When Cleaning Too Much Pollution Can Be a Bad Thing: A Field Experiment of Consumer Demand for Oysters

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Abstract
Oysters are a special kind of green product. They filter phytoplankton from water and thereby reduce nutrients, the primary driver of eutrophication of water that can consequently harm human health. Yet, where they can provide the most ecosystem benefit is in highly eutrophic waters and being raised in these 'polluted' waters may be an unattractive attribute for consumers. In this research, we use revealed-preference dichotomous-choice field experiments to test if and under what pollution mitigation circumstances oyster consumers will pay price premiums for oysters. The results from 290 adult participants in the Mid-Atlantic of the US suggest that providing information about eutrophication and oysters' ability to filter nutrients increases participants' WTP price premiums for oysters from low-nutrient waters and decreases their WTP price premiums for oysters from eutrophic waters with more nutrients. These results illustrate an important tension in how best to market green products like oysters, as the situations where they provide the most ecosystem benefits (in eutrophic waters) are also situations, which appear to raise the highest level of concerns amongst consumers. These results have implications on whether oysters should be actively marketed as a green product.

Keywords: Experimental economics, consumer behavior, provision of ecosystem services, oysters

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1. Introduction

Oysters are a unique kind of green product. They filter phytoplankton from water, which serves as a food source (helping oysters grow and reach marketable size), at which point oysters are harvested, thereby effectively removing nutrients from waters that are potentially suffering from eutrophication. Unlike other green products, such as shade-grown coffee, where the provision of the ecosystem services does not invoke any food safety concerns amongst consumers, oysters' provision of ecosystem services (filtering pollution out of water) may be viewed by consumers as a food safety risk. Therefore, there exists an inherent tension between potential safety concerns and the positive externalities provided by oysters, which are greatest the more eutrophic the body of water. In other words, when oysters are identified as being raised in waters that suffer from eutrophication they may induce disgust or concerns about contamination for consumers. This may create potential challenges for marketing oysters as a pollution reduction practice that not only provides these ecosystem services but is a desirable and profitable food source.

To our knowledge, consumers' willingness-to-pay (WTP) for water quality ecosystem services provided by oysters has not been studied. Based on earlier findings related to green markets, one might assume that oysters, being a green product, would fetch a price premium in the market. The literature on contamination and disgust, however, suggests that consumers might actually pay less for oysters that were produced in water polluted by nutrients. We designed a revealed-preference dichotomous-choice field experiment to examine consumers' WTP a premium for oysters that provide water quality ecosystem services using three information treatments. The results from 290 adult consumers suggest that participants will pay higher prices for oysters when provided with information about the oysters' ability to filter water and the nutrient level of the water from which the oysters were harvested. Furthermore, participants were more likely to buy oysters produced in eutrophic water in our baseline treatment in which no information was provided. However, the more information participants received about the oysters' ability to filter water and eutrophication problems, the less likely they were to purchase oysters from areas that had moderate to high nutrient waters.

According to the U.S. Environmental Protection Agency (EPA), "Nutrient pollution … is one of America's most widespread, costly and challenging environmental problems" (EPA 2012). Howarth et al. (2002) found that 60% of coastal rivers and bays in the United States had been moderately to severely degraded by eutrophication, a process in which an excess of organic nutrients builds up in a water body. Mid-Atlantic estuaries in the US have been the most severely impaired by eutrophication (Bricker 2007, Driscoll et al. 2003), which has caused overgrowths of algae that reduce the amount of oxygen in the water. The lack of oxygen in turn damages the plants and animals that inhabit the water. Consequently, eutrophication threatens the health of many estuarine systems and coastal zones, which are among the most productive ecosystems in the world (Agardy 1997).

Eutrophication is associated with substantial economic impacts (Smith and Schindler 2009, Anderson et al. 2000, Palm-Forster et al. 2016). A study by Dodds et al. (2009) estimated that the United States suffered annual losses of approximately $2.2 billion related to decreases in recreational use, declining real estate values, the cost of recovery efforts for endangered species, and loss of drinking water supplies. Similarly, Smith and Schindler (2009) estimated the cost of eutrophication pertaining to fisheries, drinking water, and human and livestock health in the billions of U.S. dollars per year.

Eutrophication and resulting algal overgrowths also affect human health. Dolah et al. (2001) point to the economic impacts from healthcare-related costs linked to blooms of toxic algae and the need to understand current and future impediments to provide improved risk assessments (see also Hoagland et al. 2002 and Granéli and Turner 2006). These problems, however, are not confined to the United States; similar impacts have been reported in Europe and China (Camargo and Alonso 2006, Giles 2005, Kronvang et al. 2008, Leone et al. 2009, Woodward et al. 2012, Le et al. 2010).

One way to manage nutrient pollution is by employing water quality ecosystem services provided by shellfish aquaculture. Oysters, for example, are suspension feeders that consume phytoplankton and thereby reduce the amount of organic matter in the water, reducing eutrophication (Kirby and Miller 2005). Oyster aquaculture is a versatile industry that provides a renewable and consumable private good along with ecosystem services, which are public goods, from estuaries and other water bodies. Rose et al. (2015) showed that oyster aquaculture can outperform other commonly applied best management practices for removing nitrogen on a per-acre basis and thus can provide a cost-effective management tool. The U.S. National Oceanic and Atmospheric Administration (NOAA) supports using shellfish aquaculture to remove nutrients and eliminate eutrophication (National Center for Coastal Ocean Science (NCCOS) 2015).

Unfortunately, in the Chesapeake and Delaware Bay, oyster numbers have declined by 90–99% from historic numbers due to disease and overfishing, and globally, 85% of all oyster reefs have collapsed (Beck et al. 2009). NOAA’s Chesapeake Bay office estimates that oysters once were able to filter the entire Chesapeake Bay in one week, providing a substantial public service (National Oceanic and Atmospheric Administration 2015). A major concern associated with private investment in oyster aquaculture in the Mid-Atlantic is that market prices for oysters are likely to understate their true societal value, because their provision of ecosystem services are not included in the price and thus may lead to underinvestment, which translate to under-provision of the ecosystem services.

One potential solution is the “green” market for local, environmentally friendly goods. Products demanded from green markets are impure public goods because they display characteristics of both public and private goods. They can be provided privately but increase social welfare in the process (Vandermerwe and Oliff 1990, Ferraro et al. 2005). The expansion of green markets is largely due to consumers’ willingness to pay (WTP) price premiums for goods that exhibit environmental benefits. Examples of green products are electricity generated by renewable energy, eco-tourism, pollination services provided by honey, organic produce, and shade-grown coffee (Wu et al. 2015; Messer et al. 2000). Laroche et al. (2001) reported on then increasingly environmentally conscious market place, and Coddington (1990) found that 67% of Americans reported being willing to pay 5–10% more for environmentally friendly goods. Markets for foods labeled as environmentally friendly has experienced strong growth both nationally and internationally with more than 450 different types of eco-labels (Ecolabel Index 2015; Messer et al., 2017; CAST 2015). Certified organic food labels, among others, is an example for foods that are perceived as reducing the environmental footprint. Bernard and Mathios (2005), for example, used scanner data and found that individuals were willing to pay a $0.73 price premium for milk that was labeled as organic versus conventional milk. Kanter et al. (2009) showed that participants in an experiment were willing to pay a $0.29 price premium for milk that was labeled as organic compared to conventional milk. Dhar and Foltz (2005) and Lui et al. (2013) find that individuals place considerable value onto organic and rbST-free milk resulting in their WTP significant price premiums for these attributes. Moreover, Blend and van Ravenswaay (1999) showed that more than 40% of individuals were willing to pay a price premium of $0.40 per pound of apples that had an eco-label attached to them. Similarly, labels pertaining to sustainable practices (such as organic) have been shown to generate price premiums (Loureiro et al. 2002).

On the other hand, consumers have concerns when oysters are identified as being raised in waters that suffered from eutrophication. Some of these responses may be reflected by disgust while other individual responses may be the result of actual fear of bodily harm. According to James et al. (2010) there are five major toxic syndromes in humans associated with harmful algal blooms (paralytic shellfish poisoning, diarrhoetic shellfish poisoning, neurotoxic shellfish poisoning, amnesic shellfish poisoning and azaspiracid poisoning). However, Smayda (1997) reports that only 60-80 of the 3,400 – 4,100 phytoplankton species, about 2%, are harmful. In the United States, State programs are responsible for managing estuary health and prohibit harvest of oysters during harmful algae blooms. Therefore, all marketable oysters are expected to be safe[1] for human consumption. However, people may still perceive oysters harvested from nutrient rich waters as potentially dangerous and react by shunning the consumption. Kecinski et al. (2016) showed that some consumers shun items despite the lack of an objective or scientific risk. Furthermore, Hansen et al. (2003) point out that decision makers assess food risks on the grounds of personal value systems. Slovic (1987) argues that individuals risk perception is driven

[1] Note, there are risks associated with consuming raw seafood, including oysters. Therefore, when we say "safe", we are referring to risks that are considered normal for raw seafood consumption. Furthermore, harmful bacteria accumulations in estuaries such as V. vulnificus and V. parahaemolyticus are generally associated with warmer water temperature, hence the "old" rule of thumb to consume oysters during months that contain the letter "r" and avoid the warmer months (May-August). Our experiments were carried out during March and April. Additionally, the National Shellfish Sanitation Program requires that oysters harvested for raw consumption to meet specific time-to-temperature requirement during months when water temperature exceeds 26.6 degrees centigrade (Froelich and Noble 2016).

by the potential for catastrophic risk and unknown risk, whereas Klein and Kunda (1994) report on individuals' preferences for controllable risks – oysters harvested from a water column may be perceived as "having little control" over the water quality and potential contaminants.

Few economic studies have examined the preferences for oysters. Bruner et al. (2014) used an experimental auction to measure consumers' WTP for traditional raw oysters versus postharvest-processed raw oysters. Though postharvest-processing reduces the health risks associated with eating raw oysters, the authors showed that consumers had greater WTP for traditional raw oysters than for processed ones. Dedah et al. (2011) looked at the impacts of oyster demand and labels warning of serious illness and death among people who suffered from liver disease, chronic illnesses, and weakened immune systems after consuming raw oysters. They found that such warning labels reduced demand for oysters from the Chesapeake and Gulf regions but increased demand for oysters from the Pacific region and imported oysters. Two studies, (a) Li et al. (2017) and (b) Kecinski et al. (2017) use experimental economics to study oyster demand. Specifically, (a) looked at demographic factors that make consumers more likely to select different type of oysters, such as how older consumers are relatively less likely to purchase oysters; whereas as (b) studied the importance of brand, locality and aquaculture on purchase decision, suggesting that more experienced consumers prefer aquaculture oysters.

2. Experimental Design

This field experiment consists of a simple dichotomous choice design. Dichotomous choice experiments, also known as posted-price experiments, have a binary decision structure (yes/no). Participants choose whether to purchase a good or perform a task at a posted price. Wu et al. (2014) showed that dichotomous choice designs could provide more-realistic estimates of WTP than an auction design. Arrow et al. (1993) recommended using dichotomous choice questions because they provided a more realistic decision situation. Another reason why we decided to use a dichotomous choice setting for our experiments, as opposed to, for example an auction design, was that we wanted participants to be confronted with decisions that resembled "real-life" decision-making, such as the ones confronted in a grocery store or restaurant, where individuals make simple yes/no decisions concerning a product. The advantage of dichotomous choice decision-making is that the decision environment is simple. However, more data is required to draw similar conclusions and WTP estimates compared to, for example, an auction design, which is why we collected 2,320 observations. After the participant had made decisions on all eight of the purchasing decisions, one of the purchasing decisions was randomly selected and implemented for determination of whether they purchased the oysters.

As described in the experiment instructions (see Appendix A), participants were told they would each receive $10 as an initial balance and could use this money to purchase oysters. For the randomly selected decision, if the participant had decided *to not purchase* any oysters at the posted price, the administrator gave each participant $10 at the end of the experiment. On the other hand, if, for the randomly selected decision, the participant had decided *to purchase* the oysters at the posted price, that amount was subtracted from their $10 balance, and the participants received whatever funds remained plus the oysters.

Participants could choose between purchasing three, six, nine or twelve oysters.[2] Note, irrespective of participants' quantity decisions, all faced the same treatments, therefore

[2] Typically in a restaurant setting, oysters are sold by the dozen or half dozen.

endogeneity through self-selection does not present a problem[3] – it does, however, provide an indicator for participants' quantity preferences. The posted price varied for each of the purchasing decision. These per oyster prices prices were randomly drawn from a normal distribution with a mean of $1.50 and standard deviation of $0.50.[4] Note that since the quantity of oysters was selected by the participants, the total price of the oysters could exceed $10. In this case, participants would use personal funds to make up the difference. Cash, checks, and credit cards were accepted. This possibility of having the total cost of oysters was explicit in the consent form and in the instructions (see Appendix A). Of course, the participants had the opportunity to say "no" to all of the purchase decisions, which would ensure that they would not buy any oyster and keep the entire $10.

Furthermore, participants were offered to have their oysters put in a bag of ice to be taken home or they could be eaten on site either raw (on the half-shell) or fried. All oysters were purchased from a local seafood store that was able to order the oyster from a variety of places in the United States. The oysters were shucked and presented by a professional shucking service to meet all food safety requirements and ensure that participants received the oysters to consume in about the same amount of time as would be required at a restaurant.

The participants made all of their purchasing decisions on mobile computer tablets in an area separate from the oyster table to ensure that their decisions would not be affected by conversations taking place at the oyster table. Thus, the participants made their decisions in a physical space that could not see the oysters nor were the participants allowed to taste the oysters

[3] Endogeneity would have been a problem had participants made their quantity decision prior to consuming oysters, as regular consumers, who may have more fully formed preferences would be less effected by considering how they would consume them, hence, we placed the order of the quantity decision up front.
[4] This range of prices was consistent with market prices at restaurants and retail stores in the United States at the time of the research.

before making their purchase decisions. Upon making their purchase decisions, participants were able to view the shucking and inspect the oysters, which were presented at a table.

Adult participants were recruited at three locations to provide a broad and diverse sample. Two took place on Friday nights at different brewpubs—a local craft beer brewery on a Friday night, their busiest night, and a brewpub known locally as serving alcoholic beverages at low prices that attracts a large crowd on Fridays, especially at "happy hour." Neither location served food, ensuring that we would not be competing with in-house kitchens and food prices. The third session was conducted at a public community event that attracts several thousand people.

Water Nutrient Levels

In these experiment, the level of nutrients in the water from which the oysters were harvested was the only information shared with all participants. To address our central research question about consumers' WTP a premium for water quality ecosystem services provided by oysters, all of the purchasing decisions involved oysters harvested from a eutrophic body of water as reported in the National Estuarine Eutrophication Assessment Update (Bricker et al. 2007) by NOAA.

The purchasing decisions in this research involved four nutrient levels in the water and for each oyster the participants were told that the oysters were raised in water that had been categorized by NOAA as one of the four following options:

N1. Unknown Nutrient Level

N2. Low Nutrient Level

N3. Moderate Nutrient Level

N4. High Nutrient Level

The unknown-nutrient-level oysters came from Tomales Bay, California. The low-nutrient-level oysters came from Willapa Bay, Washington. The moderate-nutrient-level oysters came from Chincoteague Bay, Virginia. The high-nutrient-level oysters came from Long Island Sound, New York. Participants were presented with each of these four types of oyster two times. Each of these two choices had different posted prices. Thus, each participant made eight purchase decisions (within-subject design). The order of the purchase decisions and prices was randomized to control for potential order effects.

If participants show an increased demand for oysters that provide positive environmental externalities, it would signal current and potential oyster producers that investments in oyster aquaculture in estuaries suffering from eutrophication could be both environmentally beneficial and more profitable. In addition, it could provide policymakers with evidence of the profitability of establishing areas for aquaculture in such estuaries and consequently provide local economic benefits. If, on the other hand, participants respond negatively to oysters identified as being produced in medium or high-nutrient waters, suppliers may want to avoid bringing attention to these positive externalities to avoid their product being stigmatized due to food safety concerns.

Information Treatments

To understand how information about nutrients, excess amounts of nutrients in water, and oysters' ability to provide water quality ecosystem services affect decision-making, each participant was randomly assigned one of three nutrient information treatments (between-subject design). The nutrient information treatments provide different amounts of information.

Treatment 1 (T1): No information was provided in this baseline treatment. Thus, participants in the baseline treatment based their purchase decisions on the purchase price and on the level of nutrients in the water (N1–N4).

Treatment 2 (T2): Participants were provided with a figure (Figure 1) that showed the water quality scale used in NOAA's National Estuarine Eutrophication Assessment Update (Bricker et al. 2007). This figure is henceforth referred to as the NOAA scale. The NOAA scale uses colored boxes that color-codes the quality of the water based on the nutrient-stress of the water column in an estuary: (1) unknown, (2) low, (3) moderate low, (4) moderate, (5) moderate high, and (6) high. The NOAA scale also includes a one-word assessment of water quality based on the nutrients that were tested: "unknown," "high" for a low nutrient level, "moderate" for a moderate nutrient level, and "bad" for a high nutrient level.

Treatment 3 (T3): Participants were provided with the NOAA scale and additional information about environmental concerns associated with eutrophication and oysters' ability to filter water:

> "Nutrients, such as Nitrogen and Phosphorous, are naturally occurring elements that are essential for growth and reproduction in both plants and animals.
>
> Excess levels of nutrients, however, can cause overstimulation of growth of aquatic plants and algae, leading to algal blooms, oxygen depletion, clogged water intakes, fish kills, a general loss of key habitats, and affect the use of water for fishing, swimming, and boating.
>
> Oysters are filter feeders, consuming free-swimming algae and improve water quality.
>
> New research from the National Oceanic and Atmospheric Administration (NOAA) supports using shellfish aquaculture for nutrient removal.
>
> *(This information comes from the Marine Biological Laboratory, the United States Geological Survey, the National Oceanic and Atmospheric Administration)"*

At the end of the experiment, participants completed a short demographic survey (Appendix B) that included questions about their consumption of seafood generally and oysters in particular. The survey also asked whether the participant was the primary seafood shopper in the household, their general preferences for oyster characteristics such as color and shape, and how many glasses of alcoholic beverages they consumed prior to participating in the research.

3. Results

We collected data from 290 adult participants. The average age of these participants was 34 years, 45% were men, and 55% were women. The average household income was between $75,000 and $99,999. Participants were politically liberal (38.3%) and 47.4% had either a Bachelors or graduate degree. Most participants consume oyster one to two times per year and they reported that smell of the oysters was the most important attribute. Selected summary statistics pertaining to the participants' survey responses are provided in table 1.[5]

Each participant made eight purchasing decisions, resulting in 2,320 yes/no decision observations. In 606 of those decisions, participants chose to buy the oysters at a mean price of $1.23 per oyster with a standard deviation of $0.56. Therefore, on average for all of the treatments, participants expressed a willingness to purchase the oysters at the posted price about 25% of the time. The 1,714 no decisions were for oysters at a mean price of $1.63 per oyster with a standard deviation of $0.58.

Hypotheses

[5] A copy of the survey questions in included in Appendix B.

The experiments consisted of three information treatments as laid out in the method section. Each treatment involved four different types of oysters, which were distinguished by the nutrient level of the water column they were grown in. Note, an argument can be made that participants may have preferences for oysters to clean eutrophic waters closer to where they live, and, therefore, spatial elements may impact decision-making. However, these local preferences were not subject of this study. Moreover, in order to tease out these potential spatial preferences, the experiment sessions would have had to be conducted at several locations, in close proximity to where oysters where harvested, which was beyond the scope of this study.

We begin the econometric analysis with an initial set of hypotheses in table 2 pertaining to the three treatments and four oysters. We anticipate that information has an impact on participants' decisions but do not make no assumptions about the direction of the effect, which is why the null hypothesis equates willingness-to-pay for the different oysters types in each of the three treatments. Overall, we find that information concerning the level of nutrients in the water column (low, moderate and high) have an impact of participants' decisions – we can reject the null hypothesis for all of the cases in all treatments except treatment three where we find no WTP difference between oysters from low and unknown nutrient waters. Furthermore, we find behavioral differences in treatment three (NOAA scale and additional information) compared to treatment one and two. In treatment three, we observe a significant WTP differences for low versus moderate nutrient waters and low versus high nutrient waters; but not between moderate and high nutrient waters – the additional information appears to move participants towards paying higher prices for oysters from low and unknown nutrient waters

To gain further insight into participants' reactions to the information treatments, we use a random-effects logic model with a binary (yes/no) choice as the dependent variable. A Hausman test was performed, indicating that random effects, rather then fixed effect, was the appropriate model specification. Price and oyster type (in terms of nutrients in the water column the oysters were grown in) are the explanatory variables, and gender is included as a dummy variable.

The explanatory variables are reported in log-likelihood units, and the unknown-nutrient (N1) oysters served as the baseline for the analysis. It follows, then, that the coefficients for the remaining types of oysters [low nutrients (N2), moderate nutrients (N3), and high nutrient (N4)] indicate an increase or decrease in the log-odds of the probability of participants choosing to purchase a specific type of oyster compared to an oyster that came from water that was of an unknown quality.

The random effects model for person *i* can be summarized as

$$log\,\frac{P_{ij}}{1-P_{ij}} = \alpha + \beta_1 {*} D_{ij} + \beta_2 {*} N2_{ij} + \beta_3 {*} N3_{ij} + \beta_4 {*} N4_{ij} + \beta_5 {*} Male_{ij} + \mu_i + \varepsilon_{ij}, \qquad (1)$$

where $\mu_i \sim N(0, \sigma_\mu^2)$ and $\varepsilon_{ij} \sim N(0, \sigma^2)$.

In the model, *P* is the probability of a yes decision, *D* is the oyster price, *N2* represents low-nutrient-level oysters, *N3* represents moderate-nutrient-level oysters, *N4* represents high-nutrient-level oysters, *Male* is the gender dummy variable, and subscripts *i* and *j* pertain to the specific individual and that participant's decision. *N1* is the base line (unknown nutrients) and omitted from the regression. We separately estimated the model by treatment (1-3), as to isolate the impacts each treatment had on the likelihood that participant purchase each of the four oysters types (low, moderate, high, and no information concerning nutrients in the water column).

The results of the random-effects logit model are summarized in table 3. Not surprisingly, we find that price matters. The coefficients on the price variable are significant at the 1% level under all of information treatments; the lower the price of the oysters, the more likely the participants were to purchase oysters. The gender dummy variable reveals no significant difference between men and women in in any of the information treatments.

A key observation from the analysis shown in table 3 is that information about the level of nutrients in the water in which the oysters were produced appears to matter greatly to the participants. For example, the coefficient for a moderate nutrient level under the No Information treatment (Treatment 1) is 1.4851 and is significant at the 1% level, indicating that participants who received no information were significantly more likely to purchase oysters from water containing moderate levels of nutrients than to purchase oysters from water containing an unknown level of nutrients. In fact, all but one of the coefficients are significant at the 1% level, indicating that these participants were significantly more likely to purchase oysters from low, moderate, and high nutrient environments than oysters from an unknown nutrient environment.

The one non-significant coefficient related to the nutrient levels is for oysters from a low nutrient environment and no information provided (Treatment 1). This result is likely due to the mixed meanings of the term “nutrients”. For instance, in the absence of information about the negative environmental consequences, nutrients can be perceived as positive. For instance, nutrients are essential for growth and health in living organisms. Thus, some participants may perceive a low level of nutrients as an impoverished environment that would have a negative effect on the quality of the oysters. The potential for mixed messages should be reduced in Treatments 2 and 3, which provide participants with information linking nutrients to the negative water quality.

We use the random-effects logit coefficients to identify price premiums participants were willing to pay for oysters under each of the information treatments (see Figure 2). The price premiums are computed as the quotient of the *independent variable coefficient* over the absolute value of the *price coefficient.* Thus they specify the difference between WTP for oysters from the baseline scenario of unknown nutrient levels and WTP for oysters from waters containing low, moderate, and high levels of nutrients. We used STATA to compute these price premiums, however, the results can easily be obtained from Table 3, by dividing the coefficients of the independent variables by the price coefficient. For example, figure 2 shows that participants will pay an average price premium of $1.32[6] for oysters grown in moderate nutrient waters over unknown nutrient waters when they are shown the NOAA scale. Table 3 also reports the resulting WTP estimates, which are computed by adding the price premiums to the baseline WTP.

Overall, participants who received one of the information treatments (NOAA scale or NOAA scale and additional information) were willing to pay higher price premiums for all types of oysters relative to participants in the no-information treatment. This result is in line with the result that participants were more willing to purchase oysters from a known nutrient environment than from an unknown nutrient environment.

The price premiums reported in figure 2, stress the importance participants placed on information. We find that when participants were provided with information concerning the nutrient level of the water column the specific oyster is grown in, participants' willingness to pay

[6] The price premium of $1.32 can be computed by dividing the coefficient for moderate nutrient level (N2), 1.8352, by the absolute value of the price coefficient, 1.3814.

price premiums went up. The most striking treatment effect was for the oysters from low-nutrient waters. When participants received information about the nutrient levels, they were willing to pay much larger premiums for oysters from low-nutrient waters. These price premiums are computed using oysters from unknown nutrient waters as a baseline, which were \$0.27 (no information treatment), -\$0.14 (NOAA scale treatment) and -\$0.01 (NOAA scale and additional information treatment), respectively. Given that the econometric analysis revealed negative WTP estimates for both information treatments, indicating participants concern about consuming oysters from unknown nutrient waters once they received information concerning eutrophication and oysters' filtration ability, the differences in price premiums between the treatments becomes even more pronounced. In the No Information treatment the price premium (\$0.16) is not significant ($p>0.05$) for low nutrient waters compared to unknown nutrient waters. In both information treatments, however, the price premiums, \$1.13 (NOAA scale treatment) and \$0.64 (NOAA scale and additional info treatment), are significant ($p \leq 0.05$).

Interestingly, participants were willing to pay lower price premiums when provided the NOAA scale and additional information about oysters and filters than compared to when they just saw the NOAA scale. Thus it appears that providing information about oysters' ability to filter water seems to have led some participants to pay lower price premiums for oysters. Perhaps this information could be "too much of a good thing" when participants visualized the oysters' filter feeding process, resulting in disgust or food safety concerns among some participants who learned about how oysters feed from the information treatment.

To gain greater insight into participants' decision-making and the impacts of the information treatments and nutrient environments, we use another random-effects logit model that includes interaction effects between the information treatments and water nutrient levels. Equation 2 summarizes the model for person *i*:

$$log \frac{P_{ij}}{1-P_{ij}} = \alpha + \beta_1 * D_{ij} + \beta_2 * N2_{ij} + \beta_3 * N3_{ij} + \beta_4 * N4_{ij} + \beta_5 * T2_{ij} + \beta_6 * T3_{ij}$$

$$+ \beta_7 * (T2_{ij}N2_{ij}) + \beta_8 * (T2_{ij}N3_{ij}) + \beta_9 * (T2_{ij}N4_{ij}) + \beta_{10} * (T3_{ij}N2_{ij}) + \beta_{11} * (T3_{ij}N3_{ij}) + \beta_{12} * (T3_{ij}N4_{ij})$$

$$+ \beta_{13} * Age_{ij} + \beta_{14} * \text{Male}_{ij} + \beta_{15} * PrimaryHouseHoldShopper_{ij} + \beta_{16} * \text{FirstTimeConsumer}_{ij} +$$

$$\beta_{17} * Politics_{ij} + \beta_{18} * \text{Income}_{ij} + \mu_i + \varepsilon_{ij},$$

where $\mu_i \sim N(0, \sigma_\mu^2)$ and $\varepsilon_{ij} \sim N(0, \sigma^2)$ and *T2* and *T3* represent the information treatments (NOAA scale and NOAA scale and additional information, respectively). Treatment 1 is the omitted baseline (no information). As before, *P* is the probability of a yes decision, *D* is the oyster price, *N2* represents oysters from low-nutrient waters, *N3* represents oysters from moderate nutrient waters, *N4* represents oysters from low-nutrient waters and the subscripts *i* and *j* pertain to the specific individual and that individual's decision respectively. We have also included several demographic dummy variables for age, gender, whether or not the participant was the primary household shopper, first time oyster consumer, political affiliation and income.

A number of the results from the model, which are reported in table 4, are particularly interesting. First, when the nutrient level is unknown, provision of the NOAA scale and additional information (T3) has no significant effect on participants' WTP. These results are intuitive since the nutrient level of the water was unknown. Providing them with the NOAA scale and additional information about eutrophication and oysters' ability to filter nutrients from water should not be sufficient to alter their decision processes, which otherwise are based primarily on price.

Second, participants are significantly more likely to select oysters from moderate-nutrient and high-nutrient waters only under the no-information treatment; both coefficients are significant at the 1% level. However, none of the interaction terms involving oysters from moderate or high nutrient waters are statistically different than zero. This result suggests that, absent of additional information, the participants viewed higher levels of nutrients in the water as a benefit. For example, these nutrients may improve the oysters' quality and/or taste. However, giving participants information about the quality of water in which these oysters were raised and/or providing them additional information about oysters as filter feeders did not increase participants' WTP for oysters. This result addresses the question of the circumstances under which consumers would pay a price premium for oysters for their provision of greater ecosystem services. In other words, a no-information treatment may be required for consumers to prefer oysters from those waters because sharing information about a high level of pollution appears to raise consumers concerns about food safety.

Third, when interacting the information treatments and nutrient types, we find that participants are most likely to select oysters from low-nutrient waters. This result is statistically significant at the 1% level for the interaction of the NOAA scale and additional information treatment and low-nutrient waters and is marginally significant at the 10% level for the NOAA scale information treatment and low-nutrient waters. Thus, it appears that participants prefer oysters from cleaner waters when they are provided with enough information to choose between oysters that provide ecosystem services and oysters that come from cleaner waters and it may not matter that the nutrients do not affect the safety of consuming oysters.

Furthermore, as shown in Table 4, we find that a number of demographic dummy variables have an impact on participant decision-making. Age has a negative coefficient and is marginally significant slightly above the 5% level, indicating that older participants were less likely to decide to purchase oysters. On the other hand, male participants were significantly (1% level) more likely to purchase oysters compared to female participants. And, primary household shoppers were significantly more likely to purchase oysters, this effect was significant at the 5% level. We did not find significant effects for first time oyster consumer, political affiliation and most household income – except for participants who fell into two of the higher income brackets (see $100,000-$149,000 and $200,000-$250,000), indicating that some higher income household were more likely to purchase oysters in general.

4. Summary

Eutrophication of water bodies is a major environmental problem in many countries around the world and has a negative effect on their economies. In the United States, NOAA supports use of aquaculture of shellfish, such as oysters, which feed by filtering suspended organic matter from the water, to reduce eutrophication.

Economically, oysters are a mixed good—part private as a marketable commodity and part public as a provider of a water quality ecosystem services. Markets rarely fully account for public good traits, leading to undervaluation and thus underproduction of mixed products such as oysters. However, green markets can provide an outlet in which to privatize the public good benefits through price premiums. Some classic examples are shade-grown coffee and eco-tourism. Oysters are different from other green products because they are grown in the environment they are meant to clean and consumers may stigmatize oysters associated the nutrient pollution.

We used revealed-preference dichotomous-choice field experiments involving 290 adult consumers to test whether consumers are willing to pay a premium for oysters that provide ecosystem services and, if so, the circumstances in which such premiums arise. Our estimates reveal that participants were sensitive to the amount of information provided about oysters' ability to clean water and the environmental impacts of eutrophication. Once such information was provided, participants were relatively less likely to choose oysters from eutrophic waters – the vary waters where these ecosystem services would be most valuable. Consequently, highlighting the water quality ecosystem services of oysters may actually deter consumers from buying them. When no information about pollution and ecosystem services was provided, participants were relatively more likely to select oysters from waters containing a moderate to high level of nutrients, as these nutrients may have been perceived as being healthy for the oysters and improving their quality and/or taste.

These results have relevant policy implications, especially for areas in which oyster aquaculture is viewed as a way to mitigate eutrophication. Public and private investments in oyster aquaculture may depend on expected returns from sales of the aquaculture products so it will be important to know how best to label those products. Additionally, our results may contribute to an improved understanding of demand differences for oysters from different water columns, which in turn can contribute to designing improved consumption behaviors. For example, one could implement an optimal oyster tax or subsidy that would induce purchasing behavior towards the "green" product (here, oysters from eutrophic waters). These optimal policy responses will also have to rely on further data collections and more insight gained through replication and adding new designs and research questions. Likewise, these results are relevant for the development of other foods that are produced in ways are potentially beneficial for the environment but depending on how the production process is presented can lead to consumers to stigmatize these products.

Table 1. Selected survey responses

		Count	Percentage
Income Distribution	<$10,000	32	11.20%
	$10,000-$14,999	16	5.60%
	$15,000-$24,999	20	7.00%
	$25,000-$34,999	17	5.90%
	$35,000-$49,999	24	8.40%
	$50,000-$74,999	34	11.90%
	$75,000-$99,999	39	13.60%
	$100,000-$149,999	57	19.90%
	$150,000-$199,999	19	6.60%
	$200,000-$249,999	13	4.60%
	>$250,000	15	5.20%
		Count	**Percentage**
Preferred Consumption	Half Shell	99	34.60%
	Shooter	11	3.90%
	Fried	105	36.70%
	Grilled	49	17.10%
	Other	22	7.70%
		Count	**Percentage**
Political Affiliation	Conservative	77	27.80%
	Moderate	94	33.90%
	Liberal	106	38.30%
		Count	**Percentage**
Education	High School	38	13.20%
	Some College	94	32.50%
	Associate Degree	20	6.90%
	Bachelor Degree	81	28.00%
	Graduate Degree	56	19.40%
		Count	**Percentage**
Annual Oyster Consumption (occurrences)	0	78	27.00%
	1-2	103	35.60%
	3-5	56	19.40%
	6-9	22	7.60%
	>9	30	10.40%
		1 (Not Important) - 9 (very important)	
General Oyster Preferences	Species	4.11	
	Shell Size	4.84	
	Meat Size	6.31	
	Shell Appearance	5.05	
	Saltiness	5.67	
	Smell	6.99	
	Shell Color	4.24	
	Meat Color	6.22	
	Harvest Location	5.56	

Table 2. Hypotheses testing by treatment and oyster type

Treatment	Conjecture	Hypotheses	Result
No information treatment (T1)	No directional assumptions are made. We anticipate that information on nutrients of the water column the oyster has an effect on WTP.	H_0: $WTP_{low} = WTP_{moderate}$ H_1: $WTP_{low} \neq WTP_{moderate}$	*Cannot Reject H_0 ($p > 0.05$)*
		H_0: $WTP_{low} = WTP_{high}$ H_1: $WTP_{low} \neq WTP_{high}$	*Cannot Reject H_0 ($p > 0.05$)*
		H_0: $WTP_{low} = WTP_{unknown}$ H_1: $WTP_{low} \neq WTP_{unknown}$	*Reject, $WTP_{low} > WTP_{unknown}$ ($p \leq 0.05$)*
		H_0: $WTP_{moderate} = WTP_{high}$ H_1: $WTP_{moderate} \neq WTP_{high}$	*Cannot Reject H_0 ($p > 0.05$)*
		H_0: $WTP_{moderate} = WTP_{unknown}$ H_1: $WTP_{moderate} \neq WTP_{unknown}$	*Reject, $WTP_{moderate} > WTP_{unknown}$ ($p \leq 0.05$)*
		H_0: $WTP_{high} = WTP_{unknown}$ H_1: $WTP_{high} \neq WTP_{unknown}$	*Reject, $WTP_{high} > WTP_{unknown}$ ($p \leq 0.05$)*
NOAA scale information treatment (T2)	No directional assumptions are made. We anticipate that NOAA scale and information on nutrients of the water column have an effect on WTP.	H_0: $WTP_{low} = WTP_{moderate}$ H_1: $WTP_{low} \neq WTP_{moderate}$	*Cannot Reject H_0 ($p > 0.05$)*
		H_0: $WTP_{low} = WTP_{high}$ H_1: $WTP_{low} \neq WTP_{high}$	*Cannot Reject H_0 ($p > 0.05$)*
		H_0: $WTP_{low} = WTP_{unknown}$ H_1: $WTP_{low} \neq WTP_{unknown}$	*Reject, $WTP_{low} > WTP_{unknown}$ ($p \leq 0.05$)*
		H_0: $WTP_{moderate} = WTP_{high}$ H_1: $WTP_{moderate} \neq WTP_{high}$	*Cannot Reject H_0 ($p > 0.05$)*
		H_0: $WTP_{moderate} = WTP_{unknown}$ H_1: $WTP_{moderate} \neq WTP_{unknown}$	*Reject, $WTP_{moderate} > WTP_{unknown}$ ($p \leq 0.05$)*
		H_0: $WTP_{high} = WTP_{unknown}$ H_1: $WTP_{high} \neq WTP_{unknown}$	*Reject, $WTP_{high} > WTP_{unknown}$ ($p \leq 0.05$)*
NOAA scale &	No directional	H_0: $WTP_{low} = WTP_{moderate}$	*Reject, $WTP_{low} > WTP_{moderate}$ ($p \leq 0.05$)*

additional information treatment (T3)	assumptions are made. We anticipate that NOAA scale, additional explanatory language, and information on nutrients of the water column have an effect on WTP.	H_1: $WTP_{low} \neq WTP_{moderate}$	
		H_0: $WTP_{low} = WTP_{high}$ H_1: $WTP_{low} \neq WTP_{high}$	*Reject, $WTP_{low} > WTP_{high}$ ($p \leq 0.05$)*
		H_0: $WTP_{low} = WTP_{unknown}$ H_1: $WTP_{low} \neq WTP_{unknown}$	*Cannot Reject H_0 ($p > 0.05$)*
		H_0: $WTP_{moderate} = WTP_{high}$ H_1: $WTP_{moderate} \neq WTP_{high}$	*Cannot Reject H_0 ($p > 0.05$)*
		H_0: $WTP_{moderate} = WTP_{unknown}$ H_1: $WTP_{moderate} \neq WTP_{unknown}$	*Reject, $WTP_{moderate} > WTP_{unknown}$ ($p \leq 0.05$)*
		H_0: $WTP_{high} = WTP_{unknown}$ H_1: $WTP_{high} \neq WTP_{unknown}$	*Reject, $WTP_{high} > WTP_{unknown}$ ($p \leq 0.05$)*

Table 3. Willingness to pay for oysters by water nutrient content and information treatment using a random effects logistic regression model

	Treatment 1 (No Information)				Treatment 2 (Scale only)				Treatment 3 (All Information)			
Yes - Decision	**N = 1040**				**N = 640**				**N = 624**			
	Coefficient	**St. Error**	**p-Value**	**WTP**	**Coefficient**	**St. Error**	**p-Value**	**WTP**	**Coefficient**	**St. Error**	**p-Value**	**WTP**
Price	-1.8912	0.2168	0.000		-1.3814	0.2405	0.000		-1.6444	0.2429	0.000	
Low Nutrients	0.3077	0.3220	0.228	$0.43	1.5666	0.3544	0.000	$0.99	1.0566	0.4488	0.019	$0.63
Moderate Nutrients	1.4148	0.2872	0.000	$1.02	1.8352	0.3801	0.000	$1.19	1.4970	0.3754	0.000	$0.90
High Nutrients	1.4577	0.3738	0.000	$1.04	1.2538	0.4189	0.003	$0.77	1.2720	0.4684	0.007	$0.76
Unknown Nutrients		(Baseline)		$0.27		(Baseline)		-$0.14		(Baseline)		-$0.01
Constant	0.2744	0.3250	0.398		-0.1463	0.5522	0.791		-0.0109	0.4890	0.982	

Notes: Positive coefficient = participants are more likely to choose “Yes”.

Table 4. Willingness to pay for oysters by water nutrient content and information treatment using a random effects logistic regression model including interaction terms

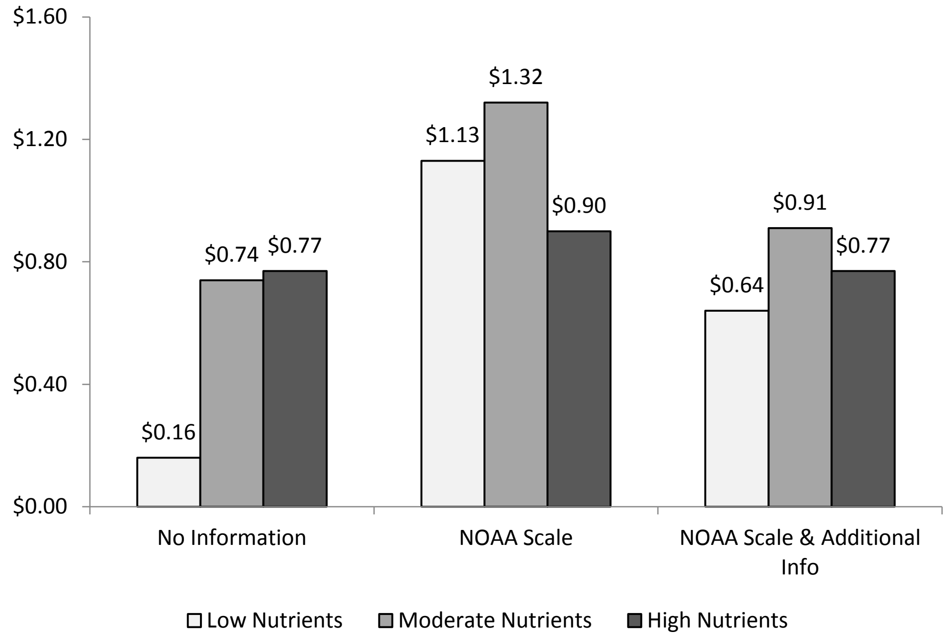
Yes - Decision	Coefficient	St. Error	p-Value
Price	-1.6686	0.1205	0.000
Unknown Nutrient Level (N1)	0.3511	0.2933	0.231
Low Nutrient Level (N2)	1.4027	0.2716	0.000
Moderate Nutrient Level (N3)	1.4613	0.2735	0.000
High Nutrient Level (N3)		(omitted)	
No Information (T1)	0.0063	0.3908	0.987
NOAA Scale (T2)	0.1479	0.3789	0.696
NOAA Scale and Additional Information (T3)		(omitted)	
NOAA Scale (T2) x Low (N2)	0.7884	0.4532	0.082
NOAA Scale (T2) x Moderate (N3)	0.1472	0.4340	0.734
NOAA Scale (T2) x High (N4)	-0.1334	0.4359	0.760
NOAA Scale and Additional Info (T3) x Low (N2)	1.3515	0.4406	0.002
NOAA Scale and Additional Info (T3) x Moderate (N3)	0.6517	0.4211	0.122
NOAA Scale and Additional Info (T3) x High (N4)	-0.0431	0.4273	0.920
Age	-0.0147	0.0077	0.058
Male	0.5756	0.2004	0.004
Primary Household Shopper	0.4262	0.2072	0.040
First Time Oyster Consumer	-0.1997	0.2170	0.357
Political Affiliation			
Liberal		(omitted)	
Moderate	0.1237	0.2170	0.569
Conservative	-0.2327	0.2491	0.350
Other	0.4000	0.5455	0.463
Income			
<$10,000		(omitted)	
$10,000 - $14,999	0.6221	0.4771	0.192
$15,000 - $24,999	-0.5461	0.4758	0.251
$25,000 - $34,999	0.2947	0.4576	0.520
$35,000 - $49,999	0.3209	0.4311	0.457
$50,000 - $74,999	0.5739	0.4000	0.151
$75,000 - $99,000	0.3223	0.3864	0.404
$100,000 - $149,999	0.7628	0.3574	0.033
$150,000 - $199,999	0.1805	0.4696	0.701
$200,000 - $250,000	0.8795	0.5155	0.088
> $250,000	0.6388	0.4992	0.201
Constant	-0.3346	0.4203	0.426

Notes: Positive coefficient = participants are more likely to choose “Yes”. N=2,320.

Figure 1. NOAA classification of water quality based on nutrient content of estuary (based on Bricker et al. 2007).

Nutrient Level	Unknown	Low	Mod. Low	Moderate	Mod. High	High
Water Quality based on Nutrients	Unknown	High	Good	Moderate	Poor	Bad

Figure 2. Price premiums for oyster types (low, moderate and high nutrient waters) by treatment



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Appendix A – Experiment Instructions

Please read these instructions carefully and do not communicate with any one while you are making your decisions.

- **We will give you $10 that you may keep and/or use to purchase oysters**. You may think of this money as a bank account from which you can withdrawal money.
- Depending on your decisions, you may receive a combination of cash and oysters. There is the possibility of you owing us money if the cost of your oysters is greater than $10.

Rules

(1) Decide how many oysters you would want to buy (3, 6, 9 or 12)
(2) Decide if you want to buy the oyster options at the listed price by selecting "Yes" or "No"
(3) Roll a die to determine which oyster option will be implemented (only one will be implemented)
(4) Fill out a short survey

Example 1: If you selected 'Yes' for an oyster bundle that cost $7 and this decision was implemented, you will receive the oysters and $3 cash ($10 - $7 = $3).

Example 2: If you selected 'No' for an oyster bundle and this decision was implemented, you will receive $10 and will not receive any oysters.

Example 3: If you selected 'Yes' for an oyster bundle that cost $15 and this decision was implemented, you will receive the oysters and owe $5 cash ($10 - $15 = -$5).

Appendix B: Copy of Survey

1. What is your age?

2. Are you male or female?
   - Male
   - Female

3. How often do you consume oysters?
   - 0 times per year
   - 1-2 times per year
   - 3-5 times per year
   - 6-9 times per year
   - >9 times per year

4. Are you the primary shopper in your household?
   - Yes
   - No

5. What is your profession?
   - Government
   - Academia
   - Business
   - Agriculture
   - Other (please specify)

6. Are you:
   - Politically liberal
   - Politically moderate
   - Politically conservative
   - Other (please specify)
7. Which category best describes your <u>household</u> income (before taxes) in 2014?
   - Less than $10,000
   - $10,000-$14,999
   - $15,000-$24,999
   - $25,000-$34,999
   - $35,000-$49,999

- $50,000-$74,999
- $75,000-$99,999
- $100,000-$149,999
- $150,000-$199,999
- $200,000-$249,999
- $250,000 and above

8. What is the highest level of education that you have completed?
    - Grade school
    - Some high school
    - High school graduate
    - Some college credit
    - Associate degree
    - Bachelor's degree
    - Graduate degree/Professional

9. On average, how often do you go to the beach each year?
    - 0 times per year
    - 1-2 times per year
    - 3-5 times per year
    - 6-9 times per year
    - >9 times per year

10. Are you a first time oyster consumer?
    - Yes
    - No

11. In a typical month, approximately how often do you eat seafood?

12. In a typical month, approximately how often do you eat at restaurants?

13. When you eat at a restaurant, what is the percentage of seafood versus other food?
    Other (100%) Seafood (100%)

14. How often do you eat seafood at home versus at a restaurant?
    Home (100%) Restaurant (100%)

15. Are you the primary seafood shopper in your household?
    - Yes
    - No

16. How often do you catch your own seafood?
    Never (1) Often (9)

17. How important is location in your oyster choice?
    Not Important (1) Very Important (9)

18. For oysters from the Delaware Bay, I would...
    - pay more than other locations.
    - pay less than other locations.
    - pay the same as other locations.

19. For oysters from the Delaware Inland Bays, I would...
    - pay more than other locations.
    - pay less than other locations.
    - pay the same as other locations.

20. How do you usually prefer the preparation of your oysters?
    - Raw on the half shell
    - Raw in a shooter
    - Fried
    - Grilled
    - Other

21. How important are the following oyster characteristics to you?
    Oyster Species:
    Not Important (1) Very Important (9)

    Size of the oyster shell:
    Not Important (1) Very Important (9)

    Size of the oyster meat:
    Not Important (1) Very Important (9)

Appearance of the oyster shell:
Not Important (1) Very Important (9)

Saltiness of the oyster:
Not Important (1) Very Important (9)

Smell of the oyster:
Not Important (1) Very Important (9)

Color of the oyster shell:
Not Important (1) Very Important (9)

Color of the oyster meat:
Not Important (1) Very Important (9)

Location of harvest:
Not Important (1) Very Important (9)

		Count	Percentage
income distribution	<$10,000	32	11.20%
	$10,000-$14,999	16	5.60%
	$15,000-$24,999	20	7.00%
	$25,000-$34,999	17	5.90%
	$35,000-$49,999	24	8.40%
	$50,000-$74,999	34	11.90%
	$75,000-$99,999	39	13.60%
	$100,000-$149,999	57	19.90%
	$150,000-$199,999	19	6.60%
	$200,000-$249,999	13	4.60%
	>$250,000	15	5.20%
		Count	**Percentage**
Preferred Consumption	Half Shell	99	34.60%
	Shooter	11	3.90%
	Fried	105	36.70%
	Grilled	49	17.10%
	Other	22	7.70%
		Count	**Percentage**
Political Affiliation	Conservative	77	27.80%
	Moderate	94	33.90%
	Liberal	106	38.30%
		Count	**Percentage**
Education	High School	38	13.20%
	Some Collage	94	32.50%
	Associate’s Degree	20	6.90%
	Bachelor's Degree	81	28.00%
	Graduate Degree	56	19.40%
		Count	**Percentage**
Annual Oyster Consumption (occurrences)	0	78	27.00%
	1-2	103	35.60%
	3-5	56	19.40%
	6-9	22	7.60%
	>9	30	10.40%
		1 (Not Important) - 9 (very important)	
General Oyster Preferences	Species	4.11	
	Shell Size	4.84	
	Meat Size	6.31	
	Shell Appearance	5.05	
	Saltiness	5.67	
	Smell	6.99	
	Shell Color	4.24	
	Meat Color	6.22	
	Harvest Location	5.56	