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Louisiana residents' self-reported lack of information following the *Deepwater Horizon* oil spill: Effects on seafood consumption and risk perception

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Abstract

In 2010, the *Deepwater Horizon* (DWH) oil spill adversely impacted many communities along the Gulf of Mexico. Effects on Gulf waters, marshes, aquatic life, and fisheries were evident in the following days, months, and years. Through studying affected communities' perceptions regarding the DWH accident, we aim to identify behavioral changes, understand public information sources, and inform dissemination strategies that improve communications from regulatory agencies. Over a three-year period (2012 −2015), residents (n = 192) from 7 coastal parishes in southeast Louisiana were surveyed about their perceptions and behaviors before, during, and after the DWH accident. Self-reported consumption of local seafood decreased significantly (50%) during the DWH oil spill but returned to pre-event reported levels by 2015. However, negative seafood quality perceptions remain and have not returned to what were generally positive pre-event levels. Over 30% of study participants trust relatives, friends, and neighbors more than government officials or scientists as information sources regarding locally harvested seafood. Importantly, nearly 50% of participants report that they lack the information needed to make informed decisions regarding the safety of consuming local seafood. We conclude that a lack of information and trust in government agencies exacerbated negative perceptions of oil spill-related dangers. In some cases, overestimation of perceived dangers likely led to behavioral modifications that persist today. Efforts should be made to improve relationships between public health agencies and communities in order to properly inform all citizens of risks following environmental disasters.

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Keywords

Deepwater Horizon oil spill; Disaster perception; Risk communication

1. Introduction

Sixteen percent of the total commercial seafood production in the United States of America is supplied by the Gulf of Mexico coastal region, which includes Texas, Louisiana, Mississippi, Alabama, and the west coast of Florida (NOAA, 2011). The most recent assessment of commercial fisheries by the National Marine Fisheries Service (NMFS) division of the National Oceanic and Atmospheric Administration (NOAA) ranks Louisiana as the second largest producer by volume of seafood in the United States of America (NOAA, 2011; NOAA, 2013a). On average, Louisiana's commercial seafood landings account for 10% of the nation's total volume of commercial seafood production, which is 2.3 times more than all other Gulf States combined (NOAA, 2013a; NOAA, 2014). The economic benefits of this staple industry provide nearly 2 billion dollars in revenue and 1 out of every 70 jobs for the state of Louisiana annually (NOAA, 2014; NOAA, 2013b; Louisiana Seafood, 2015).

On April 20th, 2010, an explosion on the *Deepwater Horizon* (DWH) offshore drilling platform resulted in the immediate loss of 11 lives and initiated an unprecedented environmental disaster that had multifaceted, long-term effects. Over a period of 87 days, until the reported containment of the damaged well, nearly 210 million gallons of oil were released into the Gulf of Mexico 47.6 miles from the coast of Louisiana (NOAA, 2013b; Louisiana Seafood, 2015; British Petroleum, 2010; NOAA, 2010b; US EPA, 2010). Ten days after the initial explosion on April 30th, 2010, officials in Louisiana closed portions of 3 state fishery zones as a precautionary measure due to predicted oil movement. On May 2nd, 2010, NOAA officially closed the first federal waters, an area of 6812 square miles, due to the oil spill (British Petroleum, 2010; NOAA, 2010b; US EPA, 2010; United States Coast Guard, 2011; LDWF, 2010; Deepwater Horizon, 2015). Federal fisheries were closed based on NOAA's forecast of oil slick movement through predictive computer modeling, ocean currents and weather patterns, as well as visual flight assessments of surface oil contamination (NOAA, 2010b; United States Coast Guard, 2011; LDWF, 2010; Deepwater Horizon, 2015). NOAA closed federal harvest areas with visible oil in addition to buffer zones adjacent to those areas. By June 2nd, 2010, the height of closures in the federal waters of the Gulf Exclusive Economic Zone reached 36.6% (NOAA, 2010b; Deepwater Horizon, 2015).

NOAA, in collaboration with the U.S. Food and Drug Administration (FDA) and the U.S. Environmental Protection Agency (EPA), implemented a systematic reopening procedure guided by scientific testing (Deepwater Horizon, 2015; US FDA, 2010a). In order for previously closed waters to have been reopened, they must first have been free of visible oil for 72 h and have no potential for reintroduction of oil within the next 7–10 days (United States Coast Guard, 2011; US FDA, 2010a). On April 28th, 2010, regulatory agencies began sampling seafood in areas free of visible oil out of concern for potential health risks from

consumption of tainted seafood (United States Coast Guard, 2011). Samples of commonly harvested seafood species were collected from 100 defined sampling grids of approximately 900 square nautical miles each (equivalent to 1191.9 square miles) (United States Coast Guard, 2011; Moreno, 2010; Ylitalo et al., 2012). Each sample was subjected to sensory testing in raw and cooked forms by a panel of 7 trained experts. If no petroleum or dispersant odor or taste was detected by at least 70% of the expert panel, the FDA then evaluated samples further for the presence of contaminants with highly sensitive and specific chemical analysis. Scientists at the Northwest Fisheries Science Center (NWFSC), a division of NOAA Fisheries, utilized gas chromatograph/mass spectrometry (GC/MS) to detect crude oil chemicals such as polycyclic aromatic hydrocarbons (PAHs) as well as liquid chromatography-tandem mass spectrometry (LC-MS/MS) to detect the oil dispersant component dioctyl sodium sulfosuccinate (DOSS) in seafood samples. The NWFSC and the National Seafood Inspection Laboratory (NSIL), also a division of NOAA Fisheries, conducted additional testing of seafood samples for PAH contaminants using high-performance liquid chromatography fluorescence analyses (HPLC-fluorescence) (Ylitalo et al., 2012). Regulatory levels of concern (LOCs) for each analyte, including PAHs and DOSS in seafood, were derived by the FDA and based on human health toxicity and/or carcinogenicity. Additionally, the EPA conducted water column and sediment tests to ensure quality and safety prior to reopening. Areas were reopened only if all analytic measures showed results below the accepted federal regulatory LOCs for each analyte (US FDA, 2010a; Moreno, 2010).

While NOAA retains legislative authority to close federal waters, state agencies worked closely with NOAA, the EPA, and the FDA to determine closures of state waters. Before state agencies could reopen closed waters, they were required to submit samples to the FDA following the same procedures, test levels, and guidelines that were applicable to federal waters. States were only approved to reopen waters when samples from each specific sampling grid passed federal sensory testing and chemical analysis (US FDA, 2010a; US FDA, 2010b).

By April 2011, all federal waters once closed due to the oil spill had reopened, and on April 26th, 2011, the Louisiana Department of Wildlife and Fisheries (LDWF) reported that over 99.4% of state closed fisheries were reopened (US FDA, 2010b; LDWF, 2011; NOAA, 2010a). The FDA confirmed that “99% of samples contained no detectable dispersant residue” and that “When oil residue was found, the levels were 100 to 1000 times lower than the levels of concern” (LDWF, 2011; NOAA, 2010a; US FDA, 2010c). In September 2015, the Louisiana Department of Health and Hospitals (LDHH) reported that of the 7071 seafood samples collected and tested for reopening from April 30th, 2010 to January 31st, 2014, none of the samples, which included shrimp, oysters, finfish, and crab, showed levels of analytes that exceeded the federally set LOCs and thus were safe for consumption. Additionally, 62 water samples were collected and analyzed for total petroleum hydrocarbons in Louisiana. All of which were negative (US EPA, 2010; US FDA, 2010c; LDHH, 2015; LDHH, 2012).

The DWH oil spill undeniably affected the communities and fisheries that sustain the majority of the seafood production in this region, notably in Louisiana. In 2010, commercial

fishery closures in Louisiana resulted in an estimated 11% decrease in income for harvesters. Restaurants and grocers reported a combined estimated 23% reduction in seafood sales for 2010 in Louisiana. Fishery closures and reduction of sales resulted in a 28% decrease in employment for all sectors associated with seafood industry (e.g. grocers, restaurants, harvesters, and primary and secondary distributors) in 2010 (US EPA, 2010; LDHH, 2015; LDHH, 2012; NOAA, 2012). However, in 2011, Louisiana's commercial fisheries landed a record 1.3 billion pounds of seafood, approximately 345 million pounds more than the average production from 2004 to 2009 (NOAA, 2014; NOAA, 2012). In 2012 and 2013, Louisiana's average commercial seafood production exceeded that of the average production in the 6 years preceding the oil spill by 53 million pounds. Income for commercial seafood harvesters increased by 35% in 2011. Seafood restaurants and grocers experienced a combined increase of 64% in sales in 2011 in comparison to 2010, and employment numbers increased by 30% in 2011 and have remained above levels compared to the 3 years preceding the oil spill (NOAA, 2014; NOAA, 2012).

Nevertheless, the negative perceptions regarding the quality and safety of Gulf seafood after the DWH accident have been persistent, and some behavioral patterns remain altered because they are based on these perceptions. Misinformation, lack of factual information, presumed obscurity of official sources, as well as previous or initial conceptions (e.g. anchoring) formed during experiences of other environmental disasters can dramatically impact and influence perceived risks (NOAA, 2012; Field, 1999). For example, even after implementation of stringent government testing policies and confirmation of seafood safety by state and federal officials, public opinion continued to reflect concern about seafood quality and safety after the DWH accident despite the factual information that was released by NOAA and the FDA (Field, 1999; Safford et al., 2012; Biello, 2011). In part, concerns regarding seafood safety were most likely impacted by media selectivity of sensational news stories such as pictures of oiled birds, deceased dolphins, beaches covered with tar, and seafood with anatomical abnormalities and/or apparent lesions from individual interviews with local fishermen (Safford et al., 2012; Biello, 2011; Curth, 2015; Fox 8 WVUE, 2015; Jamail, 2012; Schleifstein, 2015; Smith, 2014). While many of these examples highlight exposures to oil on aquatic organisms, they cannot be used as proxies to determine the levels of contaminants in edible portions of seafood.

In order to evaluate the perceptions of individuals living in communities who are highly reliant on the Gulf of Mexico seafood industry, we surveyed residents from 7 parishes along the southeastern Louisiana Gulf coast from 2012 to 2015. Participants were asked about their environmental awareness of the oil spill and cleanup, seafood consumption behaviors, perceived seafood quality, concerns regarding health risks, knowledge of testing procedures, preferred sources of oil spill and seafood information, and trust in regulatory agencies. Our goals were to determine specific perceived risks within these communities due to the DWH accident and to identify areas for improvement in response and communication efforts. Strengthening communication and building trust before environmental disasters occur is imperative for improving recovery. This will require government representatives, regulatory agencies, public health officials, and scientists to critically reevaluate and reinvent their relationship with the public so that individuals living in highly impacted communities are more accurately and better informed of health risks.

2. Methods

2.1. Study participants

Participants (n = 192) were recruited from 7 coastal parishes in southeastern Louisiana impacted by the DWH oil spill, including Terrebonne, Orleans, Jefferson, Lafourche, St. Bernard, Plaquemines, and Assumption, on a voluntary basis as part the Gulf Resilience on Women's Health (GROWH) study through Tulane University. Of the total participants, 7 were recruited in 2012, 29 in 2013, 29 in 2014, and 127 in 2015. This ongoing study focuses on pregnant women and women of reproductive age, 18–45 years of age, who are considered a vulnerable subpopulation because of an increased risk of physical and emotional stressors due to the DWH oil spill. Exposure to environmental contaminants due to the oil spill and clean up efforts could affect reproductive health of women and birth outcomes in this region (Perera et al., 2015; Vishnevetsky et al., 2015; Rios et al., 1993; Choi and Perera, 2012). The National Academies of Sciences, Engineering, and Medicine, Health and Medicine Division (formerly the Institute of Medicine) research priorities established after the DWH oil spill highlight pregnant women as vulnerable populations in part due to the potential for increased exposure to heavy metals in seafood and changes in seafood consumption patterns (Institute of Medicine (US), 2010). Both exposure to heavy metals or decreased consumption of dietary fatty acids through decreased consumption of seafood could lead to poor birth outcomes and neurodevelopment issues in children (Shirai et al., 2010; Lewis et al., 1992; Al-Saleh et al., 2014; Robillard and Christon, 1993; Meher et al., 2016; Grieger and Clifton, 2015; Carlson et al., 2013). Additionally, women have been shown to be more vulnerable to psychological distress than men after disasters and can be affected for longer periods of time post-disaster (Dunkel Schetter, 2011; Ehrlich et al., 2010; Martini et al., 2010; Norris et al., 1999, 2002). Specifically, women affected by the DWH oil spill may experience increased anxiety over social factors, job loss, lifestyle changes, and affects to family members, which can cumulatively affect birth outcomes. Women were primarily recruited during health visits to participating community clinics, primarily those serving women, infants, and children (WIC), as well as the Bayou Interfaith Shared Community Organizing (BISCO) foundation and Mary Queen of Vietnam Community Development Corporation (MQVN-CDC). This study was approved by the Tulane University Institutional Review Board (IRB No. 11-262504).

2.2. Survey methodology

Questionnaires were developed from those used in a previous, sister study that was conducted in collaboration with Washington State University Social and Economic Sciences Research Center in the summer and fall of 2010 and continued through the spring of 2011 (Wilson et al., 2015). Pilot surveys were administered in representative groups selected by our community partners and refined in order to improve clarity and comprehension within the target population. All participants gave informed consent before participating in the study. Surveys were conducted on an individual basis either at participant's homes or at meetings organized by community group partners BISCO and MQVN-CDC. Self-administered, supervised responses were recorded using iPads (Apple Inc.) and the iFormBuilder Mobile Platform (Zerion Software, Inc., Herndon, VA). Responses were exported from iFormBuilder to Microsoft Excel for cleaning, coding, and processing.

Supervision was necessary to address confusion on any participant's behalf and improve completion of questionnaires. Participants were compensated with a $25 gift card for completing the survey series. Sixteen percent of the total number of eligible individuals contacted fully participated in the study. Summary statistics and statistical testing with chi-square analysis and Fisher's exact test were conducted with Graphpad Prism Version 6.0 (GraphPad Software, Inc., La Jolla, CA). Statistical significance was determined at $p < 0.05$.

2.3. National marine fisheries data acquisition and usage

2.3.1. Annual commercial fisheries landing data—Data was obtained through the publically accessible database on commercial fisheries statistics through the Office of Science and Technology, NMFS and NOAA, at the following web address:

> http://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index (NOAA, 2014; Curth, 2015; Fox 8 WVUE, 2015; Jamail, 2012; Schleifstein, 2015; Smith, 2014).

Data was extracted using the following parameters: all species combined, from 2004 to 2013 (latest available year), and by Gulf state as well as total US. The query returned annual commercial fishery landings for Gulf States (West Coast of Florida, Alabama, Mississippi, Louisiana, and Texas) and total US in metric tons, pounds, and revenue in US dollars. Microsoft Excel was used to sort data by year and state and to calculate and compare totals, averages, and poundage.

2.3.2. Seafood industry impacts data—Data was obtained through the publically accessible database (Interactive Fisheries Economic Impacts Tool) on annual seafood industry impacts through the Office of Science and Technology, NMFS and NOAA, at the following web address:

> https://www.st.nmfs.noaa.gov/apex/f?p=160:1:0::NO (NOAA, 2014; NOAA, 2012).

Data was extracted using the following advanced query parameters: from 2006 to 2012 (earliest and latest available years), the state of Louisiana only, all impact categories, and all sectors. The query returned annual seafood industry impacts for all Louisiana sectors from 2006 to 2012. Sales and income were reported in US dollars and employment impacts were reported in number of jobs (full-time and part-time). Microsoft Excel was used to sort data and to calculate and compare totals, averages, and percent change. Only "total impacts" for each category were used to generate values because they include direct, indirect, and induced economic impacts (NOAA, 2013b; NOAA, 2012).

3. Results

Percentages were rounded to one significant digit after the decimal. Questions regarding time, before, during, and after, in relation to the DWH accident were defined to participants as follows: "before" was prior April 20th, 2010, "during" was April 20th, 2010 until July 15th, 2010, and "after" was following July 15th, 2010 when the damaged oil well was capped and the uncontrolled release of oil widely reported to have stopped. Additional figures and tables not depicted here – including graphical depiction of all data categories and survey questions – can be found in the Supplemental Information (SI) file.

3.1. Sociodemographic information

Only female participants of reproductive age, 18–45 years of age, were recruited for the study in accordance with IRB approval (Tulane University Biomedical IRB 11-262504). The median age was 30 years of age (SI 1). Eighty-six point six of participants self-identified with 1 of 3 racial/ethnic categories: 43.0% reported African-American, 26.3% reported Caucasian, and 16.7% reported American Indian. The remaining participants self-reported with the following racial/ethnic categories: 9.1% of participants reported Vietnamese, 2.2% reported Hispanic, 1.1% reported Asian, 0.54% reported Chinese, 0.54% reported Native Hawaiian, and 0.54% reported other (SI 2). Participants reported permanent residence in 1 of 7 Louisiana coastal parishes with 37.8% from Terrebonne, 21.1% from Orleans, 20.0% from Jefferson, 9.2% from Lafourche, 7.6% from St. Bernard, 3.2% from Plaquemines, and 1.1% from Assumption parish (SI 3). Exactly 50.0% of survey participants reported that they were unemployed (SI 4). The median gross annual household income was $10,000–$25,000 (SI 5).

Seventy-six point seven percent of respondents completed either some high school (12.4%), some college (29.2%), or high school/GED (35.1%). Five point nine percent reported earning a graduate or professional degree. Five point four percent of participants reported completion of technical or trade school, 4.9% completed a four-year college program, 2.2% completed some graduate school, 1.6% of participants completed a two-year college program while 1.1% reported completing elementary school or less, and 2.2% of participants preferred not to answer (SI 6).

3.2. Environmental awareness of the DWH accident

Participants were asked about their knowledge of the DWH accident in comparison to estimates that were generally accepted and reported by research scientists and government agencies (e.g. 210 million gallons of oil released for a duration of 3 months) in order to assess availability and comprehension of material used to inform their knowledge surrounding the incident. Specifically, participants were asked about the year of the spill, the volume and duration of oil released, if they believed there were safe levels of exposure to oil and dispersants, and if they believed oil from the DWH accident was in the Gulf near their coast. Forty-four point four percent of participants identified the year “2010” as the year of the oil spill while 16.9% reported that they did not know, and 4.2% thought that it spanned multiple years (SI 7). Fewer than 20% of participants identified the accepted volume of oil spilled (16.4%) and duration that oil was released from the damaged well (18.5%) while over half of participants reported that they did not know about the amount of oil (56.1%) or the length of time it was released (59.0%) (SI 8 and 9).

Fifty-four point two percent of participants surveyed across all years believed that there is still oil from the DWH accident in the Gulf near their coast (SI 10A). By year surveyed, 57.1% of participants surveyed in 2012, 58.6% in 2013, 65.5% in 2014, and 50.4% in 2015 believed that there is still oil from the DWH accident in the Gulf near their coast (SI 10B). Differences by year were not significant when tested for trend.

Approximately 30% of participants believed they or their families were exposed to oil (30.3%) and dispersants (30.2%) from the DWH accident. On the other hand, 42.6% did not believe they were exposed to oil, and 38.6% did not believe they were exposed to dispersants. (SI 11 and 12). Participants were asked if they believed there is a safe level of exposure to oil and dispersants. Thirty-four point zero percent and 41.8% believed that there is no safe level of exposure for oil and dispersants, respectively (SI 13 and 14).

3.3. Seafood consumption

Seafood consumption patterns and behaviors were examined in order to determine if self-reported changes were influenced by the DWH accident, how consumption may have been affected, and if any changes due to the DWH accident returned to self-reported pre-event levels. Overall, the differences of reported local seafood consumption before, during, and after the DWH accident were statistically significant (χ^2 177.0 dF 2, $p < 0.0001$). There were no significant differences when comparing self-reported local seafood consumption before and after the oil spill. During the DWH accident, only 39.1% of participants reported eating local seafood while 60.9% reported that they did not eat local seafood. There were approximately 50% fewer participants consuming local seafood during the DWH accident which was statistically different from self-reported local seafood consumption before (89.0%) and after (94.2%) the oil spill (Fisher's $p < 0.0001$) (Fig. 1). After the event, 36.5% of respondents reported eating non-local seafood (SI 16).

In order to study seafood consumption patterns in more detail, participants were asked if they made changes to the amount, types, and frequency of seafood consumed because of the DWH accident. Sixty-one point four percent reported not changing the amount of seafood they consume, while 33.3% of participants reported that they eat smaller portions now because of the event, and 5.3% reported eating larger portions now (SI 18). Sixty-one point nine percent report that they have not changed the types of seafood that they consume whereas 38.1% reportedly did change the type of seafood consumed (SI 19). Regarding the frequency of seafood consumption, 50.6% said that they have not made changes, while 38.3% reported eating seafood less frequently, and 11.1% said they eat seafood more frequently now due to the DWH accident (SI 20). Participants were then asked to report their consumption frequency for the 4 most commonly consumed local seafood types – fish, shrimp, crab, and oyster – before, during, and after the DWH accident (SI Tables 1–4). Participants reported eating fish and shrimp most frequently overall regardless of the time in relation to the event (SI Tables 1 and 2). Oysters were consumed the least frequently overall throughout each time point (SI Table 4).

3.4. Seafood sources

Participants were asked to provide information about how they determine if their seafood is local. Sixty point nine percent of participants either know the vendor or source (34.8%) or catch/harvest seafood themselves (26.1%). Thirteen point seven percent look at the label or packaging, 13.7% assume that it is local, and 6.8% ask the vendor or source for information to determine if the seafood is locally harvested while 5.0% reported that they did not know (SI 21). The most preferred source of local seafood identified by 41.3% of participants was catching and harvesting their own seafood. Twenty-five point zero percent prefer a neighbor,

friend, or family member as a source, 22.0% prefer to obtain local seafood from seafood markets, 7.5% from grocery stores, and only 4.4% of participants reported restaurants as a preferred source of seafood (SI 22).

The most commonly used self-reported seafood sources remained fairly constant before, during, and after the event with the exception of restaurants and seafood markets. Participants ranked restaurants as the overall least preferred seafood source (SI 22). During the event, 15.8% of participants reported using restaurants as a source of local seafood in contrast to only 6.2% and 7.5% of participants before and after the event, respectively (Fig. 2). Seafood markets were the second most preferred source of local seafood reported by participants (SI 22). Eleven point eight percent of participants reported using seafood markets as a source of local seafood during the event, which was reduced from 23.6% and 22.4% of participants reporting seafood markets as source before and after the event, respectively (Fig. 2). Differences in restaurants and seafood markets as seafood sources as reported by participants were statistically significant overall when comparing before, during, and after the DWH accident (χ^2 10.2, dF 2, $p < 0.05$). To examine more closely, restaurants and seafood markets as seafood sources were compared before and after (not significant, Fisher's $p = 0.63$), before and during (Fisher's $p < 0.001$), and during and after the DWH accident (Fisher's $p < 0.05$) (Fig. 2).

3.5. Seafood quality and perceptions

As an indication of perceived seafood quality, participants were asked to rank their seafood quality before, during, and after the DWH accident. Before the DWH accident, the majority, 89.1%, of participants reported excellent, good, or adequate seafood quality while only 2.0% reported poor or unsafe seafood quality (Fig. 3A). During the event, only 38.5% of respondents considered seafood quality to be excellent, good, or adequate while 42.2% regarded seafood quality as poor or unsafe (Fig. 3B). After the event, 77.1% of participants perceived seafood quality to be excellent, good, or adequate while 10.4% of participants perceived seafood quality as poor or unsafe (Fig. 3C). There was an increase in positive perceptions of seafood quality, such as excellent, good, or adequate, after the oil spill as compared to positive perceptions of seafood quality during the event. However, 12% fewer participants ranked seafood quality as excellent, good, or adequate, and 8.4% more participants ranked seafood quality as poor or unsafe after the DWH accident in comparison to before the accident (Fig. 3A and C).

Differences in seafood quality perception before, during, and after the DWH accident were tested using chi-square and Fisher's exact tests. For statistical testing, responses excellent, good, and adequate were combined to define a positive perception category, and responses poor and unsafe were combined to define a negative perception category. There was a significant difference in overall seafood quality perception before, during, and after the DWH accident (χ^2 109.6, dF 4, $p < 0.0001$). To examine more closely, positive and negative perception categories were compared before and after (Fisher's $p < 0.05$), before and during (Fisher's $p < 0.0001$), and during and after (Fisher's $p < 0.0001$) the DWH accident. In order to examine if the differences in the number of don't know responses about seafood quality before, during, and after the DWH accident were significant, all responses, with the

exception of don't know, were combined to define a "know" category which included excellent, good, adequate, poor, and unsafe. All responses of don't know defined the don't know category. Although there was an increase in the percentage of participants who answered don't know from 8.9% of respondents before the accident to 19.3% during the accident and 12.5% after the DWH accident, the difference was not statistically significant (before versus after Fisher's $p = 0.48$; before versus during Fisher's $p = 0.05$; and during versus after Fisher's $p = 0.27$) (Fig. 3). Approximately one third (30.7%) of respondents believed that the DWH accident permanently affected the quality of their local seafood (SI 23).

Participants were also asked if they believed that consuming locally harvested seafood posed a health risk before, during, and after the event. Before the DWH accident, 2.1% of participants reported that consuming local seafood posed a health risk while 72.4% reported no health risk and 25.5% did not know. During the DWH accident, 41.1% of participants reported that they believed consumption of local seafood posed a health risk while 26.6% believed that it did not, and 32.3% did not know. After the DWH accident, the percentage of participants who perceived that consumption of local seafood posed a health risk was 9.9%, in comparison to only 2.1% of participants before the event. Fifty-six point two percent of participants believed that consuming local seafood did not pose a health risk after the DWH accident, and 33.9% did not know (Fig. 4). Responses, yes, no, and don't know, regarding local seafood consumption and health risk were compared before, during, and after the event and were significantly different (χ^2 135.2, dF 4, $p < 0.0001$). To examine more closely, yes and no response categories were compared before and after (Fisher's $p < 0.001$), before and during (Fisher's $p < 0.0001$), and during and after the DWH accident (Fisher's $p < 0.0001$). In order to determine if there were significant changes before, during, and after the DWH with regards to local seafood consumption and health risks between yes/no responses and don't know, responses of yes and no were combined to form a "know" category. "Know" responses were not significantly different from don't know responses before, during, and after the DWH accident (Fig. 4).

To determine if participants would attribute changes in seafood safety to future environmental events, participants were asked if they thought a hurricane or storm, unrelated to an oil spill, would cause their seafood to be unsafe. Thirty-eight point five percent of participants responded that they believed such an incident would cause their seafood to be unsafe while 41.7% reported that they did not know how a hurricane or storm might affect the safety of local seafood, and 19.8% did not know if a hurricane or storm might affect the safety of local seafood (SI 24).

3.6. Public trust and perceived DWH effects

Participants were asked a series of questions to gauge their level of agreement with statements regarding the overall effects of the DWH accident, the duration of the effects, and the understanding of the effects. Sixty-two point two percent of participants somewhat or strongly disagreed with the statement "There have been no effects" (SI 26). When asked if they felt that the effects of the DWH accident were something they could control, 50.0% disagreed (SI 27). When asked about the effects of the DWH accident on health risks, 43.6%

of participants somewhat or strongly disagreed that the effects caused little or no health risks (SI 28). Fifty-two point six percent of participants somewhat or strongly disagreed when asked if the DWH accident affected only a few people (SI 29). Participants were asked to gauge their perception about the duration of the effects. Forty-three point one percent disagreed when asked if the effects were short term (SI 30). Fifty-three point two percent disagreed when asked if they thought the effects were no longer present (SI 31).

Next, participants were asked if the effects were understood by themselves, fisherfolk, scientists, public health officials, and medical doctors. Fifty-three point one percent somewhat or strongly agreed that they understood the effects, 17.2% of participants somewhat or strongly disagreed that they understood the effects while 29.7% answered neutral (SI 32). Fifty-four point seven percent agreed that the effects were understood by fisherfolk (SI 33). Sixty-nine point two percent and 69.3% agreed that the effects were understood by scientists and public health officials, respectively. Ten point four percent and 13.1% somewhat or strongly disagreed that the effects were understood by scientists and public health officials (SI 34 and 35). Seventy-one point nine percent of respondents agreed that the effects were understood by medical doctors (SI 36).

In order to understand who they believed was knowledgeable about the DWH accident, participants were asked to rank 12 groups, including themselves, as none (not knowledgeable), less than most, more than most, or completely knowledgeable. Seventy-eight point three percent of respondents ranked themselves as the least knowledgeable group (responses ‘not knowledgeable’ and ‘less than most’ combined). Ninety-two point one percent of participants ranked industry scientists and officials as the most knowledgeable group (responses ‘more than most’ and ‘completely knowledgeable’ combined). Ninety-one point six percent of participants ranked state health agencies and officials as the second most knowledgeable. Local or network television media or other media were ranked by 80.4% of participants as the sixth most knowledgeable group (Fig. 5).

In a separate survey section, participants were then asked to rank 11 different groups according to their most trusted sources of information regarding the DWH accident. Thirty-four point five percent ranked relatives, friends, and neighbors as their most trusted source. Sixteen point four percent ranked federal health officials and agencies such as the FDA, EPA, and NOAA as their most trusted source. Six point two percent ranked local health agencies such as city or public health officials as their most trusted source (Fig. 6).

Seventy-nine point seven percent of respondents had a positive perception (responses of excellent, good, and adequate) of how public health agencies responded to ensure their health and safety regarding locally harvested seafood, 6.3% had a negative perception (response of poor) of the efforts, and 14.1% did not know (SI 37). Approximately half (51.0%) of participants felt as though they had enough information to make a decision themselves about the safety of consuming locally harvested seafood while 49.0% did not (SI 38). Only 22.9% reported that they knew how regulatory agencies determined if locally harvested seafood is safe to catch and consume while 77.1% reported that they did not know (SI 39). When asked how often they trust and follow government agency seafood consumption health advisories, 8.3% responded that they always trust the advisories, and

17.7% responded that they always follow the advisories. Six point three percent and 7.3% reported that they never trust and follow the advisories, respectively. Forty-one point one percent trust and 40.1% follow advisories occasionally, and 33.9% trust and 24.0% follow advisories often. Approximately 10% of respondents were not aware of advisories (Fig. 7).

4. Discussion

The DWH accident was the largest offshore oil spill to occur in U.S. waters (NOAA, 2013b; US Department of the Interior, 2011). Because of the magnitude and duration of the spill, as well as the public and economic impacts of this disaster, the DWH oil spill was the first to be classified by the federal government as a Spill of National Significance (SONS) since the classification was established in 1994 (United States Coast Guard, 2011; US Department of the Interior, 2011). While some of the immediate consequences due to oil spill-related fishery closures were evident, others, such as behavioral effects, were less obvious and may continue to linger, especially in affected Gulf coastal communities. We surveyed reproductive age women (18–45 years of age) from 7 coastal parishes in Southeast Louisiana in order to better understand how women within these communities were affected by the DWH oil spill and to identify areas for improvement in risk communication. We discovered that some participants made lifestyle changes specifically due to the DWH oil spill. Between 33% and 38% of participants reported altering the amount, frequency, and/or types of seafood consumed because of the DWH accident. These changes included a statistically significant decrease in seafood consumption by 50% of participants during the event, changes to the types of seafood consumed (e.g. crab consumption) during and after the event, and changes in local seafood sources used during the event (e.g. increase in the least overall preferred source, restaurants) (Fig. 1, SI Tables 1–4, Fig. 2). Behavioral modifications affecting seafood consumption patterns and seafood sources were primarily observed during the DWH accident and have since returned to pre-event levels. Some of the self-reported change during this time may have been a function of altered access to local seafood due to fishery closures. Additionally, market fluctuations likely impacted access to locally harvested seafood. Increasing prices of some seafood, because of limited availability, could have disproportionately affected a lower SES demographic such as those participating in our study (United States Coast Guard, 2011; Schuh, 2014; Bourgeois et al., 2014). However, our results also indicate that concerns regarding safety and quality were paramount and that those concerns influenced consumption choices and behaviors. Our results demonstrate that perceptions regarding the safety and quality of local seafood in some participants have not returned to pre-event levels. After the event, approximately 5 times more participants perceived local seafood quality to be poor or unsafe and that consuming it posed a health risk in comparison to perceptions before the event (Fig. 3). Thirty point seven percent of participants perceive that there are permanent, negative changes in their seafood quality because of the DWH oil spill (SI 23).

In order to understand the basis of their conclusions, we examined participants' perceptions of the overall effects of the DWH accident on seafood quality, perceptions of regulatory agencies, participants' trusted sources of information, and how participants evaluated their own knowledge. Over 50% of participants agreed that most groups (i.e. fisherfolk, scientists, public health officials, medical doctors) as well as they understood the effects of the DWH

accident on seafood quality (SI 32–36). We found compelling information in the differences between the groups that participants ranked as most *knowledgeable* about the DWH oil spill in comparison to the groups ranked as most *trusted* sources for information regarding the event. A large fraction of participants (34.5%) ranked family, friends, and neighbors as the most trusted source of information, but they ranked family and friends as the tenth most knowledgeable (out of 12 groups) (Figs. 5 and 6). Ninety-two point one percent of participants ranked industry scientist and officials as the most knowledgeable, while 78.3% of participants ranked themselves as the least knowledgeable (out of 12 groups) about the details of the DWH accident overall (Fig. 5). Between 55.6 and 83.6% of participants identified basic facts about the incident that largely conflicted with the widely accepted and officially reported data such as the year of the event, the duration of the spill, or the amount of oil spilled (SI 7–9). Overwhelming percentages of participants reported that they lacked information about seafood safety guidelines (77.1%) and knowledge needed to make informed decisions about locally harvested seafood (49.0%) (SI 38 and 39). Therefore, it is not surprising that less than half of participants only occasionally trust (41.1%) and follow (40.1%) government seafood consumption health advisories (Fig. 7).

In general, participants' responses from this demographic in this region indicated three key points: a lack of knowledge regarding the processes utilized by government officials to ensure safety, a lack of necessary information with which to make their own informed decisions, and a lack of trust in regulatory agencies as a primary source of information. Each of these issues can contribute to the other. We hypothesize that these concerns are indicative of other communities and regions with a similar demographic composition. Deficiencies in communication with the public were recognized early in the recovery process. In 2012, Lubchenco et al., accurately described several critical factors contributing to the public's skepticism and confusion concerning the DWH accident, notably, inaccurate and highly variable oil flow-rate estimates from the damaged well leading to mistrust and confusion, ineffective communication among government, scientists, and communities, and hesitation from the scientific community to share findings due to publication pressures (Schuh, 2014; Bourgeois et al., 2014; Lubchenco et al., 2012). Our results not only support the authors' initial conclusions in 2012 but also confirm that they may have lasting implications insofar as our study examined participants from 2012 to 2015. Further evidence of misconceptions regarding the oil spill events has been documented. A report compiled by Oxford Economics in July 2010 for the U.S. Travel Association revealed significant declines in tourism to the entire Gulf region in the months after the DWH oil spill, and declines were predicted to continue over the next several years (Lubchenco et al., 2012; Oxford Economics, 2010). Misconceptions about the oil spill and the extent of its effects are believed to have contributed to the majority of trip cancellations to the region after the oil spill.

Communication of accurate, timely, and culturally appropriate information that can adequately meet the needs of populations with disparate levels of environmental health literacy is essential for successful recovery response efforts (Oxford Economics, 2010; Finn and O'Fallon, 2015). Among the greatest obstacles to providing accurate information to communities during a disaster or an environmental accident is media bias. News agencies often report sensational stories in order to increase and maintain viewership during disasters or to influence public opinion (Finn and O'Fallon, 2015; Vasterman et al., 2005; McCombs

and Shaw, 1972). Stories repeatedly focused exclusively on areas severely affected by the oil spill rather than an assessment of the area as a whole (Fox 8 WVUE, 2015; Vasterman et al., 2005; McCombs and Shaw, 1972; Walker, 2015). Local news stations conducted interviews with individual fishermen who reported anecdotal observations that were neither tested nor verified by scientific sources, and some news stories directly blamed British Petroleum (BP) based on these observations (Fox 8 WVUE, 2015; Walker, 2015). Published findings related to the oil spill also made headlines, and many media outlets interpreted results in order to capture audiences and vilify petroleum industry officials. For example, in May 2015, Venn-Watson et al., published findings describing an unusual mortality event (UME) in bottlenose dolphins in the Gulf of Mexico "following the *Deepwater Horizon* oil spill" (Walker, 2015; Venn-Watson et al., 2015). The authors describe the UME as beginning in February 2010, 2 months before the DWH accident, and continuing through 2014. The authors' findings lead to the possibility of the DWH accident contributing to dolphin deaths in the most severely oiled locations, and they conclude with a hypothesis that the DWH accident may have contributed to the UME. However, news headlines utilized language that more definitively blamed the DWH oil spill and BP for the dolphin deaths. Headlines read "The BP oil spill killed a lot of dolphins," "BP oil spill still responsible for Gulf of Mexico dolphin deaths," "Study: BP oil spill led to biggest Gulf dolphin die-off recorded," and "Spike in dolphin deaths directly tied to *Deepwater Horizon* oil spill, researchers say" (Venn-Watson et al., 2015; Zillman, 2015; Biello, 2015; Schlanger, 2015; Grenoble, 2015).

Eighty point four percent of participants in our study ranked local or network media as the 6th most knowledgeable (out of 12 groups) regarding details of the DWH accident (Fig. 5). Because perceived risk is subjective and often influenced by the media as well as social context (e.g. hurricane disasters, SES, etc.) media bias can greatly hinder the efforts of regulatory agencies and public health officials to adequately deliver accurate information and gain public trust (Field, 1999; Finn and O'Fallon, 2015; Zillman, 2015; Biello, 2015; Schlanger, 2015; Grenoble, 2015). The fact that approximately 20 times more participants in our study believed that consuming local seafood posed a health risk during the DWH accident (41.1%) in comparison to before the event (2.2%) is evidence of this phenomenon. Equally important to note is the increase in participants who perceived the local seafood as posing a health risk after the event (9.9%) in comparison to before the event (2.2%) (Fig. 4). Commercial media played an important role in these perceptions as well with headlines such as "Gulf seafood officially safe, but questions and oil linger" contributing to skepticism and distrust rather than providing the public with valuable, vetted information about the regulatory and testing processes (Field, 1999; Biello, 2011; Finn and O'Fallon, 2015). In actuality, Gulf seafood was more extensively and methodically tested during and after the DWH accident than prior to the event or in comparison with seafood from any other source destined for consumption by US consumers. Additionally, the Food, Drug, and Cosmetic Act, enacted by Congress in 1938, along with subsequent amendments and policies (e.g. Food Quality Protection Act 1996) forbids the sale of any food containing an adulterant or contaminant that would "render it injurious to health" (Biello, 2011; US FDA, 2004). Because of these regulations, any seafood contaminated due to the DWH oil spill would not have been permissible for sale in the seafood market (Lubchenco et al., 2012; US FDA, 2004; Gohlke et al., 2011).

While media bias plays a significant role in shaping perceptions, social context and anchoring also form a strong basis for the public response and recovery during and after a disaster. Persistent public concerns are likely indicative of distrust in government, regulatory agencies, and petroleum industry officials. Since 2001, on average less than 50% of the public has reported that they trust their government most of the time (Lubchenco et al., 2012; Gohlke et al., 2011; Pew Research Center, 2014). During the oil spill, only about 50% of people nationwide reported that they trusted the federal government regarding oil spill-related information (Pew Research Center, 2014; Motel, 2015). A lack of trust in regulatory and government agencies in the Gulf coast may stem from framing during previous environmental disasters. Just 5 years prior to the DWH oil spill, Hurricane Katrina, one of the most destructive hurricane to make landfall in the United States, devastated the central Gulf coast. The government's response to the DWH accident was publicized and criticized on all levels which left lasting impressions on the communities in this area. Local and national news coverage focused considerably on the government's mismanaged efforts (Motel, 2015; Barnes et al., 2008). Studies after the Exxon Valdez oil spill suggest that technical risk assessment information, scientifically proven evidence released by government and regulatory agencies to ensure health and safety, does not necessarily change a communities' perception of risk (Field, 1999; Finn and O'Fallon, 2015; Barnes et al., 2008). Messages laden with technical and scientific information and terminology is likely difficult for lay public, including low-income communities, to understand and as such may be viewed with distrust (Field, 1999; Finn and O'Fallon, 2015). In addition, a disconnect in communication between those agencies responsible for releasing technical information and communities may contribute to participants' reporting that they lack information and do not understand health-related regulatory guidelines.

In the aftermath of the DWH oil spill, federal agencies strived to make real time data available to the public. Much of the information was released through internet resources, interactive websites, and social media; however, self-interpretation of information, especially highly technical information, often leads to frustration, misunderstanding, and misinterpretation (Finn and O'Fallon, 2015; Motel, 2015; Pew Research Center, 2010). Delivering evidence that is accurate, accessible, timely, and easily comprehended by all audiences during a disaster is understandably difficult but would greatly improve efforts to educate communities about their risks. In our study, state and local officials were ranked lower by participants as trusted sources of information in comparison to federal officials and agencies (Fig. 6). We hypothesize that these views may stem from a perceived lack of transparency in state agencies and a lack of available oil spill-related information from state resources. From our own experience, we found considerably less available information from Louisiana state agencies (LDWF, LDHHS, etc.) regarding the DWH oil spill, and searchable information was significantly more difficult to navigate and less detailed than information that was available through federal sources. For example, we were unable to locate a comprehensive list of closures and reopenings of Louisiana state waters due to the DWH oil spill through LDWF. An LDWF employee confirmed the absence of this information through personal communication.

Educating communities increases resilience. Therefore, we should examine the methods used by agencies to relay information. In Louisiana, much information regarding the oil spill

was disseminated to the public through social media and community meetings such as those organized by community groups including our partners BISCO and MQVN-CDC. While these methods serve as useful tools, there is a need for improvement. First, information should be made available so that it is clearly understood by the target audience. An explanation of scientific procedures used to test seafood for safety must be delivered differently to local community members, a scientific panel of experts on seafood safety guidelines, or a class of middle school students, for example. However, the goal should be the same: to educate each of these groups so that they become better informed. Second, information must be made readily available. As social media is utilized more frequently as a method of communication, it is increasingly important to consider the target audience. Not all individuals have access to or engage in social media. Additionally, these platforms may not be ideal for circulating the depth of information needed to notify citizens of topics such as regulatory procedures and health guidelines. Likewise, community meetings are valuable in informing communities and fostering camaraderie among members, but meetings may not be accessible to all residents. Third, state and local agencies require support and resources to effectively and transparently improve their communications with the affected public that they serve. Because trust in federal agencies was ranked higher than other groups in our study, we hypothesize that increased federal involvement in community outreach and education may assist state and local agency outreach. Fourth, it is the responsibility of regulatory agencies to properly inform citizens in the event of a disaster. Because the media has a strong impact on perceived risk, it is imperative for media to accurately report facts without bias or exaggeration. Television and radio media are powerful tools with which to rapidly disseminate information, therefore the media should focus on educating communities and providing information that is lacking. For example, educational news segments dedicated to explaining procedures used by the government in determining fishery closures and seafood safety could help bridge the gap in knowledge described by participants in our study. Lastly, it is imperative to engender positive relationships and trust in communities so that efforts to provide factual, timely information will be better received. To do this, all stakeholders must work together to improve public relations.

While our study has provided valuable information about the communities affected by the DWH oil spill, we acknowledge its limitations. Although study participants were a representative population for the GROWH study focusing on women of reproductive age, they do not necessarily represent the totality of Louisiana coastal communities with respect to gender, socioeconomic status, or age. Future studies to assess the effects of the DWH oil spill could be conducted to include men and possibly children. Additionally, participants were surveyed from 2012 to 2015 depending on the year of enrollment in the study. Because some survey questions relied on participant recall, recall bias may have introduced error over the duration of the multi-year study. Finally, the number of participants enrolled in each year of the study was not equivalent. Later years with more participants are more heavily represented than earlier years in which participant enrollment was lower, but we believe that the results as a whole represent the views and perceptions of the survey population.

5. Conclusions

While the severity of the DWH oil spill was unprecedented, public response reflected concern, misinformation, and distrust. The availability of accurate, timely, and culturally appropriate information is crucial in educating affected communities of their risks during and after a disaster. Our results demonstrate that coastal Louisiana residents lacked information necessary to make informed decisions following the DWH oil spill and that there is a need for improved methods in disaster and risk communication. While government agencies, scientists, and media outlets strive to be more transparent and community-friendly, trusting relationships with communities as well as vetted dissemination strategies and approaches must be established before the onset of an environmental disaster.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2016.05.030.

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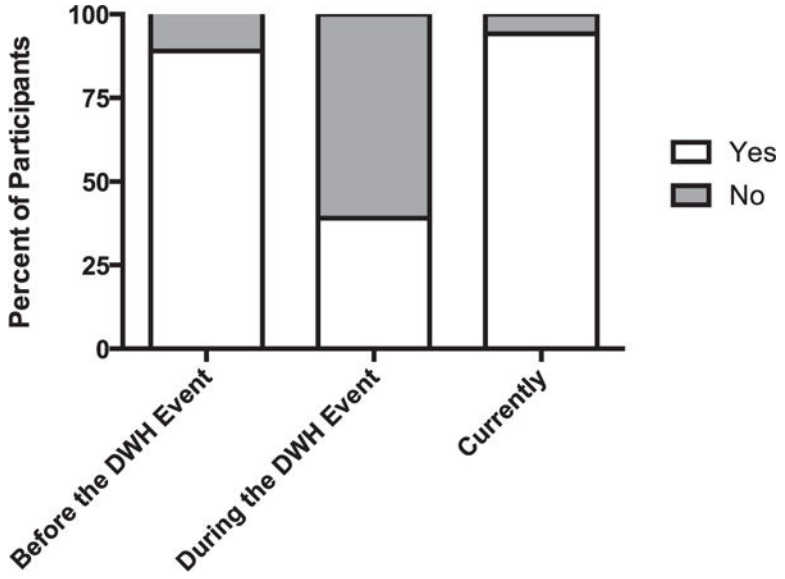

Fig. 1.

Local seafood consumption before, during, and after the DWH accident. Bars as a whole represent the percent of participants in each category. Grey portion of bars represents percent of participants answering “no” while white portion of bars represents percent of participants answering “yes” at each time point. Overall, the differences of reported local seafood consumption before, during, and after the DWH accident were statistically significant (χ^2 177.0 dF 2, $p < 0.0001$). Eighty-nine point zero percent and 94.2% of participants reported that they ate local seafood before and after the event, respectively (not significantly different). Eleven point zero percent and 5.8% reported that they did not eat local seafood before and after the event, respectively (not significantly different). During the DWH accident, only 39.1% of participants reported eating local seafood while 60.9% reported that they did not eat local seafood. There were approximately 50% fewer participants consuming local seafood during the DWH accident which was statistically different from reported local seafood consumption before and after the event (Fisher’s $p < 0.0001$).

Fig. 2.

Seafood sources used the most by participants before, during, and after the DWH accident. Bars as a whole represent the percent of participants in each category. Differences in restaurants and seafood markets as seafood sources as reported by participants were statistically significant overall when comparing before, during, and after the DWH accident (χ^2 10.2, dF 2, $p < 0.05$). To further examine these differences in seafood sources, restaurants and seafood markets were compared before and after (not significant, Fisher's $p = 0.63$), before and during (Fisher's $p < 0.001$), and during and after the DWH accident (Fisher's $p < 0.05$).

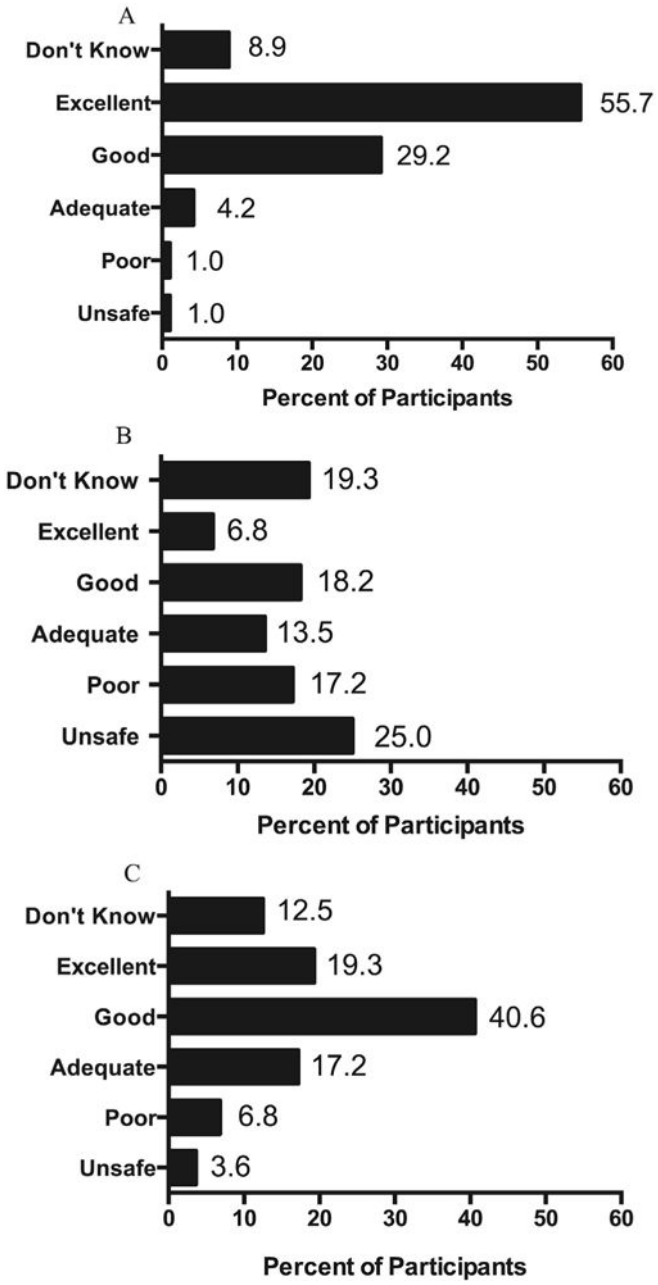

Fig. 3.

Participants perceived seafood quality before (3A), during (3B), and after (3C) the DWH accident. Bars represent percent of participants in each category. There was a significant difference of overall seafood quality perception before, during, and after the DWH accident (χ^2 109.6, dF 4, $p < 0.0001$). To examine more closely, positive and negative perception categories were compared before and after (Fisher's $p < 0.05$), before and during (Fisher's $p < 0.0001$), and during and after (Fisher's $p < 0.0001$) the DWH accident. In order to examine if the differences in the number of don't know responses about seafood quality before, during, and after the DWH accident were significant, all responses, with the exception of don't know, were combined to define a "know" category which included excellent, good,

adequate, poor, and unsafe. Although there was an increase in the percentage of participants who answered don't know from 8.9% of respondents before the event to 19.3% during the event and 12.5% after the DWH accident, the difference was not statistically significant (before versus after Fisher's $p = 0.48$; before versus during Fishers $p = 0.05$; and during versus after Fisher's $p = 0.27$).

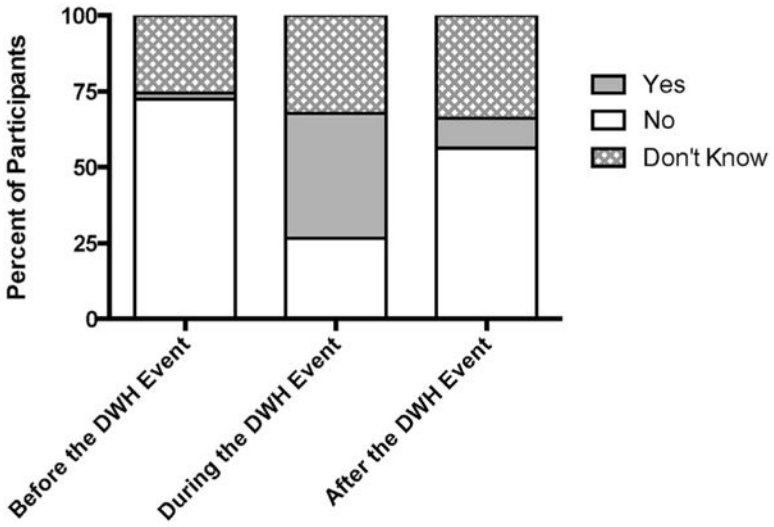

Fig. 4.

Perceived health risk and local seafood consumption before, during, and after the DWH accident. Bars represent the percent of participants in each category. Participants were asked if they believed that consuming local seafood posed a health risk to them or their families. Responses, yes, no, and don't know, regarding local seafood consumption and health risk were compared before, during, and after the event and were significantly different (χ^2 135.2, dF 4, $p < 0.0001$). To examine more closely, yes and no response categories were compared before and after (Fisher's $p < 0.001$), before and during (Fisher's $p < 0.0001$), and during and after the DWH accident (Fisher's $p < 0.0001$). In order to determine if there were significant changes before, during, and after the DWH with regards to local seafood consumption and health risks between yes/no responses and don't know, responses of yes and no were combined to form a "know" category. "Know" responses were not significantly different from don't know responses before, during, and after the DWH accident.

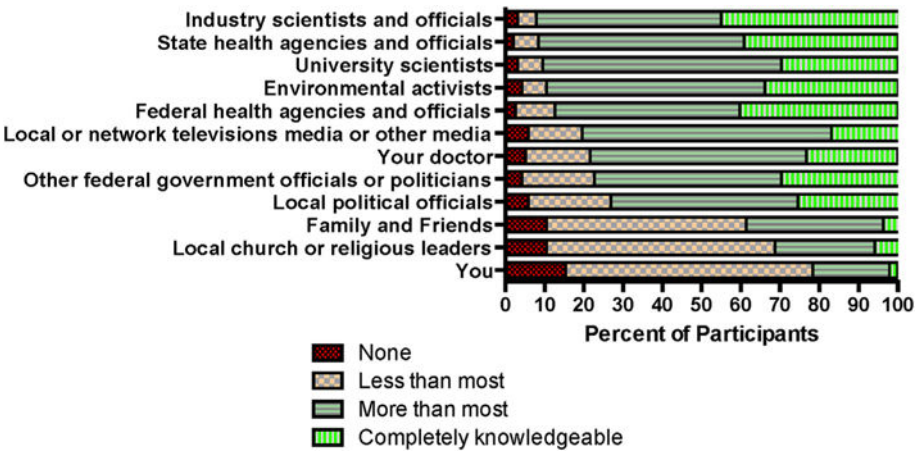

Fig. 5.

Level of knowledge regarding the DWH accident. Bars represent the percent of participants in each category. Participants were asked to rank groups, represented on the y-axis, based on how they perceived each group's level of knowledge regarding the details of the DWH accident.

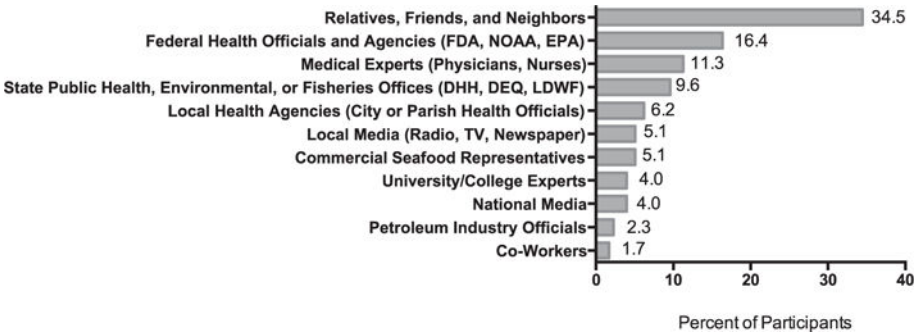

Fig. 6.

Most trusted sources for information regarding seafood safety. Bars represent percent of participants in each category. Participants were asked to rank their most trusted sources, represented by the y-axis, regarding information on seafood safety.

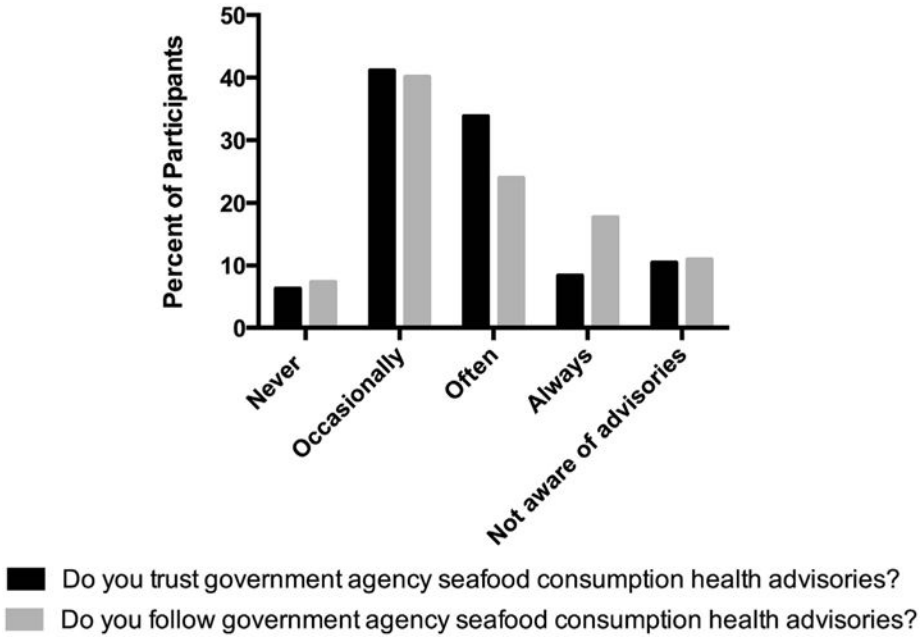

Fig. 7.

Trusting and following seafood consumption advisories. Participants were asked if they trust (black bars) and if they follow (grey bars) government agency seafood consumption health advisories. Bars represent the percent of participants in each category.