with economic valuation. On its own, the appropriateness of economic valuation of services is questioned as some contend that framing ecological problems via market strategies affects the human-nature relationship, potentially in a way detrimental to effective resource management (e.g., Gómez-Baggethun et al., 2010; Kallis et al., 2013; Kosoy & Corbera, 2010; Martínez-Alier, 2002; McCauley, 2006; Rees, 1998; Robertson, 2004; Soma, 2006; Spash, 2008; Turner & Daily, 2008). Others emphasize the need for pluralistic valuation and consideration of socio-

political context, goals, and potential social-ecological outcomes when proposing the valuation of nature (Kallis et al., 2013; Lebreton et al., 2019; Raymond et al., 2014; Small et al., 2017). Linked services and benefits introduce further complication when trying to assign value. In the case of bivalve shellfish, it is likely that ecosystem services have been undervalued with the near absence of cultural services. For example, consider the oyster a farmer sells for 65 cents. The local economic contribution of that oyster can be assessed, even if imperfectly (Northern Economics, Inc. 2013; Botta et al., 2021). Dollar values have been assigned to nutrients it sequestered while in the water, to the extent that oyster farmers can receive nutrient trading credits (Parker and Bricker, 2020). But what about the cultural benefits enabled by growing that oyster, beyond the economic input of the market chain? Some may argue that those are just the sort of benefits that one cannot put a price on, but excluding them from valuation underestimates what that farmed oyster is worth. Understanding these types of connections between benefits is also critical to assess the impact of a social-ecological system transitioning into aquaculture.

### 4.3 Shellfish Aquaculture and Wild Fisheries

In many parts of the United States, commercial fishermen are encouraged to diversify or transition into aquaculture, though shellfish growers have entered the industry from a variety of fields (Michaelis 2020; Stoll et al., 2019). Still, if aquaculture is presented and promoted as a sustainable alternative or supplement to wild harvest, it is important to understand what that transition means for commercial fishermen. Previous work suggests that despite sharing a resource base, aquaculture is not necessarily an obvious or easy transition for wild harvesters (Brugère et al., 2008; Cinner, 2014). With the socio-cultural aspect of this transition in mind, wild fisheries are noted for their high levels of job satisfaction and well-being, and the cultural benefits documented here contribute to both (e.g., Acheson et al., 1980; Gatewood & McCay,

1990; Kaltenborn et al., 2017; Pollnac & Poggie, 1988; Poggie & Gersuny, 1974; Pollnac & Poggie, 2006; Smith, 1981). The question then follows: can commercial fishermen obtain the same types of benefits and associated job satisfaction in shellfish aquaculture? Data from this study suggest that, yes, commercial fishermen can receive similar benefits, however it is not a clean cut answer.

Based on interview questions targeting differences, only two benefits were largely recognized as diminished with a transition from a wild fishery to shellfish aquaculture. The first of these was adventure. Although characteristics resembling adventure were shared related to aquaculture, the thrill of the hunt and risk associated with a wild fishery was perceived as not replicated in aquaculture. This suggests that in areas where commercial fishermen are encouraged to transition into aquaculture, the absence of this benefit may be a key hurdle to their sustained involvement. For many of the wild harvesters interviewed in this project, adventure was a benefit they were prepared to lose, in order to obtain greater stability. Still, many maintained their wild permits (where possible), just in case they "felt the itch". In areas where resource managers hope to see wild harvesters transition into aquaculture, it may behoove harvesters and managers alike to consider options to maintain opportunity for "adventure". For example, managers may investigate possible wild harvest options, even if limited, or collaborative wild population monitoring that mimics the "thrill of the hunt" to complement aquaculture ventures. These are suggestions that would require significant consideration and policy analysis beyond the scope of this study, but illustrate possible ways to maintain this diminished benefit in the midst of an aquaculture transition.

The second benefit diminished in aquaculture was aesthetic appreciation. What was unique about this "diminished" benefit was that participants discussed it not from their own

perspective, but thinking about industry opponents. Participants noted that floating aquaculture gear has been critiqued by property owners who do not wish to see aquaculture operations in their viewshed. Based on interviews, the same is true of property owners' desires to hear and see commercial fishing boats, but participants offered this as one of the aquaculture-associated concerns. This reflects sentiment in other work that showcased perceived public suppression of fishers and farmers (Michaelis et al., in press). From a management and policy perspective this points to an area in need of outreach and community awareness efforts. Social license is one of the noted barriers to aquaculture in the United States, and industry members have accepted this purported diminished benefit, even if they disagree with it (Knapp & Rubino, 2016; Sinner et al., 2008). Beyond this study, question exists over who actually provides social license, how it is defined, and whether the prevailing narrative surrounding aquaculture is driven by the majority or a vocal few (Jenkins, 2018; Sinner et al., 2008). Regardless, social license stigma has pervaded the perceptions of shellfish industry members as observed in this study.

Benefits recognized as enhanced through work with aquaculture totaled 12 and included several benefits connected to the positive ecological effects from adding oysters to the water (N = 4). They also included three PES, emphasizing local, safe, and sustainable food products. Five benefits identified as enhanced via aquaculture were CES. Of these, two were associated with responsibility of care and two connected to the quality of seafood being produced. All of these enhanced benefits represent opportunities for positive press and targeted outreach efforts to improve public awareness of shellfish aquaculture. To date, the ecological benefits (RSES) are routinely mentioned in public relations efforts, and increasingly the ability of shellfish aquaculture to provide safe, healthy, and sustainable protein is promoted, but cultural benefits are typically not featured. Showcasing how shellfish aquaculture can enhance cultural benefits - for

example by contributing to job satisfaction for shellfish growers who act as caretakers of both their waterbody and crops, or providing safe working conditions for local employees - could help to better connect to stakeholders who are under-informed or disinterested.

Twelve benefits were not identified as changed with a transition into aquaculture. Similar to benefits enhanced via aquaculture, these benefits could be utilized in efforts to enhance social acceptance. Particularly in working waterfront communities, the number and type of unchanged benefits suggests that, socioculturally, aquaculture could be a reasonable alternative or supplement in place of declining wild fisheries. This is important both for individuals considering work in shellfish aquaculture, as well as communities debating its introduction or expansion.

Many benefits (N=20) were discussed in contrasting ways by participants; they were perceived as both enhanced and diminished in aquaculture relative to a wild fishery. Of these, one of the more interesting benefits was the CES-enabled experience of independence. It was the third most frequently mentioned benefit overall but was also one of the benefits most associated with wild fisheries in interviews. Still, many shellfish growers, including those who were also wild harvesters, perceived a sense of independence through their work in aquaculture even if it was slightly different from independence associated with a wild fishery. This illustrates that some benefits discussed in contrasting ways may be benefits that are not necessarily enhanced or diminished, simply different. Additional targeted interviews and analysis is necessary to evaluate whether this difference influences overall job satisfaction and well-being.

> *"The best thing I guess is the freedom. I have the ability to work at my own pace. I can do what I want to do – It's not like I'm dedicated to a 9 to 5. I work when I want to work."*
>
> *- Wild Harvester*

In the case of 'independence', the contrasting perception of this change could also connect to concern over large-scale industrialization or corporate involvement in aquaculture (Barnaby and Adams, 2002). This was a worry mentioned in interviews by wild harvesters and shellfish farmers, as it could represent a departure from one of the reasons they entered fisheries or aquaculture initially - the ability to be self-employed. It also is a stakeholder concern for resource managers and policy-makers to think about as aquaculture expands throughout the United States.

Understanding the likelihood of enhanced or diminished services in a shifting social-ecological system is challenging because, especially with cultural services, it is dependent on perceptions. This is reflected in dual perspectives on many of the listed benefits and reiterates the need for pluralistic valuation (Raymond et al., 2014; Small et al., 2017). Incorporating another group with interest in shellfisheries, such as adjacent property owners, would likely yield another perspective on diminished services associated with either type of shellfishery, but recognition of these multiple views is critical.

Focusing on the original question "do farmed shellfisheries provide the same sort of benefits as wild fisheries?," the data here suggested that overall, yes, individuals working with shellfish in an aquaculture setting experienced a similar suite of benefits to those working in a wild fishery. In fact, many who perceived diminished benefits discussed aquaculture without having worked in it. In other words, this perceived diminishment of benefits was an assumed or predicted perception that could change with improved outreach and public awareness efforts. Overall, the data suggest similarly high levels of job satisfaction among wild harvesters and shellfish growers. Interviews suggested that shellfish growers received those benefits and then some, as there were more benefits enhanced through work with aquaculture than diminished. For

those benefits identified as both enhanced and diminished with a hypothetical transition into aquaculture, results underscore the effect of perception and interpretation.

## 5 Conclusion

The list of shellfish-associated ecosystem services is long and wide-ranging (Appendix 1). Approaching this topic targeting 'benefits' more broadly as identities, experiences, and capabilities revealed that individuals involved in shellfisheries receive a wide range of benefits from their work, which includes many cultural ecosystem services (CES), along with benefits enabled through provisioning, regulating, and supporting ecosystem services. The success of this participatory research approach, which integrated mixed methods with a flexible CES framework, supports recent work encouraging expansion of frameworks, methods, and application (Cabana et al., 2020). Additionally, participants produced a highly integrated list of benefits. Linked services were abundant as no single benefit was recognized as a stand-alone category. This connectivity makes counting benefits and services extremely complicated, possibly even ill-advised, echoing the assessments of others (Chan, 2012; Costanza et al., 2017). This list of ecosystem services and benefits enabled through work with shellfish, however, can now be used in more quantitative analyses and fills a gap related to bivalve shellfish and cultural benefits.

This study showed that, for the most part, shellfish aquaculture can provide similar benefits to a wild fishery. This was complicated by differences in interpretation of benefits and how they may be enhanced or diminished with a hypothetical transition from work in wild fisheries to aquaculture. Many benefits (20 out of 46) were discussed as both diminished and enhanced, depending on participant perspective. For effective ecosystem management, it is important to understand how ecosystem service delivery changes within dynamic social-

ecological systems. This study illustrates how complex this task may be with cultural ecosystem services, a group of benefits noted for their associated quantification difficulty. Because cultural services are so dependent upon personal experiences, documenting changing cultural services beyond a homogenous participant population may be a challenging undertaking. In this case, shellfish growers and wild harvesters had different perspectives on how livelihood changes would impact the delivery of cultural services and benefits. Understanding these differences in perception is critical for policy-makers advancing management practices as they attempt to meet both ecosystem and stakeholder needs.

The study presented here was the first to generate a comprehensive list of cultural ecosystem services associated with shellfish aquaculture. Its participatory approach paired with its broad geographic range and participant sample suggest that these benefits should be salient for shellfisheries at large, at least within the eastern US. Such data are valuable and much-needed for resource managers, policy-makers, industry proponents, and others involved in the progression of shellfish aquaculture. The data from this project are useful for the integration of cultural services and social values into resource management and related decision-making. Failure to incorporate these concepts will result in an incomplete understanding of the role that wild and farmed shellfisheries play in a community and hinder resource management and community planning. Similarly, resource managers, community planners, and other leaders must determine whose social values shape management decisions, and ultimately, who has access to the ecosystem services detailed (Roux et al., 2020). Integrating more perspectives, particularly from those working directly with the resource, can yield better management outcomes and a reduced gap between policy and people (Krause et al., 2019).

Finally, the cultural benefits detailed in this study can improve acceptance or social license of shellfish aquaculture in areas where it may be hindered by public opinion. This list of benefits illustrates a suite of positive impacts from shellfish aquaculture that is not usually acknowledged. Sharing these types of benefits with communities can create a higher awareness of the industry and its relationship to community members, as well as contribute to greater trust of the aquaculture industry (Mazur and Curtis, 2008). In this vein, it also provides a pathway for continued research to understand how these newly identified benefits are valued by different groups. Beyond simply knowing that these benefits exist, recognizing the importance different individuals or groups place on each benefit is useful in specifying aspects of the industry that are most valuable in order to foster development of those assets.

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## Appendix 1. Ecosystem Services Enabled Through Work with Shellfish

The ecosystem services and benefits mentioned in interviews with participants are detailed below. Cultural services were broadly targeted during interviews and the resulting list is likely a fairly complete representation of the cultural services enabled through work with shellfish. Other service types – provisioning (PES), regulating and supporting (RSES) – were not specifically targeted and those included here are not meant to represent an exhaustive list of these services. Instead, the provisioning, regulating, and supporting services detailed in this section represent those services that are important perceived benefits to participants interviewed in seven study states for this project. Each category is framed with an example quote from interviews with wild harvesters, commercial fishermen, shellfish growers, and others in roles supportive to shellfisheries.

To illustrate the relative frequency of mention for each benefit, the number of participants who discussed each type of benefit are noted out of the total sample of 218 participants interviewed. Linked services are also listed, but likely do not account for all potential linked services. The number of linkages, however, illustrates the complexity of tracking ecosystem services and how very few are perceived or received as standalone benefits.

### 1 Cultural Ecosystem Services (CES)

Cultural ecosystem services presented below are organized according to three subcategories: 1) identities framed by work with shellfish, 2) experiences enabled by work with shellfish, and 3) capabilities equipped by work with shellfish.

#### 1.1 Identities Framed by Work with Shellfish

1) **Contribution to Community.** Identity is shaped by the ability to contribute to local jobs and market chains through work with shellfish. This includes: providing stable, accessible employment; helping to maintain working waterfronts; reducing the need for out-migration. (N = 96; Linked to CES: cultural heritage, sense of place, security and reliability, social capital.)

   *"The hatchery provides jobs and larvae. Farmers get seed and they get trained workers. That extends to wholesalers [and] the shops that farmers stop at on their way to work. There's a constant chain of jobs and increased labor opportunities."*

   *- Shellfish Hatchery Employee*

2) **Cultural Heritage.** Identity is shaped by local or regional tradition of working the water (fisheries). Work with shellfish allows for continued presence of working waterfronts and contributes to local identity and community pride. (N = 50; Linked to CES: contribution to community, lifestyle, occupation, pride, sense of place; PES: food (general).)

   *"I love the cultural heritage of commercial fisheries. They are huge part of the Chesapeake Bay. I've lived within a block of a creek or river my whole life. I would miss that part if it were gone. But we, as aquaculture people, are developing our own heritage. Massachusetts and Rhode Island are ahead of us, but we've been going here in Virginia 20 years. It's going to be a different kind of cultural heritage but… for example in France, they probably don't even remember a wild oyster fishery. I would like to see a public oyster fishery, but it's more and more difficult to sustain."*

   *- Shellfish Farmer*

3) **Family Heritage**. Family identity and traditions are shaped and strengthened through work with shellfish. (N = 67; Linked to CES: cultural heritage, occupation, sense of place, social capital, spiritualism.)

*"I'm doing what we've done for 5 to 6 generations. Working on the water, being outside, and making a living. I don't know what else you could [adapt]. [Aquaculture's] not exactly what we've done. But it's the same place."*

*- Shellfish Farmer, Former Net-Fisherman*

4) **Novel Occupation**. Beyond an occupational identity, the uniqueness or newness of the job (and/or industry) involves many benefits that contribute to an identity described as: interesting, exciting, mysterious, etc. (N = 66; Linked to CES: challenge, innovation, occupation, sense of belonging, sense of place, shared experiences, social capital; PES: local product, safe product.)

*"We're also bringing a product to market that Mississippi chefs can have. Who else is doing that? This is the first opportunity to do that. We're breaking new ground. We're pioneers. I never would have thought that."*

*- Shellfish Farmer*

5) **Occupation.** Identity is associated with type of work or livelihood activity. This identity is not necessarily connected to a family/cultural tradition, but is an important means of self-identification. (N = 52; Linked to CES: cultural heritage, family heritage, knowledge, sense of belonging, sense of place, skills; PES: food production.)

*"There's no way I could put a dollar value on the amount of friends and people I've met from one end of the bay to another. It's like one big family - watermen. Sometimes we bicker, but we all stick together."*

*- Wild Harvester/Commercial Fisherman*

6) **Responsibility of Care – Environment**. Work with shellfish contributes to an identity based on an active role in and the desire to positively affect the water or environment so that future generations may have the same opportunity to experience it. This identity is

linked to a general feeling of responsibility to be a good steward of the environment. (N = 23; Linked to RSES: all; CES: family heritage, relationship with nature, sense of place.)

*"Leave it better than you found it. Whether my kids decide to do it or not, knowing what I did with my father…the thought that they might not have that option tears me up. Any man should have that option."*

*- Shellfish Farmer*

7) **Responsibility of Care – Husbandry**. Identity is shaped by a perceived responsibility for the care, growth, and success of another animal (in this case, oysters, clams, or other bivalves). Inherent to this identity is the knowledge and ability to understand another animal's needs to identify best cultivation practices. (N = 62; Linked to CES: challenge, knowledge, pride, shared experiences, skills; PES: food (general).

*"I think that's the most fun part for me about this job - it's a challenge and I look forward to coming in every morning and being able to see the differences between the previous day and the next day. To see if those larvae have progressed a little bit more. It takes usually about two and half weeks to get through that larvae stage, so anything that I can be doing to help them get to that stage… and there's a lot of different variables that go into growing these guys. Some variables we control and some variables we can't control. But, that's kind of the job and that's what I like most about it."*

*- Shellfish Hatchery Employee*

8) **Sense of Belonging.** Identity is shaped by being part of a larger, potentially abstract, community with similar interests and goals. (N = 50; Linked to CES: novel occupation, occupation, sense of purpose, shared experiences, social capital; PES: food production (general), high quality food, local food.)

*"It's the people connected with shellfish that I enjoy. Here's your focal point – [the oyster]. It's like any food item that people are passionate about. Our common currency is that we all speak*

*oyster. [Our organization] could have been anywhere. And there are people on diametrically opposite sides, but everybody is here because of oysters. I get so jazzed on the people. No matter how they're involved. It connects people. We all think about how we can do the most good for oysters. It [creates] the opportunity to move forward."*

*- Shellfish Industry Support*

9) **Sense of Place.** Identity is shaped by strong connection to location based on familiarity, history, and/or emotion. In this case, connections are created because of shellfisheries. (N = 69; Linked to CES: aesthetic appreciation, challenge, cultural heritage, family heritage, knowledge, pride, relationship with nature, responsibility of care – environment; PES: local food product.)

*"If shellfish aquaculture had not come to Cedar Key with the net ban, it would be a pseudo-quaint fishing village, filled with condos. Shellfish aquaculture allowed it to remain a fishing, working waterfront community…Cedar Key is unique. The wild fishery is another sector of the community that makes it what it is. It's part of the community. If it's not there, does it matter? Yes."*

*- Shellfish Industry Support*

10) **Sense of Purpose.** Work with shellfish shapes an identity that is based on the sense that you are part of something larger than yourself and/or contributing to a greater good because of your involvement. (N = 32; Linked to CES: challenge, cultural heritage, family heritage, sense of belonging, sense of place; RSES: environmentally positive.)

*"I know this sounds crazy, but I was meant to do the job. My grandfather was a waterman. I grew up around him. Working the water was something I always wanted to do. In school they told you that 'you can't do that'. I was determined to make it work. I saw it as a challenge."*

*- Wild Harvester*

### 1.2 Experiences Enabled Through Work with Shellfish

11) **Adventure**. Work with shellfish provides a sense of thrill, adventure, and/or risk-taking. (N = 26; Linked to CES: challenge, income, pride, security and reliability, skills, variety.)

*"That's what I miss [about wild harvest] – the agony of defeat, the sweetness of victory. Some days you make $500-600, some days nothing."*

*- Shellfish Farmer*

12) **Aesthetic Appreciation**. Work enables the opportunity to enjoy viewing nature/weather/wildlife/scenery. (N = 66; Linked to CES: lifestyle, novel occupation; relationship with nature.)

*"The overall peace and the beauty. I still, even after all these years, am thankful we get to work in this beautiful setting. It's a privilege that we get to use state waters to do this."*

*- Shellfish Farmer*

13) **Challenge**. Work provides an array of challenges and/or continues to be challenging and stimulating. This may include novel, site-specific, or unpredictable problems. Satisfaction is found in responding to and conquering challenges. (N = 66; Linked to CES: adventure, innovation, knowledge, novel occupation, skills, shared experiences, social capital, variety.)

*"I like when no one thinks you can get a load of clams because it's blowing with a Nor'easter and I come in with a load of clams. I love going out on a morning tide when no one thinks you can go. When it's impossible and you do it anyway."*

*- Wild Harvester*

14) **Independence.** This type of work offers a sense of personal control over one's own schedule, effort, practices, etc., that is not available at every job. This enables individuals to experience a sense of independence, freedom, or flexibility because they have a relatively high degree of control. (N = 102; Linked to CES: adventure, income, innovation, lifestyle, safety.)

*"The best thing I guess is the freedom. I have the ability to work at my own pace. I can do what I want to do – it's not like I'm dedicated to a 9 to 5. I work when I want to work. Sure, if I don't go out, I don't make money. [But ultimately, I'm in control]."*

*- Wild Harvester*

15) **Innovation.** Work provides the opportunity to regularly create/design/innovate better ways of doing things or solutions in response to challenges. (N = 55; Linked to CES: challenges, independence, knowledge, novel occupation, skills, pride, shared experiences, social capital.)

*"It's exciting to try and figure this out. I wouldn't mind if it already existed. But I'm energized by the challenges of making a better oyster. I'm dreaming of a system that doesn't exist."*

*- Shellfish Farmer*

16) **Job Satisfaction.** The job contributes to a general feeling of satisfaction and fulfillment. Typically, this experience is shaped or influenced by other services. (N = 55; Linked to all CES.)

*"Job satisfaction. You gotta love it. If you don't love this job, you will grow to hate it. For those of us who love being outside and working hard, it's the best job in the world."*

*- Shellfish Farmer*

17) **Lifestyle.** Job provides a welcome associated lifestyle in terms of practices and environment (rather than income-related lifestyle). For example, work is: on the water,

outdoors, laid back, manual labor. (N = 165; Linked to CES: independence, physical health, pride, relationship with nature, social capital.)

*"I get paid to go out on a boat. I get paid to go swim in the ocean. It's fun. It's a fun job to have. I couldn't think of a better way to make a living."*

*- Shellfish Farmer*

18) **Pride**. Job enables a sense of pride based on role in providing a seafood product, including the work that went into its creation or harvest and the recognition of its quality. (N = 49; Linked to PES: high quality product, food product (general); CES: cultural heritage, contribution to community, family heritage, independence, innovation, knowledge, novel occupation, responsibility of care – husbandry, sense of purpose, skills.)

*"This first photo shows our distributor picking up the very first harvest from us. And we were so proud that we had grown those babies from tiny little seeds up to three-inch oysters and made it on time and got out there to the truck, and everything had worked perfectly. We were very, very proud."*

*- Shellfish Farmer*

19) **Relationship with Nature**. Job allows for an enhanced or unique interaction with and understanding of nature. (N = 62; Linked to CES: aesthetic appreciation, challenge, knowledge, responsibility of care – environment, sense of place, spiritualism.)

*"There are a few things that I like but they all connect to being on the water every day. I'm at the same place every day throughout the seasons. I'm intimately connected to the cycles [of this spot]. It's all the little things that nobody else gets to see. Like when the jellies show up, or when the bullfish show up."*

*- Shellfish Farmer*

20) **Safety.** Work provides a sense of safety for myself, employees, and my customers relative to other jobs. (N = 12; Linked to CES: independence; PES: high quality product, safe product.)

*"The advantage over offshore fishermen is that I get to sleep in my bed. I don't worry about losing my life in a perfect storm. If a hurricane comes, I go home."*

*- Shellfish Farmer*

21) **Security and Reliability**. Work provides stability both in terms of income, even if supplemental, as well as ability to send product to market, relative to similar jobs in area. (N = 98; Linked to CES: contribution to community, independence; PES: safe product.)

*"Shellfish aquaculture can be organized to get a fresher product to market. It doesn't have to get harvested then sold, you can plan based on sales when and what to harvest."*

*- Shellfish Farmer/Former Wild Harvester*

22) **Shared Experiences.** Work enables shared experiences with others. (N = 50; Linked to CES: knowledge, responsibility of care – husbandry, skills, social capital; PES: food (general).)

*"We do tours quite frequently here. Planned and unplanned. So we've got a lot of people [who] come through... And I think what's really cool about this part is that we're all just buried in our work every single day, whether it's me with larvae, or somebody else in broodstock, our algae person who's working hard in algae. And it's nice to be able to step back and be able to talk to people about what we do. And share our passion and share our knowledge with the public. I think that's probably what I like most about this job – being able to communicate with the public and just seeing the curiosity and the wonder on their faces when they come here. Most people know what an adult oyster looks like but not many people know what a larval oyster looks like. Or what*

*algae looks like under the microscope. And people seeing that for the first time, I think it kind of opens up their eyes a little bit."*

*- Shellfish Hatchery Employee*

23) **Social Capital.** The job has strengthened or created connections to or relationships with other people. This includes: related camaraderie, teamwork, and connections to people both in and outside of industry. (N = 165; Linked to CES: challenge, knowledge, sense of belonging, shared experiences, skills.)

*"The most gratifying part is the camaraderie. The band of brothers. The shared hardship. I can trust these guys with my life. It's that shared experience of hardships. Figuring out your limits and pushing through them."*

*- Shellfish Farmer*

24) **Spiritualism.** Job provides the opportunity for a spiritual connection or experience related to shellfish and/or work. (N = 4; Linked to CES: mental health, relationship with nature, therapy.)

*"The nonverbal stuff is very large with oysters. There's a deep connectivity to everybody and everything before us. When you handle something associated with them, that ain't of this time. There was a time when mostly everybody of the world was eating oysters. The spiritual presence. It's there."*

*- Shellfish Farmer*

25) **Therapy.** Work creates a sense of escape, relief, or peace that is calming. (N = 28; Linked to CES: mental health, relationship with nature, transformation.)

*"No oysterman has ever needed a therapist. Especially when you're out by yourself, you have all the time in the world to think about whatever is on your mind."*

*- Wild Harvester*

26) **Transformation**. Job enabled a positive transformation in life. It is more fulfilling than prior work, provides new opportunities, and/or enabled a positive change. (N = 21; Linked to CES: mental health, therapy, relationship with nature, social capital.)

*"[This] was my hometown. It was weird coming back. Life was not good. But the flats saved me. I met [my wife]. She brought me to the river and I started oystering. I carried a clam hoe with me still, it was like a pacifier. And underneath the oyster beds, it was quahog central. I demolished the quahogs. I got 5 bushels a tide because there was nobody digging them. Within 5 years, I'd cleaned up."*

*- Wild Harvester*

27) **Variety.** Duties of the job are diverse and dynamic. This variety and variability keep work interesting. (N = 76; Linked to CES: challenge, knowledge, relationship with nature, skills, social capital.)

*"There's a lot of diversity in what you do day to day. I get to wear a lot of hats, without it getting too complicated."*

*- Shellfish Farmer*

### 1.3 Capabilities Equipped Through Work with Shellfish

28) **Income.** Job provides a source of income that exceeds other job opportunities in some way. (N = 86; Linked to CES: aesthetic appreciation, contribution to community, lifestyle, relationship with nature, security and reliability. Paired with many other CES, work in shellfisheries is a way to make money that enables another benefit. RSES: sustainable product.)

*"It's good money and I don't have to go out of town to make it. I don't have to leave my kids."*

*- Shellfish Farmer*

29) **Knowledge.** Work involves hands-on and continuous learning, innovation, and discovery. It allows the application of previous knowledge. Work may also involve knowledge-sharing with others (customers, coworkers, scientists, etc.). (N = 100; Linked to CES: challenge, contribution to community, innovation, relationship with nature, shared experience, skills, social bonds, variety.)

*"It's been really interesting to learn about the benefits of raising oysters this way and helping the state to increase production of oysters. I've been preaching oyster farming to everyone we know and meet. I get excited and want to learn more. I enjoy telling our story. It's the lagniappe. The lagniappe is that I'm excited about growing oysters, and making money, and eating them."*

*- Shellfish Farmer*

30) **Mental Health**. Work provides an opportunity to reduce stress and anxiety, contributing to overall mental health. (N = 9; Linked to CES: spiritualism, therapy, transformation.

*"And emotional [benefits] too. It saves me. Every day. I don't know that I'd be alive without it."*

*- Wild Harvester*

31) **Physical Health.** Shellfish work is an active job that is physically demanding. It contributes to overall physical health and ability, as well as providing an associated satisfaction in the hard work completed. (N = 37; Linked to CES: job satisfaction, lifestyle, mental health; PES: healthy product.)

*"Mental [and physical] health. I'm someone that gets particularly stressed and anxious without full understanding and control of each day. Being out here knocks off a lot of the essentials I need to be happy. Like being physically active. My heart is always racing. My body is always pushing. I really feel like I'm working physically."*

*- Shellfish Farmer*

32) **Skills.** Work involves constant acquisition of new skills, as well as the ability to apply previously gained skills. Work overall contributes to a diverse skill set. (N = 63; Linked to CES: innovation, job satisfaction, knowledge, pride, shared experiences, social capital, variety.)

*"The ability to be creative is a big thing. And this job combines so much of my background – business, fishing, boat-building. It allows for a little bit of everything. Not many people get to do that and combine their life experiences to do something that they are perfectly suited for."*

*- Shellfish Farmer*

## 2 Provisioning Ecosystem Services (PES)

Provisioning services mentioned by participants are grouped by benefits associated with the production of food (2.1) and shells (2.2).

### 2.1 Food Production

33) **Food (General).** Work entails producing a food item for self or others to consume. (N = 75; Linked to CES: pride, shared experiences, social capital.)

*Shellfish Farmer 1: "Having something you know you grew. There's something cool about eating your oysters or clams."*

*Shellfish Farmer 2: "And sharing that with other people. Like a pie that you made or a cookie. Sharing your work with them, you know it's important."*

*Shellfish Farmer 1: "I think you nailed it. Giving someone something [you produced] carries more weight."*

*- Shellfish Farmers*

34) **Healthy Product.** Work entails producing a food item that is a healthy source of protein. (N = 8; Linked to CES: contribution to community, sense of purpose; PES: food (general).)

*"And at the end of the day, you are what you eat. What about what you're eating is eating? [Farmed shellfish are] good for you compared to steroid-[company] chicken and beef."*

*- Shellfish Hatchery Employee*

35) **High Quality Product.** Work involves producing a high-quality food item. (N = 57; Linked to CES: responsibility of care – husbandry, pride, shared experiences, social capital; PES: food (general).)

*"That's what it's all about. This is a picture of a shucked several dozen of our oysters. This is at [a] restaurant in [Alabama]. And it's really what we look for. They're firm, full meats, a lot of glycogen. You can see by how thick the meats are. The shells are very white, which indicates very low incidence of mud worms. That's really the target product that we shoot for. Clean oysters, no blemishes on the shell, so it's a nice, white shell when people eat it; it looks clean."*

*- Shellfish Farmer*

36) **Local Product.** Work involves producing a local food item. (N = 34; Linked to CES: cultural heritage, contribution to community, sense of place, shared experiences; PES: Food (general).)

*"One of the best things I anticipate is being able to provide Mississippi oysters to Mississippi chefs. I like working with chefs... I'm excited to see what they can do with our oysters. I see how fast the market can grow when we send a Mississippi-produced farmed oyster."*

*- Shellfish Farmer*

37) **Safe Product.** Work involves producing a fresh and safe food item. (N = 11; Linked to CES: safety; PES: food (general), healthy product.)

*"Oysters are great sources of protein. And it allows for a unique opportunity to help with seafood safety. Growers can prepare oysters ahead of time for harvest, so that they can get them in refrigeration within the allotted time."*

*- Shellfish Industry Support*

38) **Sustainable Product.** Work involves producing a food item in a sustainable manner. (N = 64; Linked to CES: responsibility of care – environment; PES: food (general), local product.)

*"Knowing that you're providing something good for the environment and the world. It's a good product for people to enjoy and to eat."*

*- Shellfish Farmer*

**2.2 Shell Production**

39) **For Decorative Purposes.** Work involves producing shell that can be used to make jewelry and other decorative items. (N = 2; Linked to CES: aesthetic appreciation.)

*"Because we own shells, we can use the shells for anything. Like jewelry. There's a variety of shells. And I haven't done anything with them."*

*- Shellfish Farmer*

40) **For Hobby Trade.** Work involves producing shells that can be collected as a hobby. (N = 2; Linked to CES: aesthetic appreciation.)

*"This is when we first got our very first batch of babies, 10 thousand. They were about the size of my little fingernail and we were just amazed at how they looked, even how they felt. And I was amazed that they were seashells because you know, I'm a seashell fanatic. And they were little, tiny, baby seashells, and they were beautiful."*

*- Shellfish Farmer*

**3 Regulating and Supporting Ecosystem Services (RSES)**

Regulating and supporting services as discussed in interviews are detailed by the functions provided by bivalve shellfish: filter-feeding (3.2), reef formation (3.3), and spawning (3.4).

**3.1 General**

41) **Environmentally Positive.** Work is part of an industry that benefits the environment rather than negatively impact it. (N = 87; Linked to CES: responsibility of care – environment; PES: sustainable product.)

*"Environmentally, it's doing everything we would want for this river and more. It's a way to give back."*

*- Shellfish Farmer*

### 3.2 Filter Feeding

42) **Improved Water Quality.** Generally, work with shellfish, through the presence of filtering bivalves, contributes to better water quality and overall waterbody health. Specifically, work with shellfish reduces excess nutrients, algae blooms, and toxins while enhancing submerged aquatic vegetation and human health. Participants valued this aspect of their work. (N = 52; Linked to CES: pride, responsibility of care - environment, sense of purpose; PES: sustainable product; RSES: environmentally positive.)

*"And as a side-benefit, we're saving the bay. In that sense, it's honest work and we're helping the bay. We all generally care about water quality. We take our kids out to the sandbar. We want the bay to be clean."*

*- Shellfish Farmer*

### 3.3 Reef Formation

43) **Shoreline Protection.** Work contributes to shoreline protection by helping to create living shorelines to buffer storm surge and reduce erosion. (N = 7; Linked to CES: pride, responsibility of care, sense of purpose; PES: sustainable product; RSES: environmentally positive.)

*"For both of us, we'd been looking for some sort of business [to start] and found one that was a good fit. As we looked at solutions for erosion control [at our family property], we learned about oyster aquaculture."*

*- Shellfish Farmer*

44) **Supports Other Species and Fisheries.** Work with shellfish provides habitat/refuge for other species (and substrate for spat), often in previously barren areas. It also enhances the abundance and diversity of reef species - including commercial and recreational fishery catch. (N = 51; Linked to CES: pride, responsibility of care - environment, sense of purpose; PES: sustainable product; RSES: environmentally positive.)

*"I never thought [the farm] would become an artificial reef. I've got the best diving in the state. There's double the biodiversity on and in my cages compared to in the nearby eelgrass. That's an absolutely unexpected side benefit. Seeing that diversity. Now I take my kids fishing by the lease."*

*- Shellfish Farmer*

### 3.4 Spawning

45) **Contributes to Wild Shellfish Population.** Specific to oysters, work enhances number of diploid oysters, which spawn and add both numbers and genetic diversity to wild oyster population. (N = 36; Linked to CES: pride, responsibility of care – environment, sense of purpose; PES: sustainable product; RSES: environmentally positive.)

*"Aquaculture has redeeming qualities. It doesn't impact the wild fishery, and in fact complements it."*

*- Shellfish Farmer*

46) **Supports other Species and Fisheries.** Larvae, spat, and adult oysters resulting from work are a food source for other species, including some commercial and recreational

fish and crab species. (N = 3; Linked to CES: pride, responsibility of care - environment, sense of purpose; PES: sustainable product; RSES: environmentally positive.)

*"It's all about habitat, cover, and food. One oyster produces 50 million larvae. Other animals eat it. Everything is growing quick. There are gigantic schools of drum. Recreational fishermen are all around because it's great around all oyster aquaculture."*

*- Shellfish Farmer*