2023

Seafood consumption during harmful algal blooms: The impact of information regarding safety and health

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Citation/Publisher Attribution

Bechard, A., & Lang, C. (2023). Seafood consumption during harmful algal blooms: The impact of information regarding safety and health. *Harmful Algae*, *123*, 102387. https://doi.org/10.1016/j.hal.2023.102387
Available at: https://doi.org/10.1016/j.hal.2023.102387

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Forthcoming, Harmful Algae

Seafood Consumption during Harmful Algal Blooms:
The Impact of Information Regarding Safety and Health

Andrew Bechard and Corey Lang

Abstract

Harmful algal blooms (HABs) all over the world can cause massive fish kills. However, some species of commercially caught and sold seafood is healthy and safe to eat, vastly different from the fish that might be seen washed up on shore. Prior research finds that this in mostly unknown by consumers, and that the misperception of unhealthy and unsafe fish is the dominant paradigm. To date, there has been minimal research on the effect of disseminating this information to consumers, and how consumption habits would change during a bloom. We implement a survey experiment that presents respondents with information explaining to them the health and safety of certain commercially caught seafood during a HAB, specifically red grouper, a particularly popular, large, deep-sea fish. Our results suggest that respondents receiving this information are 34 percentage points more likely to say that they would be willing to consume Red Grouper during a bloom, relative to those that were not revealed this added information. The results demonstrate the importance of correct knowledge and awareness regarding HABs, as it pertains to the efforts of stabilizing local economies dependent on seafood harvesting and consumption.

1. Introduction

Toxin-producing dinoflagellate can sometimes bloom to dangerous levels in oceans around the world. These harmful algal blooms during the last few decades have increased in frequency, severity and persistency (Landrigan et al., 2020; Gilbert et al., 2005). In the waters of the Gulf of Mexico off the coast of Southwest Florida, one dinoflagellate *karenia brevis*, more commonly known as red tide, can negatively affect hundreds of miles of coastline with blooms capable of spanning over several counties for days, weeks, or even months on end (Watkins et al., 2008; Sievers, 1969; Steidinger and Baden, 1984). Western winds and Gulf waves can cause the neurotoxins, called brevetoxins, produced by the algae to spread and further exacerbate the coverage and exposure area on the bloom (Poli et al., 1986; Baden et al., 2005). The toxins infiltrate the waters of the Gulf, or can become aerosolized and move through the air (Pierce and Kirkpatrick, 2001). Severe red tide blooms are responsible for large scale fish kills, death in shoreline sea birds and even some larger marine animals such as sharks (Hoagland et al. 2020).

The harmful effects of red tide are not nearly as fatal to humans as they are to marine life, but nevertheless, the brevetoxins can cause severe issues. Dermal contact with the algae can induce harmful effects, but more commonly it is through the consumption of shellfish that has become poisoned by the brevetoxins from *k. brevis* that leads to problems (Kirkpatrick et al., 2006, 2009; Hoagland et al., 2009, 2014; Diaz et al., 2019). Aerosolized brevetoxins, when inhaled, can again lead to respiratory issues, irritable throat and lungs, and shortness of breath (Anderson et al., 2020; Pierce et al. 2005; Plakas et al. 2002; Fleming et al. 2005). Although almost never fatal, the effects can cause widespread hospitalization, and in severe cases, school closures as far inland as 10 miles, where people are still affected by the breezes that carry red tide in from the shores (Trimble, 2018).

The negative effects from red tide can cause beach closures and sometimes restrictions are placed on the harvesting of shellfish, and what can be sold at grocery stores and restaurants (Florida Fish and Wildlife Conservation Commission (FWC), 2021). Given increases in healthcare expenditures, along with losses of revenue in coastal businesses, the blooms have negative implications for the affected economies (Morgan et al., 2009; Jin et al., 2020). Aside from financial impacts, residents and tourists state emotional distress from HABs, such as annoyance with the blooms' effects, or avoidance of coastal places (Nilsson and Gössling, 2013).

These financial and emotional impacts are sometimes discussed in local and national media when blooms are covered, along with information about red tide and how to best avoid the harmful effects. However, the effectiveness and depth of information provided to the public on red tide has rarely been studied. This is especially true for knowledge about the safety of seafood harvesting and consumption during red tide blooms. Though shellfish are unsafe to harvest and eat, commercial seafood that is caught further out in the Gulf where there is more oxygenated water and less red tide, is safe to catch and eat. This is universally agreed upon by scientists and governments alike, as federal, state, and local governments permit seafood activity even during blooms (FWC, 2020; Bechard, 2020). Kuhar et al. (2009) found that even with public information outreach programs in place, only 12 to 18% of residents and tourists correctly knew that commercial seafood was safe to eat during red tide blooms. Nierenberg et al. (2010) find 16-22% of respondents answered this question correctly in a similar survey. These results in the prior literature show that despite numerous outlets for the public to receive information regarding red tide, more work is still needed to inform the public that seafood is safe during blooms. If the correct information was disseminated and received by the public, it could result in consumption and seafood revenue maintaining its non-bloom levels, avoiding any of the economic declines seen during past red tide blooms.

In this paper, we use a survey experiment to examine how red tide blooms impact consumption of commercial seafood and how information about safety impacts consumption. Our intercept survey obtains a baseline for respondent's willingness to consume seafood in healthy, non-bloom times, and compares this to a similar question during red tide blooms. Half of respondents randomly are treated with additional information that seafood is healthy to eat during red tide. The survey also asked about knowledge of red tide, including its biological makeup and the abilities to partake in coastal activities such as commercially harvesting fish, commercially harvesting shellfish, and swimming during a bloom. Various socioeconomic characteristics were also collected, including age, gender, race, household income, education, resident/tourist status, and distance of dwelling to the shore. We used the intercept method to recruit respondents, drawn from Florida beachgoers in Sarasota County.[1] Five beaches were used

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[1] Intercept surveys that use experimental variation have proven successful in other areas of economics, giving researchers a useful tool to gather insights at a respondent level that might not otherwise be available in typical datasets (Nierenberg et al., 2010, Lang et al., 2021; Pearson-Merkowitz and Lang, 2020).

as surveying locations: Caspersen, Lido, Siesta, Turtle, and Venice Beach. At each location, recruiters were stationed at the entrance/exit to the beach and asked volunteers to participate in a brief, anonymous survey. The survey was conducted from January 17th – 30th, 2022 and collected a total of 258 completed surveys.

Using a linear probability regression model, we find that the information treatment effect is associated with a 34 percentage point increase in the likelihood of a seafood consumer continuing to do so even during blooms. Only 24% of those respondents not given safety information chose to consume Red Grouper during red tide, meaning the information led to a 142% increase in the propensity to consume. We also explore heterogeneity to understand if some types of consumers are more or less receptive to the information. We find that the treatment effect is mostly the same across socioeconomic groups. However, respondents who had prior knowledge about the safety of Red Grouper during red tide were unaffected by information. Nevertheless, since 68% of our sample did not have that prior knowledge, and this is likely reflective of the general population, clearly information dissemination could have large impacts on seafood choices. These results can aid public administrators and outreach groups in the importance of spreading this information to maintain seafood revenue generating activity as part of a healthy economy.

2. Data

We designed our survey to assess seafood consumption habits during normal non-bloom months and also during red tide blooms.[2] The purpose of measuring consumption habits during these two time periods is to be able to compare consumption in these two different scenarios. All participants were shown a question early in the survey that asked (yes/no) if they typically consumed seafood, specifically Red Grouper, during a normal visit to this area, or to the coast. The wording for this question is as follows: “Red Grouper is one of the most popular fish consumed in Southwestern Florida. Do you (Would you) consume Red Grouper in a typical scenario?” We chose Red Grouper as the fish of choice for this question, as it is one of the most popular fish caught and consumed along the Southwest coast of Florida. Over 75% of all Red

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[2] The full survey is available upon request.

Grouper caught is brought to one of the ports along a contiguous six-county stretch of land from Pinellas to Collier County (NOAA, 2021). The likelihood that a participant would know this fish or at least recognize it by name is higher than using perhaps a lesser-known fish that respondents might not have ever tried. After asking this question, the participants were shown a series of questions regarding knowledge about red tide. Specifically, respondents were asked if they had ever heard of red tide, about the biological makeup of red tide, and then four true/false questions: “It is safe to commercially catch and eat fish during red tide”, “It is safe to harvest shellfish during red tide”, “It is safe to swim during red tide”, and “There have been reports of deaths from red tide”.

Respondents were then presented with the key question that asked them if they would consume Red Grouper during a red tide bloom. Respondents were randomly assigned (50/50 split) to be shown information along with this question that notified them that commercially caught Red Grouper was safe to eat during red tide blooms. The two possible questions were worded as follows:

> [Control] Do you (would you) consume Red Grouper during a red tide bloom?
>
> [Treatment] The Florida Fish and Wildlife Conservation Commission, along with local, county, and state governments agree that many fish including Red Grouper **are safe** for commercial/recreational harvesting and consumption, **even during red tide**. Regulations are implemented to ensure that fish being sold to consumers are healthy and safe to eat. Given this information, do you (would you) consume Red Grouper during a red tide bloom?

The remainder of the survey consisted of questions regarding standard demographics, such as age, race, education, income, and distance of dwelling to the shore, which have been shown to be contributing factors to a person’s knowledge about red tide (Nierenberg et al., 2010).

2.1 Survey Collection

We conducted the survey in the winter of 2022, from January 17th to January 30th. The survey was administered at 5 public beaches along the Southwest coast of Florida: Venice Public Beach, Siesta Key, Turtle Beach, Lido Beach, and Caspersen Beach. These beaches were chosen for four reasons. First, the Southwest coast of Florida is the epicenter for red tide blooms, and these five beaches are routinely hit by blooms and any of the resulting shallow-living fish kills and smells that force a beach closure and drive away visitors. Second, they are some of the most visited shores in the world, which would make it very efficient to reach a large number of people in one place, increasing the sample size and representativeness of the beach-going population, as there are many attractions that these beaches have to offer aside from the sea and sand, such as world famous piers and "Shark Tooth Capital of the World", as well as restaurants and shops (Visit Sarasota, 2022). Third, as aforementioned, grouper is very popular in this area, especially by these beaches where restaurants often serve daily catches of grouper to patrons, making it more likely that respondents will know of this fish. Lastly, a similar survey was conducted in this county by Nierenberg et al. (2010), so previous literature provides the ability to compare results and discuss any similarities or differences.

The research protocol was as follows: a surveyor was stationed at one of the beach's main public entrances throughout the standard work week and weekend during open hours. Though hours of operation for public parts of the facility were from 6am – 10pm, surveys were conducted from 7am – sunset, which was roughly 7:30 – 8pm. Prospective participants were only asked about taking the survey as they were coming or leaving from the beach area, and not followed onto the seating areas by the water, or in the parking lot. The potential respondents were asked if they would be willing to take a 5-minute, 16 question, anonymous, multiple choice survey to be used for research purposes by students and faculty at The University of [removed for anonymous review]. If the person gave verbal consent, they were offered a touch screen tablet to complete the survey. Respondents could omit responses if they felt inclined, but only after a prompt asked them if they wanted to continue with the survey and leave the question blank. The first question asked was about age. If the respondent was under 18 years of age, they were stopped from taking the survey.

During the survey collection period, 281 initial respondents agreed to take the survey, but 8 were omitted from partaking further after answering that they were under 18. We further drop observations that were missing responses to any of the seafood knowledge, seafood consumption, or demographic questions, and those that completed the survey in under one minute. These two factors led to the exclusion of 9 and 6 responses respectively and left a total of 258 valid observations.[3]

Table 1 presents summary data of the survey respondents, stratified into two groups based on whether information was randomly shown to them in the question of interest. Column 3 presents t-tests in the differences of the variable across the two groups to ensure that our randomization worked, and the populations are similar. The results suggest similar percentages in responses from the two groups, as none of the differences in means are statistically significant at the 10% level, except for prior knowledge of the ability and safeness of harvesting commercially caught seafood during a bloom, which is statistically significant at the 5% level.[4] 38.5% of the treated group was able to answer this question correctly before treatment, whereas only 25% of the control group could do the same. If anything, this makes our results of the effect of information regarding safe consumption during a bloom an underestimate of the true effect, as the treated group could be more likely to be willing to eat grouper knowing that it is safe. Across both groups, initial consumption of Red Grouper in typical scenarios is high, 89% of those in the control group, and 92% in the treated group. The information intervention did not maintain or increase consumption from non-bloom months, seemingly there is still a stigma, rather just prevented as much of a decline in willingness to consume seafood as we see in the control group. Consumption of Red Grouper during a bloom dropped to 24% in the control group, but only 65% in the treated group, as seen in as seen in Figure 1. This quite sizeable gap in “during bloom” consumption perhaps previews success of the information intervention, in that there is a statistically significant increase in willingness to consume from those that were educated with further information. The baseline knowledge of at least hearing of red tide before is also high, over 96% in both groups. This is in line with the results from Nierenberg et al. (2010) that find

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[3] Complete summary statistics for each question of the survey are available in Table A1 of the Supplementary Appendix.

[4] Table A2 of the Supplementary Appendix presents results of a balance test in which treatment status is regressed on the control variables used in the model. The results indicate strong balance as none of the coefficients are significantly different than zero.

similarly high levels of red tide recognition and perhaps not surprising given the frequency with which this area is plagued by blooms. Beyond simply hearing of red tide, a substantially smaller number of people can identify the correct biological makeup of red tide, with 58%-66% answering correctly that red tide is considered ‘algae’. This is also similar to previous literature. One difference from Nierenberg et al. (2010) is the increase in ‘Virus’ answers chosen. This could be due to the fact that the survey was conducted during the COVID-19 pandemic, and with all the media attention placed on a virus, those unaware that red tide is an alga might have chosen ‘Virus’ due to familiarity.

Overall, our sample includes a wide range of participants. Our sample includes fewer seniors (65+) than one might expect in a city with an average age of 70. One explanation for a skewed younger sample could be that younger residents visit the beach at a higher rate than the elderly, and that tourists on average could be younger than those living there. Race was fairly different than the city estimates, which is largely white (98%). This could also be due to the large number of tourists that visit the area that are not necessarily coming from the same demographic as full-time residents.

3. Methodology

We estimate a linear probability model to understand the effect of additional information on seafood consumption during red tide. We estimate the econometric model as follows:

$$(1) \qquad consume\_bloom_i = \alpha + \beta_1 treat_i + \beta_2 consume\_non\_bloom_i + \boldsymbol{X_i \delta} + \varepsilon_i$$

$consume\_bloom_i$ is a binary variable equal to 1 if individual i answered yes to consuming Red Grouper during a red tide bloom and zero otherwise. $consume\_non\_bloom_i$ is a similar binary variable equal to 1 for individual i if they answered yes to consuming Red Grouper during non-bloom times, and zero otherwise. $treat_i$ is a binary variable equal to 1 if individual i was shown the additional information regarding the health of seafood during red tide, and zero otherwise. β_1 is the coefficient of interest and measures the impact of information in this setting. With no prior literature on the consumption changes during red tide given more information, the sign of β_1 is a priori ambiguous. However, we do not expect the sign of β_1 to be negative, as this would suggest the treatment information was causing more harm than good, negatively impacting consumption relative to those not getting any information at all. If the information had no impact on decisions, then β_1 would be statistically indistinguishable from zero. If the treatment were to be successful, we hypothesize that β_1 will be positive in sign, as consumption changes would be greater (or less negative) for the treated group relative to the control group. $\boldsymbol{X_i}$ is a vector of control variables including a binary variable if respondents were able to correctly answer the question pertaining to prior knowledge of the ability to commercially harvest seafood during a bloom, binary variables for race being White, Florida resident, female, and four of the five beaches (Caspersen Beach omitted), and continuous variables for income, education, age, and distance of dwelling (residence or place of stay) to the beach. The four continuous variables were created by first assigning values to each of the group selections in the variable. The midpoint of the group was assigned as the value for age and income brackets, and the maximum value of the group selection was given for education and distance choices. For example, a respondent who answered that they were in the 18-29 age range, the $30-$49k income bracket, with a college degree and was within 5 miles from the beach, was recorded as 23.5, 39.5, 16, and 5 for age, income, education, and distance, respectively. While these variables are not our focus, they are important determinants of consumption preferences and are included to improve model fit.

3.1 Treatment Effects across Groups

We also develop a second model that examines treatment effect heterogeneity across groups. Certain segments of the population might be more responsive to the information than others who might not believe or change their behavior based on what they are told.

The econometric model is as follows:

$$(2)\qquad consume\_bloom_i = \alpha + \beta_1 treat_i + \beta_2 characteristic_i * treat_i + \\ +\beta_3 consume\_non\_bloom_i + \boldsymbol{X_i \delta} + \varepsilon_i$$

All variables are as defined in Equation (1). $characteristic_i$ is a generic placeholder in the interaction term that is replaced by one of the control variables (from the matrix $\boldsymbol{X_i}$) of interest when interacting this variable with $treat_i$. To be clear, the isolated variable $characteristic_i$ is still included in the vector of control variables. β_2 is the coefficient of interest; if statistically significant, it would imply that this particular group is more or less responsive to information about safety. We estimate Equation (2) eight times, each with a different control variable chosen in the interaction term. The eight control variables of interest are: White, female, Florida resident, education, age, income, distance, and correct prior knowledge of the ability to commercially harvest seafood during red tide blooms. All of the continuous variables (education, age, income, and distance) were de-meaned, so that the main treatment effect coefficient, β_1, can be interpreted as an average treatment effect across groups with different education levels, age, etc., and β_2 is the heterogeneity across levels of these variables. For the binary variables (White, female, Florida resident, and Seafood safety knowledge), β_1 is interpreted as the treatment effect for respondents that do not have the given characteristic (e.g., non-white, male, etc.), β_2 is the difference in treatment effects between groups (e.g., white and non-white, female and male, etc.) and $\beta_1 + \beta_2$ is the treatment effect for respondents that do have the given characteristic.

4. Results

Table 2 presents results from estimating Equation (1) with consumption of Red Grouper during a bloom as the dependent variable. Robust standard errors are clustered at the five beaches to account for any similarities in errors that might be due to differences in beach attractions or crowds, and/or exposure to a red tide bloom should it occur. Column 1 shows a regression without any controls. The coefficient estimate on $Treat$, the main variable of interest, is 0.412 and is statistically significant at the 1% level. This result implies that the group of respondents who were given additional information about the health of seafood during red tide were on average, 41.2 percentage points more likely to consume seafood during red tide, relative to those that were not given the information.

Column 2 shows the estimates from the OLS model with individual level controls. The estimate on β_1 is 0.341 and is statistically significant at the 1% level, similar to the results from Column 1. We also find that prior seafood safety knowledge is associated with a 43.4 percentage point higher likelihood in consuming seafood during a bloom event, ceteris paribus. This implies that even amongst those in the control group without information, prior knowledge increases the likelihood that an individual consumes or would be willing to consume Red Grouper during a red time bloom. Additionally, and not surprisingly, answering yes to consumption in non-bloom periods is associated with a 16.6 percentage point increase in likelihood of an individual continuing to consume Red Grouper during blooms. In Column 3, we add beach level fixed effects to account any other time-invariant characteristics that might be due to the location and/or crowds at a certain beach. The results of this model are near-identical to Column 2.

4.1 Interaction of Treatment and Controls

Table 3 presents results from estimating Equation (2), with each column testing for a multiplicative effect with a different personal characteristic. Across columns, we primarily find that the interaction term of interest is statistically insignificant. This is true for variables White, female, education, age, and income. We interpret these results to mean that for people of different races, different genders, different levels of education, and different levels of income, the treatment effect is similar and respondents are acting on the HAB information similarly. Further, it implies that ignorance about healthy seafood consumption during HABs is spread evenly across these groups.

However, a few interaction terms are statistically significant revealing heterogeneous treatment effects. One result of interest is in Column (1), which focuses on heterogeneity with respect to prior knowledge of seafood safety during red tide blooms. The coefficient on Treat is 0.482 indicating that for respondents without seafood safety knowledge, receiving that information increases likelihood of consumption 48.2 percentage points. The coefficient on Treat x Characteristic is -0.447, nearly equal in magnitude but opposite in sign. This suggests that the treatment effect for respondents with prior knowledge of seafood safety is near zero (0.035) and is statistically not distinguishable from zero. This finding makes sense because people who already have information and not impacted by information. That being said, this group of respondents with prior safety knowledge is more likely to consume Red Grouper during red tide than the treated group. The coefficient on characteristic in Column 1 is 0.683 meaning those with prior knowledge are 68.3 percentage points more likely to consume during a bloom, which is about 20 percentage points more than the treatment effect.

Though not statistically significant at the 5% level, the interaction coefficients for *resident* and *distance* warrant some discussion. The results suggest that despite given the additional health information, residents are 18.2 percentage points less likely to be swayed by the information to consume grouper during red tide than tourists. Each additional mile of distance to the shore is associated with a 1.97 percentage point increase in the effect of the treatment information to increase consumption of Red Grouper during a bloom amongst the treated group. Though the statistical significance of these estimates is not enough to arrive at any conclusion, the signs of them are intuitive. Residents and those that live or stay close to the beach have more opportunities to be exposed to red tide than their counterparts, tourists and those that live or stay further from the beach. Whether it be resident status, or a dwelling close to the shore, it is likely that if these people on average are more likely to be exposed to, and become aware of red tide, then they might already have sufficient knowledge of a bloom's effects, and what is safe or unsafe to do. Also, dependent on the frequency of exposure, these participants could be accustomed to red tide, and have habits during bloom times, rendering the effect of the treatment information to be less than it is to a tourist or inland participant that might not be as familiar with a bloom.

5. Discussion

The results of the survey experiment suggest that additional dissemination of information regarding the health and safety of seafood during red tide blooms is needed to lessen the knowledge gap that exists with consumers. 75% of survey respondents were unaware of seafood safety during blooms, and upon given this information, were much more likely to be willing to consume Red Grouper, relative to those from whom this information was withheld. Furthermore, prior knowledge of seafood safety, while uncommon, results in much higher likelihoods of consumption during a bloom.

It could be argued that for such a high initial willingness to or habit of consuming Red Grouper in normal, non-bloom times, the during-bloom consumption is somewhat underwhelming. In both groups, there were participants who would not consume Red Grouper during a bloom, implying that even with the additional information, some were still hesitant to answer that they would consume the fish. There could be many underlying reasons as to why respondents in the sample population prefer to avoid Red Grouper during red tide. One reason could be that some people might believe that the taste or texture of the fish could be comprised, and inferior to grouper caught and prepared during normal periods. Future research can perhaps be done to spread further information about not only the health and safety of seafood during red tide, but that the taste, texture and all other characteristics that invoke a preference in the fish also remains unchanged during the bloom.

Despite the success of the information treatment increasing consumption in the treated group over 140% more than the control group, another reason the during-bloom consumption might seem lower than expected, or not closer to the initial level, is the mechanism in which the information was delivered. It was not divulged ahead of time, and was backed by the local and state government, and experts in science. Previous studies have shown that less than half of people surveyed trust government agencies regarding food and safety issues (Knight et al., 2007; Hicks et al., 2008). It is possible that some respondents were skeptical of trusting information that was just given to them without having time to verify it themselves, or from sources that are not as widely accepted for certain participants with underlying political beliefs and attitudes towards the government. Our results from Equation (2) suggest that this might be the case; that people who have prior knowledge of the health of seafood during blooms might have had more time to absorb this information and been able to verify it themselves, thus having increased likelihoods of consumption. This places more importance on the dissemination of the information ahead of time for the public to internalize it so that they can behave accordingly during a red tide bloom.

6. Conclusion

This paper examines the effectiveness of additional health safety information on seafood consumption during red tide using a survey with randomized information provision. To the best of our knowledge, this paper is the first to investigate the impact of information in the context of seafood consumption during red tide. Our randomized survey design improves on prior literature studying preferences during red tide because we build upon the lack of red tide knowledge in most participants and explore the effects of providing more information to increase knowledge in the respondents.

The results suggest that participants know very little about the health of seafood during red tide, and they respond positively to additional information regarding the health and safety of Red Grouper during red tide blooms. On average, those that were given the information were 34.1 percentage points more likely to answer that they would consume Red Grouper during a red tide bloom, relative to participants that were not exposed to the same information. Consumption for Red Grouper during a harmful bloom decreased in both groups, but it was severe in the control group that was not given any information. With seafood revenues dropping significantly in months that experience red tide, these results suggest that some of the lost revenue could be salvaged by disseminating this type of information to consumers about the health and safety of the seafood. However, we also find that respondents who already knew about the safety of eating Red Grouper during red tide before our survey were more likely to indicate they would consume Red Grouper during red tide than those treated with information. We interpret this to mean that information is most effective when people have learned it ahead of time, and can internalize it and verify it themselves before making decisions on seafood consumption during a bloom.

Future research building on these findings could go in multiple directions. First, our survey design could be repeated in different locations, either in different coastal spots in Northern of Eastern Florida, or on the east coast of Texas, where red tides also bloom, though at a less frequent rate. Southwest Florida was an excellent setting for this study, as residents are exposed to red tide more than anywhere else in the world (FWC, 2021). Consumers in other areas might have even less underlying knowledge of the health of seafood and could be more impacted by treatment information. A second direction of future research could explore if better communication of physical characteristics such as lack of taste and texture changes of Red Grouper during red tide can increase consumption preferences further. One limitation of our research is that it is an inconsequential survey and may suffer from hypothetical bias. Future research could conduct experiments with real purchases of fish under different information scenarios, similar to Wakamatsu et al. (2017), to reveal true preferences. Lastly, this survey design could be repeated for different types of seafood that, like Red Grouper, can be safely caught and sold commercially. The popularity of Red Grouper could be influencing consumption rates that might not otherwise be captured in less popular seafood.

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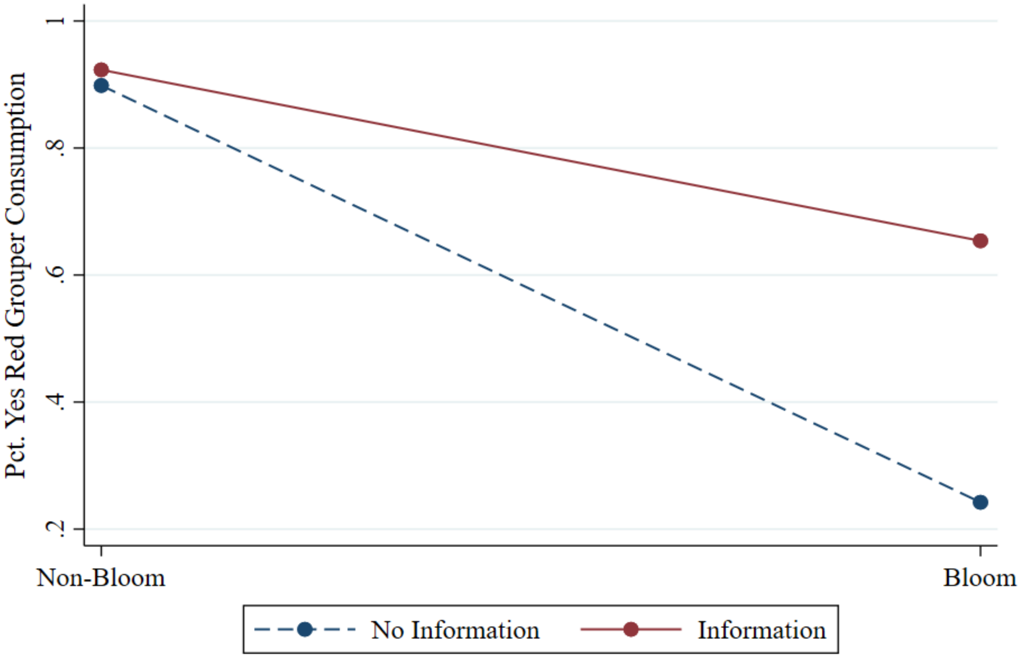
Figures and Tables

Figure 1 – Percentages of Red Grouper Consumption by Group and Time Period



Notes: Percentage of respondents that answered yes to consuming red grouper, during non-bloom and red tide periods. The group that was shown additional information regarding the health of seafood during a red tide bloom is display by the solid line, whereas the dashed line represents those that were shown no information when presented with the same question. N=258.

Table 1: Summary Statistics of Respondent-Level Characteristics

	Sample mean (standard deviation)		Difference in Means (standard error)
	Control	Treated	
Red Tide Related Variables			
Non-Bloom Consumption	0.886	0.924	-0.037
	(0.028)	(0.023)	(0.036)
Heard of Red Tide? (1 = yes)	0.969	0.985	-0.016
	(0.017)	(0.011)	(0.019)
Biological Makeup of Red Tide			
Bacteria	0.250	0.200	0.050
	(0.038)	(0.035)	(0.052)
Algae (correct)	0.594	0.669	-0.075
	(0.044)	(0.041)	(0.060)
Virus	0.102	0.085	0.017
	(0.027)	(0.025)	(0.036)
I Don't Know	0.055	0.046	0.008
	(0.020)	(0.018)	(0.027)
Seafood Safety Knowledge (1=yes)	0.250	0.385	-0.135**
	(0.038)	(0.042)	(0.058)
Socioeconomic Controls			
Resident (mean)	0.461	0.531	-0.069
	(0.044)	(0.044)	(0.062)
Female (mean)	0.508	0.523	-0.015
	(0.044)	(0.044)	(0.062)
White (race, mean)	0.773	0.792	-0.019
	(0.037)	(0.035)	(0.051)
Age (yrs.)	52.95	53.17	-0.213
	(1.629)	(1.665)	(2.329)
Income ($thousands)	95.03	98.62	-3.58
	(2.905)	(3.389)	(4.446)
Education (yrs.)	14.91	15.51	-0.601*
	(0.249)	(0.252)	(0.354)
Distance (mi.)	3.58	3.17	0.413
	(0.332)	(0.316)	(0.458)
Observations	128	130	

Notes: Treated refers to survey respondents given additional information about the safety of consuming Grouper during red tide, and Control refers to survey respondents not given additional information. Standard errors below in parenthesis in the difference in means column. *, **, and *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2: The Effect of Information Treatment on Seafood Consumption during HABs

	(1)	(2)	(3)
Treat (1=Shown Info)	0.412***	0.341***	0.342***
	(0.0348)	(0.0513)	(0.0518)
Consume Non-Bloom (1=yes)		0.164**	0.186**
		(0.0497)	(0.0447)
White (1=yes)		0.00269	-0.00501
		(0.0378)	(0.0423)
Female (1=yes)		-0.0120	-0.0104
		(0.0453)	(0.0474)
Resident (1=yes)		0.0441	0.0418
		(0.0560)	(0.0602)
Distance (mi.)		0.00168	0.00180
		(0.00315)	(0.00329)
Income ($thousands)		0.000423	0.000421
		(0.000414)	(0.000445)
Education (yrs.)		0.00517	0.00631
		(0.00928)	(0.00898)
Age (yrs.)		0.000127	-0.0000919
		(0.00128)	(0.00136)
Seafood Safety Knowledge (1=yes)		0.439***	0.425***
		(0.0491)	(0.0388)
Observations	258	258	258
R-squared	0.171	0.385	0.392
F.E. Level	None	None	Beach

Notes: Each column presents a separate regression of Equation (1), with different independent variables in each model. The dependent variable is binary, equal to 1 if the respondent was willing to consume red grouper during an HAB bloom and zero otherwise. *Treat* is a binary variable equal to 1 if the respondent was shown the additional information regarding the health and safety of commercially caught fish during blooms. Column 1 has no controls, Column 2 adds respondent level controls, and Column 3 adds beach-level fixed effects. Standard errors are shown in parentheses and clustered at the beach level. The estimates for the constant and all fixed effects are omitted for brevity but are available upon full request. *, **, and *** represent statistical significance at the 10%, 5%, and 1% level respectively.

Table 3: Information Treatment Effect Heterogeneity

	Interaction Characteristic							
	Seafood Safety Knowledge (1)	White (2)	Female (3)	Resident (4)	Education (5)	Age (6)	Income (7)	Distance (8)
Treat	0.482***	0.418***	0.370**	0.432***	0.342***	0.342***	0.341***	0.343***
	(0.0509)	(0.0901)	(0.0868)	(0.0584)	(0.0423)	(0.0518)	(0.0445)	(0.0530)
Characteristic	0.683***	0.0411	0.0157	0.135	0.0310**	-7.98e-05	0.00196*	-0.00782
	(0.107)	(0.0364)	(0.0406)	(0.0396)	(0.0374)	(0.0388)	(0.0395)	(0.0392)
Treat x Characteristic	-0.447**	-0.0959	-0.0531	-0.182*	-0.0472	-2.32e-05	-0.00257	0.0197*
	(0.141)	(0.126)	(0.122)	(0.0685)	(0.0288)	(0.00116)	(0.00148)	(0.00891)
Observations	258	258	258	258	258	258	258	258
R-squared	0.432	0.393	0.392	0.400	0.409	0.392	0.399	0.397
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Each column presents a separate regression of Equation (2), with only the main coefficients of interest displayed. The dependent variable is binary, equal to 1 if the respondent was willing to consume red grouper during an HAB bloom and zero otherwise. *Treat* is a binary variable equal to 1 if the respondent was shown the additional information regarding the health and safety of commercially caught fish during blooms. *Characteristic* is a control variable of interest, and *treat X characteristic* is the interaction of the two. Each column uses a different characteristic in the model that is identified in the column header. Standard errors are shown in parentheses and clustered at the beach level. The estimates for the constant, other control variables, and all fixed effects are omitted for brevity, but are available upon full request. *, **, and *** represent statistical significance at the 10%, 5%, and 1% level respectively.

Supplementary Appendix

Table A1: Full Survey Results

	Freq.	Percent		Freq.	Percent
Age			**Race**		
18-29	36	13.95	*White*	202	77.99
30-49	66	25.58	*Black*	22	8.49
50-64	104	40.31	*Asian*	26	10.04
65+	52	20.16	*Pacific Islander*	2	0.77
Non-Bloom Red Grouper Consumption			*Other*	7	2.70
No	23	8.91	**Income**		
Yes	235	91.09	*Less than $30k*	2	0.78
Heard of Red Tide?			*$30k - $49k*	16	6.2
No	6	2.33	*$50k - $74k*	51	19.77
Yes	252	97.67	*$75k - $99k*	100	38.76
Makeup of Red Tide?			*$100k - $149k*	64	24.81
Bacteria	58	22.48	*$150k +*	25	9.69
Algae	163	63.18	**Education**		
Virus	24	9.3	*Less than High School*	8	3.1
I don’t know	13	5.04	*High School Graduate*	60	23.26
Safe to commercially harvest fish during red tide?			*Some College/Currently*	32	12.4
Yes	82	31.78	*College Graduate*	117	45.35
No	123	47.67	*Graduate Degree*	41	15.89
I don’t know	53	20.54	**Resident/Tourist Status**		
Safe to harvest shellfish during red tide?			*Resident*	128	49.61
Yes	20	7.75	*Tourist*	130	50.39
No	183	70.93	**Distance to Beach (residents)**		
I don’t know	55	21.32	*On the Shore*	23	19.01
Safe to swim during red tide?			*Within .25 mi*	21	17.36
Yes	92	35.8	*Within 1 mi*	34	28.1
No	102	39.69	*Within 5 mi*	29	23.97
I don’t know	63	24.51	*Over 5 mi*	14	11.57
Have there been reports of deaths from red tide?			**Distance to Beach (tourists)**		
Yes	36	13.95	*On the Shore*	19	13.87
No	121	46.9	*Within .25 mi*	30	21.9
I don’t know	101	39.15	*Within 1 mi*	21	15.33
Consumption During Bloom (w/ info)			*Within 5 mi*	33	24.09
Yes	85	65.89	*Over 5 mi*	34	24.82
No	44	34.11	**Location of Survey**		
Consumption During Bloom (No info)			*Caspersen Beach*	20	7.75
Yes	31	24.22	*Lido Beach*	50	19.38
No	97	75.78	*Siesta Key*	23	8.91
Gender			*Turtle Beach*	69	26.74
Male	125	48.45	*Venice Beach*	96	37.21
Female	133	51.55			

We now present a balance test for the treatment assignment using an OLS regression with a binary variable, $treat_i$ as the dependent variable. The econometric model is shown below in Equation A1:

$$treat_i = \alpha_0 + \boldsymbol{X_i}\delta + \varepsilon_i \quad \text{(A1)}$$

where $treat_i$ is equal to 1 if respondent i was shown the additional information about the health and safety of red grouper during a bloom, and zero otherwise. $\boldsymbol{X_i}$ is a vector of control variables including a binary variable if respondents were able to correctly display prior knowledge of commercial seafood being safe, binary variables for white, resident status, female, and four of the five beaches where the survey for respondent i was taken (Caspersen Beach omitted), and continuous variables for income, education, age, and distance of dwelling (residence or place of stay) to the beach. The results are below in Table A1. Column 1 displays estimates without beach level location controls, and Column 2 adds these controls. The results from Table A1 suggest that the randomization of the treatment was balanced successfully.

Table A2: Balance Test for Treatment Assignment

	(1)	(2)
White (1=yes)	0.00427	0.00812
	(0.0695)	(0.0726)
Female (1=yes)	0.0192	0.0197
	(0.0490)	(0.0485)
Resident (1=yes)	0.00750	0.00687
	(0.0676)	(0.0686)
Distance (mi.)	-0.00691	-0.00662
	(0.00842)	(0.00919)
Income ($thousands)	0.000117	0.000169
	(0.00157)	(0.00157)
Education (yrs.)	0.00923	0.00936
	(0.0218)	(0.0218)
Age (yrs.)	-0.000210	-0.000202
	(0.00208)	(0.00214)
Lido Beach		-0.0284
		(0.0158)
Siesta Key		-0.0685
		(0.0339)
Turtle Beach		-0.0106
		(0.0233)
Venice Beach		-0.0452
		(0.0362)
Seafood Safety Knowledge	0.126	0.135
	(0.0763)	(0.0800)
Observations	258	258
R-squared	0.027	0.028

Notes: Table A2 presents the estimate on the coefficients from Equation (A1). Column 2 adds beach location of survey binary variables. All robust standard errors are clustered at the beach level. The estimate for the constant is omitted for brevity but are available upon full request. *, **, and *** represent statistical significance at the 10%, 5%, and 1% level respectively.